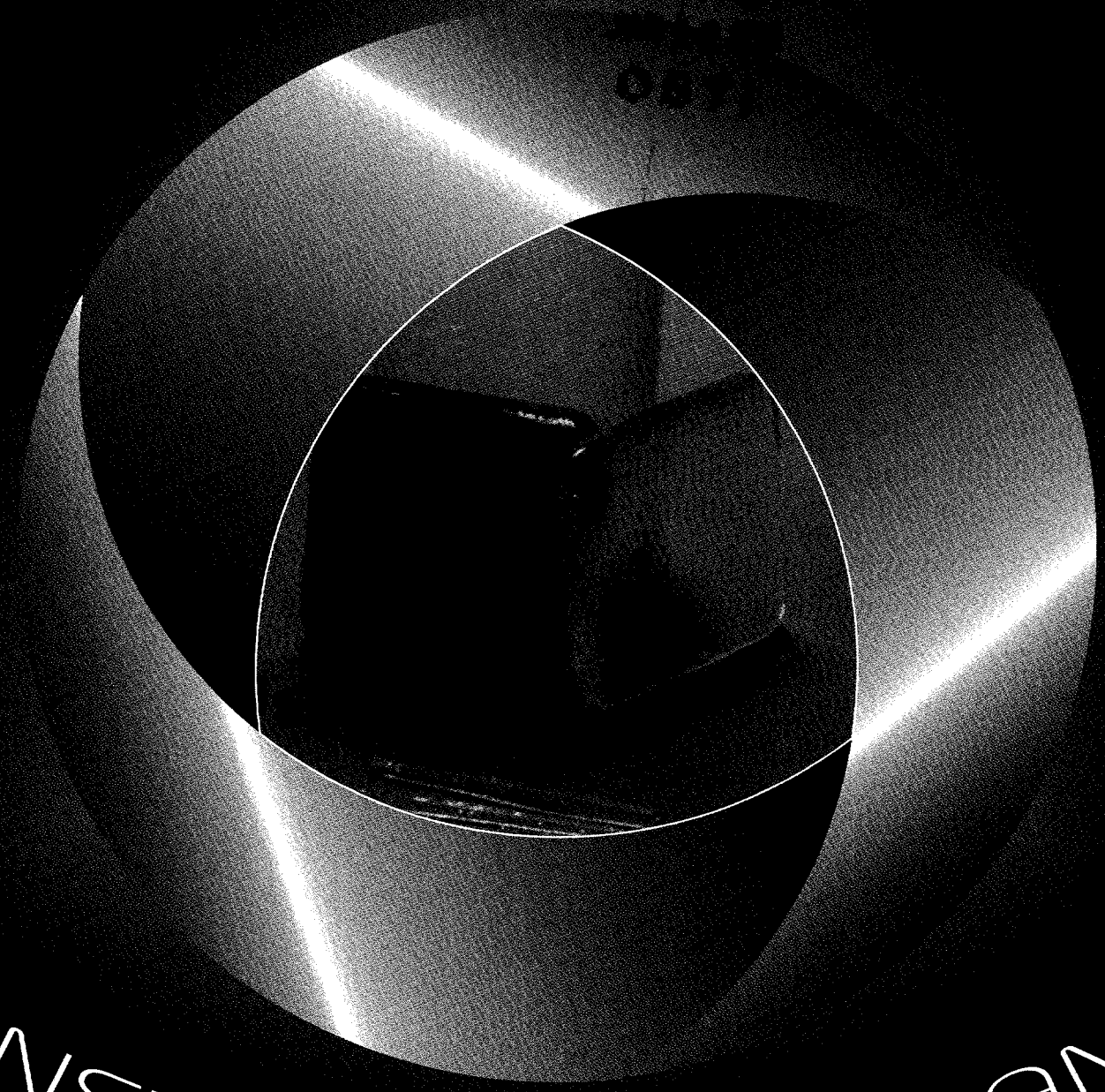
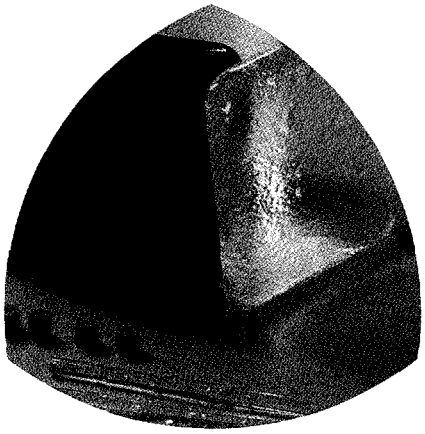
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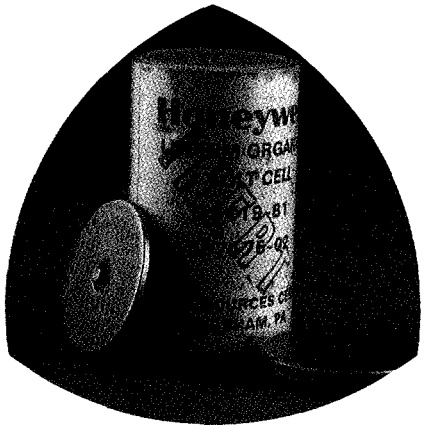


INSTITUTIONAL PLAN

"...exceptional service in the national interest."



At the top are rectangles of blue TA-23 and clear CABAL-12 glasses leaning against a support cylinder. Next down are preforms such as those used to make battery seals. At the bottom are glass rods from which the preforms are made.



Mockup of a D-cell battery for Defense Programs applications and additional views of the header.



Hermetically sealed headers. The titanium parts are sealed with Sandia's patented third-generation glass licensed to Wilson Greatbatch, Ltd.

SAND95-2059

DOE Distribution Category UC700

ABOUT THE COVER

The Sandia-developed glass inside the Möbius strip symbolizes the ways in which Sandia National Laboratories and private industry can work to their mutual benefit and to the benefit of Sandia's government customer.

In the early 1980s, commercial lithium D-cell batteries had shelf lives of about six months. This lifetime was unacceptable for weapons applications but the superior electrical characteristics of lithium cells were required. After determining that lithium battery electrolytes corroded the high-silica glass seal around the header pin, Sandia researchers, supported by funding from Defense Programs, invented a low-silicon glass (TA-23) that extended lithium battery shelf life to more than five years. TA-23 for weapon applications was then manufactured by commercial firms.

Moreover, in accordance with government policy at the time, the technology for this new glass was transferred to private industry. This resulted in new applications of batteries using TA-23 headers. The Galileo spacecraft probe contains a pack of Honeywell's D-cell-sized batteries that continues to function after a six-year interplanetary journey. Closer to home, TA-23 headers are used for lithium batteries implanted in human beings to drive heart pacemakers and other life-sustaining devices.

Because even longer shelf life was required for some military applications, Sandia researchers developed a family of calcium-modified boro-aluminate (CABAL) glasses. CABAL-12, which withstands electrolyte corrosion ten times longer than TA-23, is now the material of choice in DOE lithium batteries used for weapons applications. The technology for CABAL-12 glass was also transferred to private industry, where it is used for seals in non-aqueous environments. However, CABAL-12 has limited aqueous durability so is not used in implantations when the glass is exposed to body fluids.

Under the aegis of Sandia's Laboratory-Directed Research and Development Program, a third generation of glasses has been developed that combines CABAL-12's resistance to lithium corrosion with the thermomechnical requirements for titanium seals. Sandia has obtained a patent on this third-generation glass and licensed it to a commercial firm. Additional glasses are being developed that can be sealed to titanium and will also have better aqueous durability, making them suitable for biomedical implantation.

The iterative process above benefited Sandia in several ways. The research developed new tools for characterizing glass structure so that Sandia now has a better understanding of the relationships among the structure, composition, and properties of glass. Sandia also gained a new understanding of the electrochemical reactions between aqueous solutions and glass surfaces and developed new tools for characterizing such reactions. On a broader scale, Sandia developed one infrastructure to interface with industry for commercial applications of our glass seal technology (e.g., glass and header manufacturers) and another infrastructure to interface with component manufacturers (e.g., producers of lithium batteries). Consequently, we would not have these capabilities at Sandia today without the expanded technology, design, and manufacturing knowledge base that resulted from continuing interactions with industry.

Special thanks are extended to Richard K. Brow and Denise N. Bencoe for supplying information about and all photographs of the glasses. Additional information and/or review were provided by Daniel H. Doughty, Robert J. Eagan, Glenn W. Kuswa, Gregory L. Scharrer, Paul Shoemaker, and David E. Weigand.

INSTITUTIONAL PLAN TEAM

Manager, Corporate Planning Department	Paul E. Shoemaker
Team Leader Original Text and Review Comment Resolution	Dan Garber Scores of Sandians across the Laboratories
Senior Technical Writer/Editor Technical Editor/Indexer Senior Text Processor	Tim Peterson, TRI Sally Kmetz, TRI Debbie Rivard, TRI,
Cover, Design, Illustrations, Layout, and Production	Arnold Puentes, TRI Renee Brown, TRI

PHOTO CREDITS

Photos were contributed by Irene Dubicka, Randy Montoya, Myra O'Canna, Mark Poulsen, Camille Reyes, and Kevin Rich.

Sandia National Laboratories

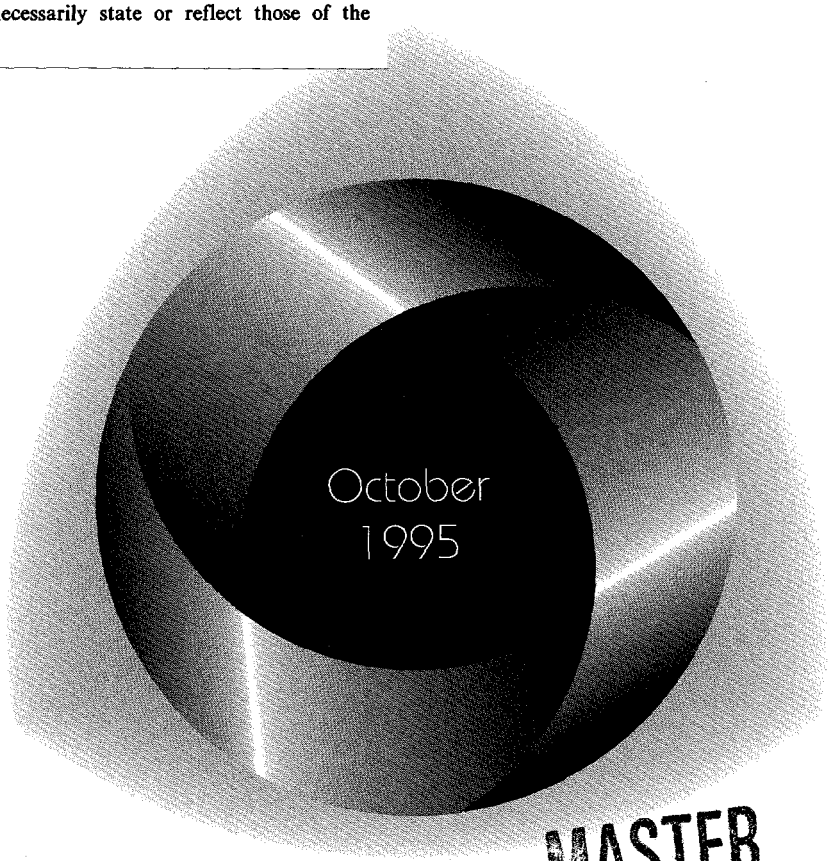
INSTITUTIONAL PLAN

FY 1996-2001

Albuquerque, New Mexico
Livermore, California

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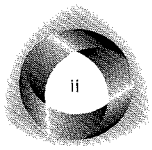
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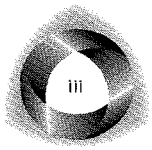
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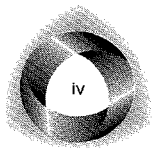
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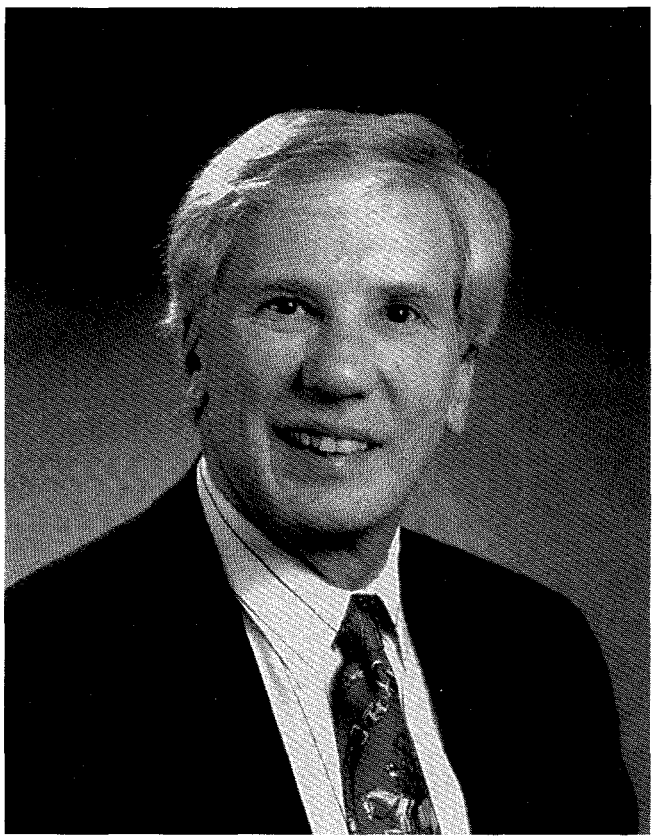




A Message from Paul Robinson, Sandia's President and Laboratory Director

There is a story about Justice Oliver Wendell Holmes riding on a train, and when the conductor asked him for his ticket he couldn't find it. Seeing that Holmes was getting quite nervous about not being able to find it the conductor said "Justice Holmes, I recognize who you are, and it's not necessary for you to find the ticket now—I know I can count on you, when you do find it, to tear it in half and send it to the railroad." Holmes replied: "Sir, my problem is a lot more serious than that; if I can't find the ticket, I won't know where to get off. I know that I'm being met at the station, but otherwise I have no idea where I'm going."

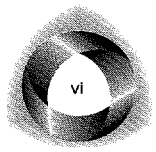
This story has lessons for us today—as individuals and as institutions. With the increasing pace of events, we can easily get too involved in today's activities and forget where we're going. Thus, we prepare this Institutional Plan each year describing ongoing activities and offering a five-year prospectus of planned efforts. It is written to articulate to ourselves and to our principal customer (the Department of Energy) and other stakeholders exactly where it is we believe we are going as a laboratory.



Sandia's Institutional Plan is by necessity a large document. As our missions have grown and diversified over the past decades, the variety of technical and site activities has increased. The programs and activities described here cover an enormous breadth of scientific and technological effort—from the creation of new materials (as shown on the cover) to the development of a Sandia-wide electronic communications system.

Today, there are three major themes that greatly influence our work. First, every federally funded institution is being challenged to find ways to become more cost effective, as the United States seeks to reduce the deficit and achieve a balanced federal spending plan. Sandia is evaluating its business and operational processes to reduce the overall costs. Second, in response to the Galvin Task Force's report "Alternative Futures for the Department of Energy National Laboratories," we and the Department of Energy are working jointly to reduce the burden of administrative and compliance activities in order to devote more of the total effort to our principal research and development missions. Third, we are reevaluating the match between our missions and the programs we will emphasize in the future. We must demonstrate that Sandia's roles—in national security, energy security, environmental integrity, and national scientific and technology agenda support—fit our special capabilities and skills and thus ensure our place in these missions for the longer planning horizon.

In August of 1995, the White House declared its intention to seek a "zero-yield" basis for the Comprehensive Test Ban Treaty now being negotiated in Geneva. This decision placed even greater weight on the science-based stockpile stewardship effort of the three nuclear weapons laboratories and will challenge our staff as never before to establish a sufficient link between the scientific and technological foundation and the performance of the US stockpile. It is envisioned that through this methodology the safety and reliability of US nuclear weapons can be maintained without any nuclear testing of the designs. The White House decision carried with it a commitment to a greater level of support for the science and technology programs that undergird the stockpile, and we will use that commitment to provide a renewed focus on our scientific roots. We will expand the fundamental understanding of the processes at work in both

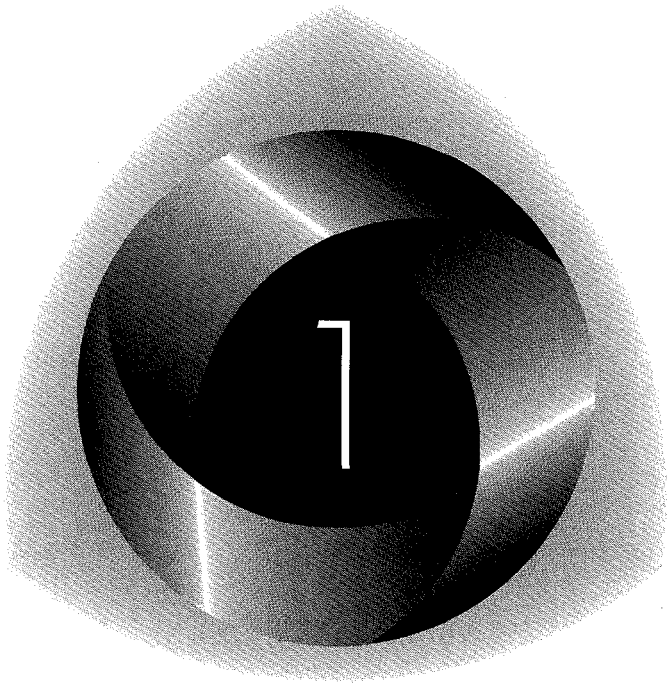


the functioning and the aging of weapons components and systems we design, and in perfecting the mathematical models to simulate those processes. This will include the development of much more powerful supercomputers needed to make the fidelity of these simulations sufficient to the task we face in maintaining the stockpile without testing.

In the past few years, Sandia and the other DOE laboratories have opened up many of our technical programs to collaboration with US industries and universities. These efforts have moved beyond the transfer of laboratory-developed technology for industrial use to become full research partnerships in which the joint efforts benefit both government missions and private sector objectives (as the text on the inside front cover illustrates). However, the support for these programs has become a controversial issue within the Congress and their fate is now uncertain. Sandia's view is that economic competitiveness is very much a long-term requirement for national security, and we are striving to show that the way in which our industrial partnerships have been carried out demonstrates a desirable way to leverage private and government resources for maximum gain.

The Galvin Task Force recommended that the DOE laboratories recreate themselves as a "system of laboratories," a view strongly endorsed by the senior leadership of DOE. Sandia has been a leader in putting forward such a vision of a future state, wherein the laboratories can be mutually involved and supportive of important national missions, with few duplications of effort. We will pursue the goal of creating an integrated system for scientific research and technology innovation that can be both more efficient and more effective in bringing the best capabilities to bear on challenging problems. We will play a lead role on behalf of the nuclear weapons laboratories in pioneering the use of high-speed computer information networks to enable the necessary level of communication and awareness of each other's capabilities, interests, and availability. We hope to build on that work to widen the level of communication, cooperation, and participation by the full set of US laboratories—in DOE, DoD, and other agencies.

C. Paul Robinson



Sandia's Missions

Sandia's missions are stated below:

> As a Department of Energy national laboratory, Sandia works in partnership with universities and industry to enhance the security, prosperity, and well-being of the nation.
>
> We provide scientific and engineering solutions to meet national needs in nuclear weapons and related defense systems, energy security, and environmental integrity, and to address emerging national challenges for both government and industry.[1]

1.1 Sandia's Mission Areas

Sandia's missions have evolved to meet challenges created by a changing world, but the general thrust is unchanged. DOE, with programs in defense, energy, and environment, continues to be our principal customer.

Established responsibilities include programs that add value directly to the nation's security, in cooperation with the private sector where appropriate, and for which the federal government is the principal customer. Established programs fall into three general areas: nuclear weapons programs, energy and environmental programs, and work other than for DOE. A fourth program area, technology partnerships and commercialization, is relatively new but has a legacy of past successes.

1.1.1 Nuclear Weapons Programs

Science-based stockpile stewardship of nuclear weapons ensures that the stockpile remains effective and safe.

In collaboration with other laboratories, Sandia preserves, sustains, and enhances the intellectual, technological, and physical infrastructure to support the missions and responsibilities of the nuclear weapons complex.

We help ensure the safety, security, and control of nuclear weapons in all environments. We develop and promulgate the underlying science, technologies, methodologies, prototype components, and system architectures.

We support national defense policy and DOE policy by helping reduce the size of the nuclear weapons stockpile while integrating the design and production capabilities to upgrade the remaining stockpile and build new weapons if necessary.

We develop technology to address potential threats from the proliferation of weapons of mass destruction. Specifical-

[1] *Strategic Plan 1994*: Sandia National Laboratories, 1994, p.9.

ly, we develop arms control, nonproliferation, and counterproliferation technologies. We also provide analysis of intelligence.

We have assumed nonnuclear production responsibilities from other elements of the nuclear weapons complex as its size is being reduced. We provide small-lot manufacturing of essential parts, commercial procurement of other parts, and standardization.

We are cleaning contaminated Sandia sites to comply with environmental laws and regulations. We comply with the Resource Conservation and Recovery Act concerning releases of hazardous waste or constituents from solid waste management units; closure of inactive treatment, storage, and disposal units; and assessment and remediation of sites where a release has occurred or where a substantial threat of a hazardous substance release exists.

1.1.2 Energy and Environmental Programs

These programs are sponsored by DOE and the Nuclear Regulatory Commission, often in support of US industry.

We identify, develop, and help deploy technology for safe, clean, and affordable energy to enhance the security of the nation and reduce global tensions over energy sources. We also develop affordable and deployable environmental technologies to enhance environmentally conscious operations in industry, help remediate contaminated DOE sites, and solve the problems associated with disposal of radioactive wastes.

1.1.3 Work Other Than for DOE

This program for DoD, other federal agencies, and nonfederal entities applies Sandia's capabilities to satisfy specific customer requirements for performance, cost, schedule, security, or other needs not readily available in the private sector.

Sandia's independent status as a national laboratory enables us to provide objective, science-based solutions for problems of enduring national importance to our customers. We also are a catalyst for precompetitive research and development alliances with industry, universities, and end users of Sandia-developed technology.

1.1.4 Technology Partnerships and Commercialization

This program shares Sandia-developed technologies, processes, and special technical expertise with the private sector, starting as early in the development as possible. These partnerships create technologies of mutual benefit to government and private industry.

Lockheed Martin funds the Technology Ventures Corporation to promote such technology partnerships. This corporation's efforts have resulted in an accelerating rate of entrepreneurial business startups and an increasing rate of inquiries about venture capital investment.

1.2 Sandia's Approaches to Achieving Our Missions

1.2.1 Core Competencies

Core competencies include skills, capabilities, technologies, and facilities needed to perform Sandia's mission and achieve strategic objectives. These core competencies are a matrix of four research foundations and four integrated capabilities that enables science-based engineering and product realization at Sandia.

Research Foundations

The four research foundations strengthen scientific and engineering disciplines necessary to conduct world-class research and apply this research to achieve results crucial to Sandia's missions.

Engineered Processes and Materials

This research foundation involves synthesis, characterization, and processing of metallic, ceramic, organic, and composite materials. A distinguishing strength is the development of advanced materials and processes tailored to meet the needs of a specific application.

Computational and Information Sciences

This research foundation provides technology to advance state-of-the-art computer use while maintaining the accuracy, security, and accessibility of information. Distinguishing strengths include the development of computational methods and software for emerging computer technologies, mathematical techniques for information surety and security, computer-based techniques for intelligent machines, and advanced computing facilities and networks.

Microelectronics and Photonics

This research foundation develops, fabricates, and produces microelectronic and photonic devices and circuits, microsensors, and intelligent microelectromechanical systems. Distinguishing strengths of this competency include materials growth and development, digital and radio frequency device design, fabrication technologies for silicon and compound semiconductor devices, radiation-hardened microelectronics, advanced packaging technologies, and design of processes and equipment for the manufacture of integrated circuits.

Engineering Sciences

This research foundation is composed of fluid and thermal sciences, solid and structural mechanics, radiation transport, aerospace sciences, geosciences, and combustion sciences. A distinguishing strength of this competency is the development of interdisciplinary capabilities and an integrated computational and experimental approach for solving complex engineering problems.

Integrated Capabilities

Sandia has four integrated capabilities: advanced manufacturing technology, electronics technology, advanced information technology, and pulsed power technology.

These integrated capabilities support national security in the conventional sense and also in a broader sense that includes economic competitiveness, energy security, and environmental integrity. The integrated capabilities are key technology development areas that can also serve a variety of national interests such as biomedical systems engineering and the transportation infrastructure. Other applications are continually being evaluated in concert with DOE, other federal agencies, and potential industry partners.

Integrated capabilities derive their scientific bases from the research foundations. The four integrated capabilities are all important to direct programs at Sandia and for the private sector. Pulsed power technology will remain a critical but very specialized capability germane to DOE Defense Programs missions and to some potential new spinoff areas. These integrated capabilities are significant to US competitiveness and have dual-benefit potential for government and the private sector.

Advanced Manufacturing Technology

This integrated capability satisfies many needs for improved manufacturing methods in US industry and the nuclear weapons complex. These needs include concurrent engineering, intelligent machines for hazardous and flexible operations, computer-aided design/engineering/manufacturing, engineered processes and materials, environmental protection and control, and an infrastructure to support production. This capability, which emphasizes precompetitive research and development guided by needs to reconfigure the nuclear weapons complex, also applies to market-driven needs. Advanced manufacturing technology makes full use of partnerships with US industries and other federal agencies, as well as specific industry-led associations such as the US semiconductor consortium SEMATECH, the United States Council for Automotive Research, and the Specialty Metals Processing Consortium.

Electronics Technology

Using Sandia's research foundation in microelectronics and photonics, we apply our electronics technology to enhance the safety, security, and use-control of nuclear weapons; make continuing contributions to defense, including new technologies to discourage the proliferation of weapons of mass destruction; and, when benefit for both our DOE customer and industry can result, expand our contributions to the nation's economic security as identified by industrial road maps. Sandia's cooperative work with industry and universities enables us to maintain a state-of-the-art electronics technology base that meets the needs of our DOE Defense Programs customer while providing value to industry. We thus ensure the availability of many of the semiconductor components needed for future DOE systems from commercial sources, and maintain the technology base at Sandia necessary to address needs not supported by commercial industry.

Advanced Information Technology

Advanced information technology fosters widespread access to information via high-performance computing networks. Sandia's differentiating expertise in information technology supports our weapons programs, related mission programs, other integrated capabilities, and national information initiatives.

Pulsed Power Technology

Pulsed power technology is used to generate and apply energetic beams and high-power energy pulses. It is distinguished by the development of repetitive pulsed-power technologies, x-ray and energetic beam sources, and electromagnetic and radiation-hydrodynamic computational capacity applicable to areas within and outside the pulsed power area. Applications include nuclear survivability of

weapons systems, weapon physics research, light-ion-beam inertial confinement fusion, materials processing, waste and product sterilization, and food treatment. Facilities include the Saturn x-ray source, the High-Energy Radiation Megavolt Electron Source (HERMES) III for gamma rays, and the Particle Beam Fusion Accelerator II.

1.2.2 Laboratory-Directed Research and Development Program

The Laboratory-Directed Research and Development (LDRD) Program, authorized by federal law and implemented under DOE Order 5000.4A, supports science-based engineering and product realization related to DOE's missions. Projects in advanced science and technology enhance Sandia's core competencies (see 1.2.1).

The LDRD Program supports innovative scientific and technological opportunities having high potential for payoff in DOE applications. The LDRD Program creates or accelerates development of technical expertise within programs important to Sandia missions for the DOE and extends the boundaries of Sandia's research foundations into promising new areas.

Projects are relatively small, focused, and short-term (maximum of three years). The program does not replace or increase funding for existing DOE or other agencies' tasks or carry projects beyond the exploratory stage. Program funds comprise more than one-third of the total annual investment in Sandia's research foundations. The LDRD Program is supported through an assessment of all costed work performed at Sandia. In FY 1995, the program was funded at $68 million. Table 1-1 shows projected yearly budget/cost estimates through FY 2001.

Each fall the Sandia Quality Leadership Council identifies initiatives for the following fiscal year and establishes budget targets. A laboratory call for proposals is issued describing the intent of the program, the program elements, and requirements for proposals. One-page proposals are submitted to programmatic teams for evaluation and possible development. Programmatic teams look for ideas that have growth potential, will impact future activities, and are aligned with Sandia's strategy. Investigators wishing to extend a project beyond one year submit a continuation proposal that details progress and describes tasks for the coming year. A technical appraisal team independently evaluates the proposed additional work, technical approach, and expected impact. The programmatic appraisal teams rank proposals in order of funding preference.

The LDRD Program Office then submits new proposals and extensions for Sandia executive management review and approval and concurrence by DOE.

1.3 Key Management Principles and Factors

Sandia's core competencies were earlier defined as skills, capabilities, technologies, and facilities needed to perform our mission and achieve strategic objectives. The quality principles, human resources, and facilities aspects of those core competencies are discussed below.

1.3.1 Total Quality Management

Sandia's efforts to meet or exceed customer expectations depend heavily on formal quality principles. Sandia's commitment to total quality management is stated explicitly in our quality policy: "To be the best demands that we integrate quality in all our work. At Sandia National Laboratories we apply quality fundamentals consistent with sound business practices." Sandia's four quality fundamentals are discussed below.

First, we "provide the greatest value to our customers by understanding and meeting their expectations." We try to satisfy our customers' explicit requirements and also try to understand how our customers' expectations influence their perception of quality with respect to cost, schedule, and performance. To exceed customer expectations we continually review these expectations.

Second, we "focus on prevention rather than correction." Although fixing problems as they occur is important, we strive to prevent problems by analyzing program tasks before beginning work.

Third, we "continually improve our skills, processes, products, and services." Quality improvement is ongoing and accommodates any changes in our customers' requirements. We constantly seek ways to provide the highest value products and services to our customers.

Table 1-1. Laboratory-Directed Research and Development Program (Fiscal Year Amounts in Millions)

	1996	1997	1998	1999	2000	2001
Total Funding	69.2	64.3	65.0	65.0	65.0	65.0

Fourth, we "measure progress using data." Metrics are used to set objectives, monitor processes, assess customer satisfaction, and ensure that resources are focused on areas with the most value added. We use the Malcolm Baldrige National Quality Award criteria to measure our progress. In 1992 we submitted Sandia's first Baldrige-type application. We have been using the feedback to accelerate our rate of progress. Sandia's yearly President's Quality Award is based on the Baldrige criteria. We are now applying for the DOE Quality Award, which uses the Baldrige criteria. This assessment and the feedback we receive will be the basis for our first application for the New Mexico Quality Award, which also uses the Baldrige criteria. The feedback from the latter will be our basis for improvement during CY 1996.

1.3.2 Human Resources

Quality principles are implemented by and through Sandia's employees. Consequently, as the work environment at Sandia responds to changes of mission, the Human Resources organization responds accordingly.

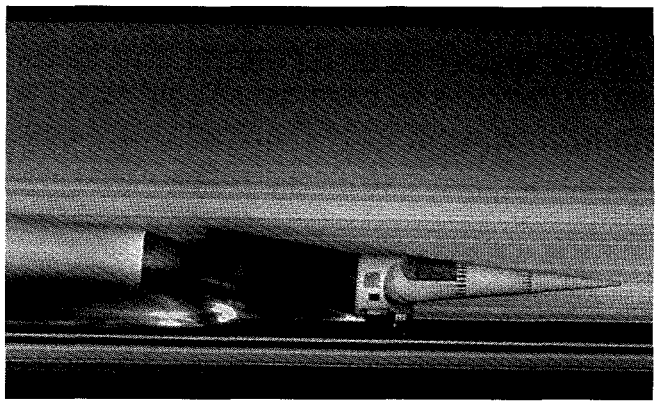
To achieve this result, Human Resources is reengineering major processes, converting to a more automated infrastructure, and fostering an environment of continuous improvement. A performance management system links job performance with organizational plans and results. External hiring, internal movement, and labor contracting processes are being further integrated. Work force agility is being enhanced by retraining and reassignment policies, part-time work opportunities, telecommuting, and a compressed work week option. On-site health services and wellness programs are also being integrated with management of health care costs.

Human Resources is committed to the quality principle that the degree to which Sandia achieves employee satisfaction will be the degree to which Sandia meets or exceeds customers' requirements.

1.3.3 Facilities

Sandia's facilities are the final integral aspect of Sandia's missions. Our executive management offices and larger laboratory complex are located on Kirtland Air Force Base in Albuquerque, New Mexico. This site is composed of five technical areas and an outdoor testing field covering 17,845 acres. This site benefits from its proximity to other major defense laboratories and testing facilities, universities, and the growing high-technology industrial base in the Rio Grande research corridor.

The Sandia complex in Livermore, California covers 413 acres. This site benefits from its proximity to world-class research universities and the intense high-technology environment of the region.



A 10,000-foot rocket sled track is one of Sandia's special-purpose test facilities.

Extensive research laboratories at both sites are part of Sandia's four major integrated capabilities: advanced manufacturing technology, electronics technology, advanced information technology, and pulsed power technology.

Sandia's array of environmental testing facilities is unique. Shock, temperature, vibration, and acceleration test facilities are used to subject components and systems to a wide range of extreme environments. Sandia also has a variety of special-purpose test facilities: a radiant heat facility; a multiple-stroke lightning simulator; a low-field, broadband electromagnetic radiation facility; blast tubes capable of operating from 1 to 2,000 pounds per square inch; a facility to provide large quantities of molten metal oxides for studying nuclear reactor accident conditions; light-initiated and other high explosives test facilities; a 5,000-foot aerial cable for impact tests; a 10,000-foot rocket sled track; and two of the world's largest centrifuges.

Sandia's specialized facilities are utilized for a variety of defense and nondefense research and development activities. Computing facilities support the simulation and modeling of complex phenomena and concurrent research, development, and engineering. An internetwork and communications infrastructure provides ready access to Sandia's supercomputers and storage servers from both the California and New Mexico locations and their distributed networks.

Robotics laboratories are used to develop prototype advanced systems with application to DOE weapon production efforts. Applications include Strategic Arms Reduction Talks-mandated nuclear weapons dismantlement and retrieval and repackaging of radioactive wastes.

The Center for Microelectronics Technologies and the Integrated Materials Research Laboratory are used to study semiconducting and other specialized materials. Advanced facilities exist for materials synthesis, growth, processing, and diagnostics. Facilities house equipment for molecular beam epitaxy and metallorganic chemical vapor deposition growth, accelerators for ion-beam

analysis and ion implantation of surfaces, solid-state and gas-phase lasers for spectroscopy and remote sensing, and equipment for numerous surface analytical techniques for microstructure and materials property analysis.

The Integrated Manufacturing Technologies Laboratory and the National Center for Advanced Information Components Manufacturing provide advanced manufacturing technology capabilities for developing integrated and agile solutions to manufacturing problems for industry and government partners.

The Combustion Research Facility is used to address problems in combustion science, energy, and the environment.

The National Solar Thermal Test Facility and other solar thermal facilities are used to test central and distributed receivers and to study high-temperature materials and processes. The Advanced Photovoltaics Facility is used to test both flat-plate and concentrator systems.

Nuclear reactor facilities are used to simulate internal environments of power reactors and to evaluate the effects of nuclear weapons on components.

The Particle Beam Fusion Accelerator II, the Saturn x-ray simulator, and the High-Energy Radiation Megavolt Electron Source (HERMES) III gamma-ray accelerator are used to simulate nuclear weapons effects and to study pulsed power approaches to fusion energy. The largest pulsed power complex in the world provides energy concentrations for testing the nuclear vulnerability of weapons, conducting inertial confinement fusion studies, and studying atomic physics in the x-ray region. Dozens of smaller specialized laboratory facilities support specialized research in core competencies.

Dedicated facilities and test equipment at DOE's Pantex plant in Amarillo, Texas are used for quality assurance and stockpile evaluation operations.

As our mission evolves, Sandia is working much more closely with US industry. Relationships with industrial partners require easier site access and appropriate security management. We are exploring concepts for changes in campus configuration at both our New Mexico and California sites to facilitate access by industrial users. Changes are likely to affect classified and unclassified business areas, traffic circulation, parking, and other infrastructures.



Laboratory Directions

2.1 Laboratory Strategic Plan

Sandia's missions have evolved to meet the challenges created by a changing world, but the general thrust is unchanged. DOE programs in defense, energy, and environment continue to be our principal missions.

2.1.1 Situation Analysis

Sandia's operating environment has changed dramatically during the past few years. On the international level, the Soviet Union has collapsed and the Cold War has ended. However, old animosities and new threats to stability make it clear that the world remains troubled and unpredictable.

A series of important developments has influenced DOE's weapons program. These developments include the sweeping arms control initiatives of 1991, the indefinite moratorium on nuclear weapons testing, and the discovery of advanced nuclear weapons development programs in Iraq and North Korea. The proliferation of weapons of mass destruction and the potential for nuclear terrorism are emerging threats.

The 1991 war with Iraq reminded the world of the strategic importance of energy. It demonstrated the overwhelming dominance of oil in the industrialized world's energy mix, and it forced the United States to reexamine the energy choices it had made. Even though the war was quickly won and the immediate threat removed, the strategic issues associated with our chronic dependence on foreign energy sources remain.

Environmental awareness has increased worldwide. Pollution from industrial sources is catastrophic in many regions of the former Soviet Union. In the United States and other affluent nations, industry is adopting cleaner manufacturing processes and designing products that have less environmental consequence throughout the product life cycle. Many governments, especially in developing nations, are concerned about problems such as hazardous waste, water, energy, and resource depletion. Many poor nations have experienced extensive environmental degradation.

In our own country, the attention of policy makers has shifted to domestic problems that have become real threats to the prosperity and quality of life that most Americans enjoy. The vitality of the US manufacturing sector is a source of concern, particularly with respect to the supply of good jobs for Americans. Transportation, the environment, crime, education, and affordable and accessible health care are examples of other urgent issues.

Recently a debate has emerged about the utility of the national laboratories with respect to these new priorities: Does their contribution justify their cost? Should they have

additional roles and missions that address emerging national priorities? Or should their missions be more narrowly circumscribed and their activities constrained?

Clearly, we will be expected to manage and operate the laboratories more cost-effectively than ever before. Modern business methods, agility and flexibility, and reengineered work processes will be required to meet this challenge. But even with these changes, we will continue to feel the constraints of declining program resources.

Strong public and official sentiment exists for dramatically reducing the research and development base that supports nuclear weapons. However, an important dilemma exists. Nuclear weapons will continue to be a component of our nation's defense. They will age beyond their designed service lives, and their constituent technologies will become obsolete. Conversely, the requirements and expectations for reliability and surety will increase as the stockpile becomes smaller and new technology makes improvements in safety and control feasible. These expectations cannot be satisfied without sustained, predictable funding for the integrated science and engineering programs that support nuclear weapons technologies.

Sandia's operating environment has, in general, become more difficult and less certain. As we plan, it is important that we identify and interpret the external forces that will influence our future.

2.1.2 Planning Assumptions

Strategic objectives and general strategies are based on sets of planning assumptions in defense, energy and environment, technology, economics, politics and society, and laboratory operations.

Defense

- Sandia's nuclear weapons stewardship responsibility will demand sustained support of our science and engineering research and development capabilities, particularly as we enter an era with no new weapons development programs, an indefinite moratorium on nuclear testing, and declining budgets.
- Restructuring the nuclear weapons complex will last a decade and will force hard decisions about research and development, production, and remediation.
- The defense budget may decline even further before it stabilizes. Competition for allocations from the research and development portion of that budget will certainly increase.
- Weapons of mass destruction will continue to proliferate, and the probability that they will be used in a regional conflict is increasing.
- For the foreseeable future, the stockpile of US nuclear weapons is not likely to get much smaller than the limits specified in the Strategic Arms Reduction Treaty II agreement.
- The moratorium on nuclear testing will challenge our technical skills as we strive to fulfill our responsibilities for nuclear weapons surety and reliability.

Energy and Environment

- Environmental considerations will become a dominant factor in decisions related to energy, transportation, and manufacturing.
- Environmental restoration and public health and safety will continue to be high priorities for the government and the public.
- Demand from developing nations for energy resources will grow.
- Responsible environmental stewardship will be required across the entire product life cycle.
- Permanent disposal of nuclear waste will be key to the future of nuclear power and essential for managing the nuclear weapons program.
- Conservation and renewable energy alternatives will be seen as viable strategies for improving US energy efficiency.
- The energy supply industry has lost most of its in-house research and development capability and will need alliances with national laboratories and universities in order to advance.
- The strategic importance of domestic oil production and alternative energy supplies will become more widely acknowledged.

Technology

- US industrial firms will not rebuild their research infrastructures but will rely on alliances and partnerships to provide technologies for the future.
- The importance and influence of information technology will increase throughout industry.
- Cycle time for technology deployment will continue to shrink.

- The need to modernize our nation's infrastructure will create new technological challenges.
- Manufacturing will be a major factor in the nation's economic vitality.
- Technology will not automatically be viewed as the solution to many of the nation's problems; it may be seen as the source of some of those problems.

Economics

- The trend to integrate the civilian and defense industrial bases will continue.
- Alliances and consortia involving national laboratories, industry, and universities will become generally accepted, and cooperative ventures with industry will expand.
- Pressure on discretionary federal spending (including defense and research and development) will become more intense.
- The increasing global scope of business will make it difficult for national laboratories to provide technology for the exclusive benefit of US companies.

Politics and Society

- Technical programs will be more open to public scrutiny. Increasingly they will be subject to debate concerning their ethical, social, political, economic, and environmental impacts.
- In the future, laboratory initiatives will require support from a broader political base than they have in the past.
- The federal government's effort to make government more efficient and cost-effective will have significant impact on the national laboratories.
- Diversity of ethnicity, gender, age, and skills will increase among our own work force and that of our customers.
- Society will continue to exhibit a strong aversion to risk imposed on individuals from any source other than through choices made by individuals themselves. To the degree that technology can contribute to reducing risk, opportunities to apply technology in new and useful ways will present themselves.

Laboratory Operations

- The ability to develop and apply human resources and technical expertise in an agile manner will be critical to Sandia's success.
- Sandia's California site will remain a strategic asset, integral to our success by serving both as a gateway into Sandia and as a window to the US West Coast and the Pacific Rim.
- Our pursuit of quality will require us to place more emphasis on operational efficiency and cost-effectiveness.
- Reengineered work processes and a modern information and communications infrastructure will become increasingly important to the efficiency of our operations and the quality of our work.

2.1.3 Strategic Objectives

Strategic objectives are established both for what we do and for how we do it. As a mission-oriented laboratory, we have obligations to our sponsors for programmatic results as well as a general obligation to the taxpayers to produce value for the investment they have made in us. Consequently, we call one subset of strategic objectives "mission objectives." These are concerned with our programmatic responsibilities and the technical foundations for our work.

A second subset of strategic objectives is concerned with the administrative management and operation of the institution. These "operational objectives" support the successful realization of mission objectives and are equally important.

To a large extent, Sandia's long-term viability will depend on how well it meets its mission and operational objectives. We think that all the objectives below are achievable and that progress toward meeting them can be measured by performance indicators.

Mission Objectives

Mission Success

Sandia's objective is to achieve mission success and customer satisfaction through superior technical execution and program management. We will identify and develop products based on Sandia's integrated capabilities: advanced manufacturing, electronics technology, advanced information technology, and pulsed power technology.

DOE missions will remain our primary focus. We will make every effort to help DOE succeed in meeting its

mission objectives. Within the system of DOE laboratories, Sandia has outstanding comparative advantages based on a heritage of industrial management and a philosophy of science-based engineering and product realization. We will further define and strengthen our missions base by cultivating these comparative advantages.

We will work with DOE to devise more efficient funding vehicles for work with other federal agencies, state and local governments, and industry. We will also work with DOE to develop innovations that will permit Sandia and the other DOE laboratories to make maximum contribution to US technology needs in defense, energy security, environmental integrity, industrial technology, and other national technology initiatives.

We will attract new federal government customers by offering products and services that can provide substantial benefit to their programs. Sandia should be the national laboratory of choice based on observable comparative advantages and quality performance demonstrated in its work for DOE. New programmatic work for other agencies must exercise our research foundations and integrated capabilities. We will encourage DOE to negotiate top-level agreements with other agencies to establish long-term, team relationships for work in areas of mutual benefit.

We will aggressively seek funding under new federal technology initiatives when we think our DOE mission capabilities can add unique value. Substantial in-house technical work will be a requirement of any program we accept. We will not accept funding where we add little technical value to a program.

Our participation in new federal technology initiatives will involve collaboration with industry groups, perhaps in technical competition with other laboratory/industry teams. This may become a new model for federal research and development procurement, one that affords the government greater confidence in technical proposals and provides a more informed basis for selection.

Defense Programs (Including Nonproliferation)

Five programmatic thrusts have been established to support and parallel DOE's National Security Strategic Plan. They are synergistic and dovetail with Sandia's integrated capabilities (advanced manufacturing technology, electronics technology, advanced information technology, and pulsed power technology), and they support these capabilities in the other Sandia sectors. Plans and strategies to support these capabilities are judged against strategic investment criteria.

Stewardship of the Stockpile

We will ensure that the stockpile remains effective, and we will create executable options to evolve the stockpile of the future. In addition, we will assure that the nuclear weapons development capabilities and expertise necessary to meet the nation's future needs are maintained.

The strategic opportunity is to advance the science and technology of nuclear weapons design and manufacture in many areas (such as model-based development, state-of-health self-surveillance, stockpile tracking and inventory, advanced surety, and innovative system concepts to meet possible future threats) while utilizing these advanced nuclear weapons design science and technologies to address other national technical problems.

Reconfiguration and Conversion

We will support national defense policy and DOE policy by taking actions necessary to reduce the size of the nuclear weapons stockpile while integrating the design and production capabilities to support the remaining stockpile and perform upgrades or new builds if necessary. The budget decreases associated with a reduced stockpile will require a significant reconfiguration of the nuclear weapons complex and the adoption of more cost-effective product processes.

The strategic opportunity is to use systems approaches for weapons production to demonstrate successful low-volume, high-reliability design and manufacturing processes through the incorporation of modern product realization principles such as agile manufacturing, concurrent engineering, and environmentally conscious manufacturing.

Strategic Surety

It is our responsibility to develop the technical means to assure confidence in the safety, security, and control of nuclear weapons in all environments. The ability to attain this confidence now and in the future for nuclear weapons and other high-consequence activities is of strategic importance to the nation. We will develop and promulgate the underlying science, technologies, methodologies, prototypical components, and system architectures for the advancement of surety.

The strategic opportunity exists for the development of goals, standards, and objectives and the implementation of system architectures and supporting technologies for achieving intrinsic surety so that undesired actions are not possible without official intent. These developments will provide the framework for the application of the science of surety to other high-risk national problems such as assuring civil security (e.g., against acts of terrorism), information security, transportation safety, and medical treatment safety.

Competencies and Capabilities

We will preserve, sustain, and continually enhance the core intellectual, technological, and physical infrastructure necessary for the support of all the missions and responsibilities of the nuclear weapons complex. To accomplish this, we must exercise these essential capabilities and competencies to meet a wide range of national needs, including the enhancement and preservation of US industrial capabilities. The strategic opportunities are to

- develop complementary support for competencies and capabilities through all lines of Sandia's business and discretionary funding sources, such as laboratory-directed research and development;
- strengthen Sandia's science and technology base by identifying opportunities to leverage cross-sector investments in new competencies and capabilities;
- anticipate and strengthen those competencies that will be required for Sandia's evolving missions, such as advanced manufacturing, sensors for smart weapons, microelectronics, and advanced modeling and simulation for design engineering; and
- develop technology partnering activities that yield significant spin-back of new or enhanced competencies and capabilities.

Responding to the Changing Threat

We will bring the full range of our technology base and systems integration competency to bear on the problem of developing technical approaches to address the evolving security challenges posed by the proliferation of weapons of mass destruction. The strategic opportunities are to

- expand our traditional roles and contributions through new technology development, systems integration, and greater partnering in vulnerability assessment to influence the full spectrum of national security issues;
- monitor technologies to support applications from cooperative monitoring to remote sensing in denied areas;
- develop advanced technologies and systems for weapons storage and management of special nuclear materials;
- expand incident response capabilities; and
- interact with other DOE Defense Program activities to influence evolving stockpile requirements.

Energy and Environment

Sandia's Energy and Environment organization will support its customers in DOE, other government agencies, and US industry with effective science and engineering solutions that improve our national energy security and the quality of our environment. We will provide managerial and technical leadership to resolve issues of national importance and impact. We will apply the full range of our engineering capabilities and scientific foundations toward delivering quality products to our customers. We will maintain our established responsibilities in energy research, fossil energy, renewable energy, nuclear energy, nuclear waste management, and environmental technologies. We will integrate these responsibilities into the larger context of sustainable development. We will establish leadership in emerging responsibilities with our customers, and we will provide the basis for DOE to identify and move into new areas of vital national concern.

Energy

Sandia will identify, develop, and help deploy full systems solutions for safe, clean, and affordable energy options that enhance the security of the nation and reduce global tensions over sources. We will improve manufacturability and reliability of alternative energy systems; develop efficient technologies for utility, industry, and automotive applications; provide leadership in applying advanced technology to the oil, gas, and geothermal industries; and establish the technical basis for safe, effective, nuclear energy systems.

Environment

Sandia will develop affordable and deployable environmental technologies that enhance environmentally conscious operations in industry, help remediate contaminated DOE sites, and solve the problems associated with disposal of radioactive wastes. We will exhibit leadership in providing technology for clean industries; advance technology for contributing to DOE's environmental cleanup; develop viable solutions for nuclear waste storage, transportation, and disposal; and support DOE and national environmental, safety, and health efforts.

Work for Others

The Work-for-Others (WFO) effort will utilize distinctive Sandia capabilities and Sandia's special independent status as a national laboratory to provide trusted, honest, objective,

science-based solutions for problems of enduring national importance to other agency customers.

WFO will add value for non-DOE customers by providing integrated solutions that combine innovative systems concepts with our enabling technical skills in manufacturing, electronics, and information sciences. The results will be practical solutions that significantly extend existing capabilities and satisfy customers' operational needs.

WFO will strengthen and enhance the US industrial technology base, including the defense industrial base, by sharing technology with industry; selecting and emphasizing dual-use technology and programs; aggressively teaming with industry and other agencies to leverage technology from all sources; and emphasizing high-level cooperative development agreements between federal agencies and private organizations.

WFO will become a catalyst for precompetitive research and development alliances with industry, universities, and users. This will establish Sandia as the leading proponent and creative implementer of effective mechanisms for establishing government/private partnerships to address important national problems.

WFO will strengthen and enhance Sandia's ability to continue serving DOE missions by emphasizing and selecting programs that synergistically nurture Sandia's core competencies while satisfying critical needs of other customers. We will establish project selection and investment/disinvestment criteria that strategically position WFO into four areas:

- Direct support of nuclear weapons (safing, arming, firing, and fuzing systems).
- Work related to the nuclear mission, such as counterproliferation and munitions research and development. In particular, we will work through DOE to apply nuclear weapons program skills, capabilities, and facilities to DoD's responsibility for developing counterproliferation technologies against weapons of mass destruction.
- Work that directly supports Sandia core competencies, such as high-performance computing and information technology components manufacturing.
- New initiatives that draw upon Sandia's core competencies and prepare the laboratories to address emerging national needs such as biomedical engineering and transportation systems.

Core Competencies

Sandia's objective is to sustain and stabilize our core competencies (research foundations and integrated capabilities) and to ensure the capability for attracting and developing the best research talent in the required disciplines.

Sandia's core competencies are a product of its forty-year heritage as a premier research and development laboratory. They are crucial to our ability to provide solutions to the nation's challenges in defense, energy security, environmental integrity, and industrial technology.

Science-based engineering is essential for leadership in technology. Engineering practice advances most rapidly when it is exposed to new principles and techniques derived from scientific discovery through engineering research.

The core competencies are a matrix of research foundations and integrated capabilities, and they make science-based engineering and product realization possible. The research foundations derive scientific and engineering principles. Those principles are used to advance the integrated capabilities that are crucial to Sandia's programs, both today and tomorrow.

Research Foundations

Sandia has four multidisciplinary research foundations:

- engineered processes and materials,
- computational and information sciences,
- microelectronics and photonics, and
- engineering sciences.

These research foundations provide the scientific knowledge base upon which Sandia's integrated capabilities depend. Our management philosophy for the research foundations is based on the guiding principles below.

The four research foundations will be managed for the benefit of Sandia's strategic thrusts. Sandia will achieve technological leadership in each of the four research foundations while remaining sensitive to the resource constraints imposed by the current fiscal environment.

Our first goal is to ensure that the research foundations provide the science and engineering wellspring from which we draw the ability to meet our customers' needs. We will accomplish this goal by establishing broad research programs that anticipate the needs of Sandia's strategic thrusts and by actively managing the programs to ensure that they adapt to changes in those needs. We will also encourage movement of personnel across division boundaries to promote the diffusion of new technologies and strengthen the ties among the research foundations and strategic thrusts.

Our second goal is to be recognized and valued, both internally and externally, for our contributions and leadership in research and technology development in these areas. We will achieve this goal by establishing high-impact, leading-edge research and technology development programs scrutinized by external peer review. We will continue to recruit and develop world-class technical staff with a diversity of backgrounds and expertise, and we will recognize and reward technical excellence, creativity, and leadership.

Our third goal is to be conscientious stewards of the resources provided for the advancement of our research foundations. We will accomplish this goal through the use of sound business practices that result in maximum leverage of our resources. We will exercise every opportunity to establish research programs that lead to the development of dual-benefit technologies. Sandia research programs will actively seek partnerships with universities, industry, and other federal laboratories to take advantage of advances made elsewhere.

Integrated Capabilities

Sandia has four integrated capabilities:

- advanced manufacturing technology,
- electronics technology,
- advanced information technology, and
- pulsed power technology.

These integrated capabilities derive their scientific bases from the research foundations. All these technologies are important to current direct programs at Sandia. They are also strategically important for future Sandia programs and for technology development in the private sector. In this context, they are sometimes called strategic thrusts, especially when their long-range importance to Sandia and the nation is being stressed.

Advanced Manufacturing Technology

We will provide technology and leadership in advanced manufacturing to make continuing, critical, and valuable contributions to our nation's defense, economic competitiveness, environmental stewardship, and energy security.

This will directly support Sandia's expanded responsibilities for production of nonnuclear components as the nuclear weapons complex is restructured, as well as other national needs for advanced manufacturing capabilities.

Electronics Technology

By leveraging Sandia's research foundation in microelectronics and photonics, we will apply our electronics technology to enhance the safety, security, and use-control of nuclear weapons; make continuing contributions to defense, including new technologies to discourage the proliferation of weapons of mass destruction; and expand our contributions to the nation's economic security by targeting major needs in dual-use technology. Through cooperative work with industry and universities, our integrated capability in electronics technology will enable Sandia to maintain a state-of-the-art electronics technology base and provide value to the nation.

Advanced Information Technology

Sandia's research foundation in computational and information sciences is used to develop and apply advanced information technologies. Focus areas include information surety, human/machine collaboration, knowledge-based engineering, and decision-directed information technologies. These focus areas are vital to our DOE mission and are relevant to other problems of national importance.

Pulsed Power Technology

We will maximize the benefit of our leadership position in pulsed power by applying Sandia's leading-edge pulsed power accelerators to problems of national importance with other DOE laboratories, US industry, and universities. We will provide large volumes of pulsed, high-energy radiation intensities for DOE Defense Programs in nuclear weapons physics, radiation effects science, and inertial confinement fusion in the laboratory, a particularly important capability in the absence of underground nuclear testing. We will apply our efficient, high-average-power sources of electron, ion, and x-ray beams to defense-related missions of materials hardening, environmental remediation, and materials welding and joining. In partnership with industry and universities, we will also apply these capabilities to commercially valuable applications in materials surface modification, electronic pasteurization of food and pharmaceuticals, sterilization of medical instruments and medical wastes, and repetitive electromagnetic force.

US Industrial Competitiveness

Sandia's objective is to make measurable contributions to the global technology leadership of US industry. We will institutionalize the interaction of all Sandia programs with appropriate industry elements and promote the national laboratories' role as a bridge from research to application in collaboration with universities and industry.

We will seek strategic alliances with industry, universities, and other laboratories to pursue industry-defined research and development objectives. These alliances will be mutually beneficial to the sponsoring DOE program and the industrial partner. Such alliances will benefit Sandia by permitting us to incorporate the most current commercial technologies into DOE products. The alliances will help industry by fostering the development of new or improved products and services based on US technology leadership. This work will include new ventures that promote private entrepreneurial activity, which in turn will create new jobs.

Our strategy for collaborative research and development will continue to emphasize large-scale alliances with industry and universities. We will emphasize teamwork with clusters of companies in which the capabilities of DOE,

industry, and universities are combined to develop enabling technology for an industry. We fully support DOE's efforts to create alliances with other federal agencies utilizing the capabilities of the national laboratories.

Sandia recognizes the role played by small business in fueling the nation's economy. We will employ a three-pronged approach to support small business growth and development. Specifically, we will form technology development partnerships with small business through the use of cooperative research and development agreements and similar arrangements. We will deploy existing technology by taking advantage of networks such as the manufacturing extension centers. We will also encourage entrepreneurial activity through alliances with organizations such as the newly formed Technology Ventures Corporation.

Sandia's user facilities will be increasingly important as vehicles for generating cooperative work with industrial partners and for building alliances involving industry, university, and government entities. User facilities help industry obtain maximum benefit from technologies and capabilities developed at Sandia. Research and development conducted in these facilities can satisfy a broad spectrum of dual-benefit needs for government and industry. User facility advisory groups, networks, and cooperative working groups will increase collaboration among industrial, university, and national laboratory participants.

To facilitate collaborative work with industrial and university partners, access to Sandia sites will be made more user-friendly. The fact that Sandia's largest technical area is located on a military installation can make it awkward for partners to conduct business with us. Visitor access to the New Mexico site will be improved by the proposed Technical Information and Outreach Center. This project includes a DOE-controlled entrance at Eubank Boulevard, construction of a new facility, and other site improvements (see 5.3.4). Changes in site layout are likely to affect classified and unclassified business areas, traffic circulation, parking, and other infrastructure.

Visitor access to the California technical area will also be improved through changes in campus infrastructure. Sandia/California's proximity to the high-technology industrial and academic centers of the US West Coast will continue to be a strategic asset for the entire laboratory. The California site will increasingly serve as a gateway to Sandia's laboratories.

Sandia excels in creating new technical information. New technology, however, is only one ingredient in new products and services. Industry also needs intellectual property protection in order to attract the risk capital needed for commercialization. Sandia will continue to increase its capacity to identify and protect intellectual property. We will progressively increase the number of Sandia patent applications filed per year over the next several years.

Sandia programs will have mission-relevant interactions with appropriate industry elements. Sandia's collaborative work will make measurable contributions to the global technology leadership of US industry.

Sandia Production Responsibilities

Sandia's objective is to assume new production responsibilities as requested by DOE to support the stockpile's need for an ongoing, low-volume supply of certain nonnuclear components.

Sandia has been assigned several new production responsibilities that complement the integrated capability in advanced manufacturing technology ongoing at its New Mexico and California locations. The closure of DOE's Pinellas and Mound facilities will result in Sandia taking on responsibility for the production of small quantities of neutron generators and other specialized components. It will also be Sandia's responsibility to manage production procurements for components available in industry and needed for DOE's stockpile stewardship mission.

Further, Sandia is being considered as a supplier of molybdenum-99 to satisfy the US requirement for this radiological diagnostic material.

This emerging production responsibility, which is an important new customer requirement for Sandia, represents an opportunity to complement our advanced manufacturing integrated capability and establish a test bed to prove developments in manufacturing technology before introducing them to industry.

Operational Objectives

Sandia's operational objectives are closely aligned with DOE critical success factors: communication and trust; human resources; environment, safety, and health; and management practices.[1]

Quality

Sandia's objective is to live up to our commitment to total quality through customer satisfaction and continuous improvement in our research and engineering, our products and services, and all our work processes. We will become world-class in our ability to satisfy and delight our customers as measured by the Malcolm Baldrige criteria.

Success and survival for Sandia in the 1990s will require an efficient, quality enterprise. The next phase of the quality implementation at Sandia will require reengineering and

[1] *Fueling a Competitive Economy: Strategic Plan:* US Department of Energy, April, 1994, p. 7.

simplifying work processes so Sandians can perform their jobs with less encumbrance and greater leverage. Work practices should be logical and relevant to real program or administrative requirements.

Sandia's work processes will be managed as an integrated system. As a general rule, continuous improvement is an effective tool for keeping processes useful and efficient. However, when processes become so complex or obsolete that they cannot be substantially improved through incremental changes, comprehensive redesign is required.

A laboratory process reengineering campaign will begin by examining several critical categories of laboratory processes and recommending fundamental changes. A modern information and communications infrastructure will be an enabling tool for process improvements in all areas.

Business Management

Sandia's objective is to achieve outstanding business management in all our administrative systems. We will strive to meet DOE's expectations for excellence in management practices and operate Sandia in accordance with best business practices to strengthen DOE's confidence in Sandia as a well-managed organization.

The DOE Strategic Plan identifies management practices as a critical success factor. It has become clear that the federal government will insist on more cost-effective operation of federal research and development facilities. Cold War practices, which emphasized performance at any cost, are not appropriate in a new era that requires the DOE laboratories to interact with a private sector that measures performance by industrial standards of efficiency.

We will incorporate proven business practices from our parent organization, Lockheed Martin Corporation, to improve Sandia's management and operation. The business leadership of Lockheed Martin will be an important resource as we strive to improve our administrative systems and emulate cost-effective practices of the private sector. We will benchmark our administrative systems against those of industry to identify areas for improvement. In addition, we will promote best business practices in the DOE contractor community and share business systems with other laboratories.

We will improve and more fully utilize the matrix management model for performing work. The sector/division matrix that currently exists will be modified for that purpose. Under this structure, the sectors, driven by customer requirements, manage programs and determine what work must be done and by what schedule. Functional organizations direct the personnel and facilities required to perform work and are held accountable for meeting their commitments to sectors. Sectors will define an explicit set of external customer interfaces. Functional organizations will focus on improving work processes and employee skills. Program managers and functional managers share responsibility for customer satisfaction.

Sandia will maintain an in-house capability for the research and development activities essential to its DOE missions and will develop emerging capabilities anticipated to be essential. Other capabilities may be outsourced to the extent it makes business sense to do so. As a general rule, we will focus Sandia's internal investments on value-added, mission-related capabilities not readily available commercially or from other government sources.

As we embrace our production responsibilities, both for DOE's Defense Programs and for other elements of DOE, we will structure and conduct the production aspects of our work in a manner appropriate for a production enterprise. We will continue to evaluate the proper relationship of our production activities to the laboratory as a whole.

We will operate our New Mexico and California sites as a single laboratory joined by common management policies, operational principles, and state-of-the-art telecommunication systems. We will reengineer work processes and systems that need fundamental retooling in order to integrate the two sites even more fully in the future. Because of its compact size, the California site will be a good environment for pioneering and prototyping new laboratory operational systems.

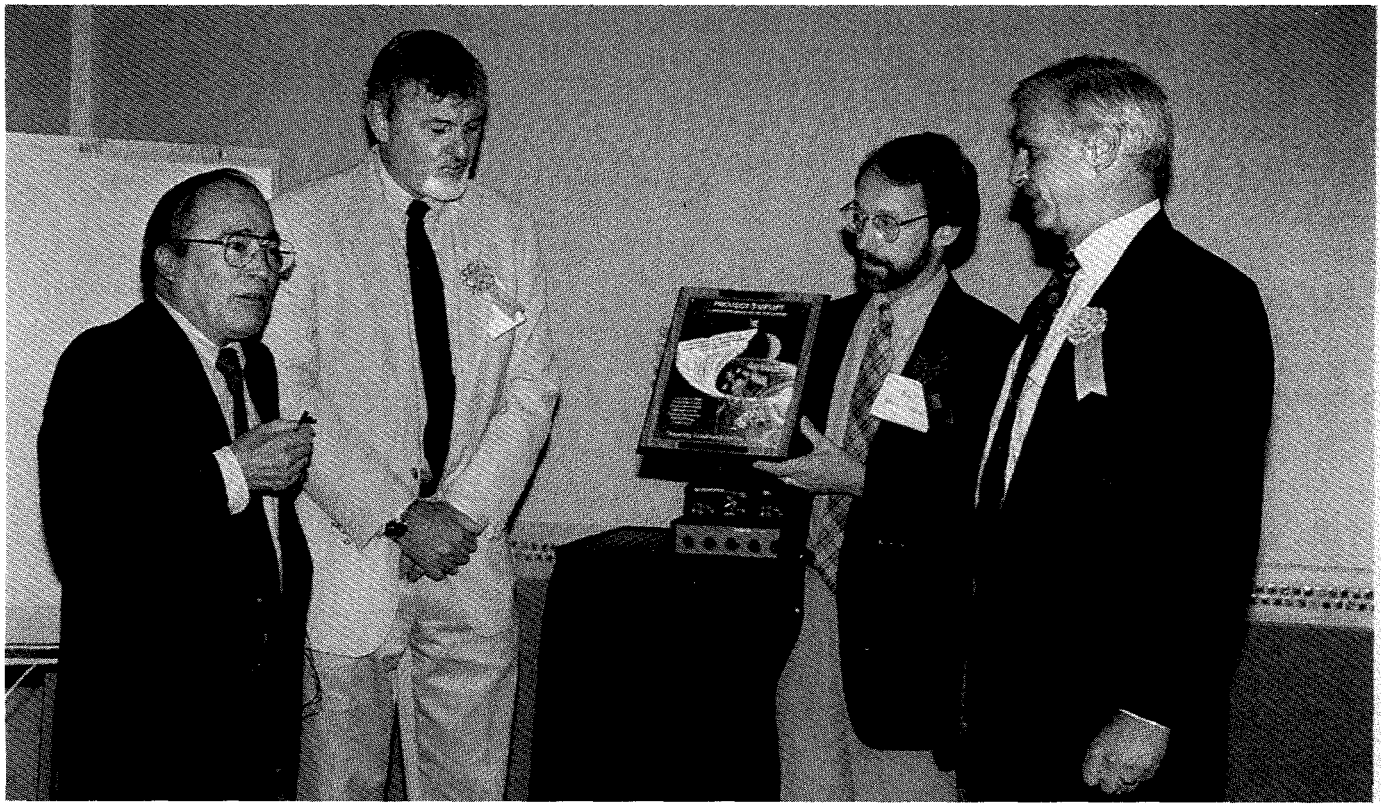
We must strive to achieve compliance with DOE directives. A graded approach to compliance based on risk management principles may be helpful in minimizing the impact on mission capabilities. In cases where DOE directives impose costly or ineffective processes, it is in the interests of DOE and Sandia to examine the requirements of the directive and propose an alternative that can achieve the intent more effectively and efficiently. The DOE Directives Improvement Project, a joint effort of DOE and its laboratories, has been very successful in reducing onerous and inefficient directives. This team effort should continue as we work with the recently established DOE Directives Management Board in the future.

DOE is one of Lockheed Martin's most important customers, representing a core business area of the corporation. We will strive to reflect credit on our parent organization through exemplary programmatic performance, high ethical practices, and faithful execution of our contract obligations.

People

Sandia's objective is to achieve mission success through talented, diverse people working in agile teams. We will encourage a work environment in which every employee has the opportunity to achieve personal success. We will manage staffing levels prudently to provide for current and future programmatic and institutional needs. We will also be a good corporate citizen by supporting the economic vitality of our communities and encouraging community involvement by Sandians.

Our human resources policies must provide the people and skills best suited to support DOE missions in a timely



The President of the National Institute for Professional Development, Henry J. Casso (left), recognized Sandia's efforts to encourage young minority students to pursue careers in science. With him are Al Narath, Paul Shoemaker, and Jim Tegnelia.

manner. To compete nationally for outstanding technical staff, we must offer challenging scientific and engineering assignments with civilian as well as military uses. Support staff will be recruited to meet national standards of education, experience, and professional certification (if applicable). Successful human resources management will help Sandia achieve its long-term programmatic goals within the context of changing work requirements and evolving demographic and societal trends.

Management of human resources at Sandia is consistent with DOE's strategic goals for attracting a well-trained and highly motivated work force and achieving a diversity that reflects American society. We will aggressively implement our human resources plan, one that enhances the ability of our staff to match their interests and skills to Sandia's work commitments. As work requirements change, we will provide employees the opportunity to grow and to assume responsibilities in new fields of endeavor.

The challenge of helping the nation accomplish some of its toughest objectives requires not only the best minds but also the broadest vision—being able to see issues and possible solutions from many different angles. The imperatives in the workplace include a high-performing, diverse work force that appropriately reflects society as a whole and an inclusive culture that fosters such a work force by embracing differences. In addition, the integration of work force diversity with education outreach, community involvement, subcontracting, and technology transfer will enable us to take a more global approach to achieving our goals.

Sandia will continue to foster a culture in which people are empowered to achieve the business objectives of the laboratories. Each person must understand the connection of what he or she does to the success of the business and assume ownership for improving the processes he or she performs.

We will be responsive to people's needs and practice our values in the workplace. The performance management and reward systems will be designed to reinforce these values. We will foster a work ethic that strives for excellence and incorporates a balance between professional and personal goals and responsibilities. Criteria for promotion and reclassification will consider people-related work skills as well as technical excellence. Career development and succession planning will also become responsibilities of line management.

It is Sandia's policy to foster a progressive and productive relationship between labor and management. This will be accomplished by maintaining an open environment for communication and establishing partnerships between management and bargaining units to enhance the utilization of the talents and abilities of represented employees in supporting Sandia's missions. We will resolve issues at the lowest possible level quickly and effectively.

We recognize that stability and continuity are essential for sustained excellence in a research and development environment. Instability in staffing can impair employee morale and productivity. We will try to avoid staffing instabilities through prudent business management and by utilizing retraining and redeployment opportunities wherever possible.

A good corporate citizen is responsible and responsive. As a responsible business, we are committed to meeting the needs of our programs today without compromising the welfare of future generations. Being responsible also means respecting our community—its values and culture as well as its quality of life. As a responsive business, we will listen and respond to the needs and concerns of our community to enable a partnership in maintaining the community's quality of life. The foundation of good citizenship is mutual trust built on communication and cooperation.

Environment, Safety, and Health

Sandia's objective is to maintain our enduring commitment to protect the safety and health of all Sandians and visitors to our sites. We will be a good corporate citizen by protecting the environment wherever we conduct operations.

Our strategy for protecting safety and health in the workplace and the community and preventing adverse impacts on the environment will be based on a methodology to achieve maximum environmental, safety, and health (ES&H) benefit cost-effectively. We will perform a comprehensive identification of ES&H risks associated with our operations and address those risks in a graded manner. In this way, optimum value can be delivered for the resources expended.

Teamwork among employees, customers, suppliers, and community representatives is essential to successfully protect the environment and guard personnel health and safety. Sandia will continue to apply total quality management principles for all ES&H activities. In addition, open, timely communication of ES&H concerns, lessons learned, plans, and status will help assure appropriate and uniform actions throughout all Sandia operations.

Sandia's environmental restoration program will address environmental problems in a timely fashion, thereby maintaining public confidence in our ability to conduct operations without harming the environment.

2.2 Major Initiatives

This section presents initiatives for consideration by DOE or reimbursable sponsors. We consider three of Sandia's major initiative areas to be integrated capabilities:

- Advanced Manufacturing Technology,
- Electronics Technology, and
- Advanced Information Technology.

These integrated capabilities are required for DOE's defense, energy, and environmental programs. They represent established roles for Sandia, and they enable other program contributions and major initiatives (e.g., Advanced Design and Production Technologies and Manufacturing Development). Sandia's general effectiveness is continuously enhanced by work in these areas, increasing our value to DOE and to the government.

Sandia has also identified five major programmatic initiatives or focus areas. Focus area initiatives extend integrated capabilities to new or emerging programmatic objectives. Focus area initiatives, which are defined by the intersection of large-scale, strategic national needs and established laboratory capabilities, include

- Post-Cold War Defense Imperatives
- Energy Research and Technology Development,
- Environmental Technology,
- Transportation Energy Technology and Infrastructure, and
- Biomedical Systems Engineering.

These focus area initiatives are logical applications of our experience base and core competencies. None will require Sandia to acquire costly new competencies that have not been historically related to its missions, but all will add to Sandia's experience and capability base. All offer opportunities to address strategic national needs cost-effectively by exploiting the existing federal investment in Sandia's integrated capabilities.

Our strategy for implementing all our major initiatives, both integrated capabilities and focus areas, is fivefold:

- We will continue to enter into cooperative research and development agreements with individual companies to help them address their proprietary needs.
- Project proposals may either respond to market-driven needs defined by industry or introduce novel technologies that have the potential for new classes of commercial applications.
- Consistent with good stewardship of public resources, all work will include a high degree of collaboration with industry, universities, and other federal laboratories through cost-sharing arrangements.
- We will help support the research and development

needs of small and mid-level businesses through special cooperative arrangements and technology outreach programs.

- We will respond most favorably to requests for partnerships that improve Sandia's capabilities so that greater value will accrue to DOE and the government.

Some projects may not be able to utilize this strategy if they involve classified national defense work. However, even in those cases we will attempt to exploit commercial capabilities to the extent possible. We will diligently identify possibilities where our work with industry will meet industry's needs and improve Sandia's capabilities to serve our government customers.

In the subsections that follow, we will discuss the established capabilities, experience base, and laboratory strengths that make Sandia a valuable and perhaps unique resource for each major initiative. Also, each major initiative discussion presents a package of project proposals for new work or major program enhancements designed to improve Sandia's capability to meet the needs of government customers. Funding and staffing requirements for these proposals are in addition to the ongoing programmatic funding summarized in chapter 7.

The inclusion of a particular project proposal under a major initiative does not imply DOE approval, nor does it represent a commitment by Sandia to implement it. However, each initiative represents a strategic commitment on the part of Sandia management. Each derives its technologies from Sandia's established core competencies and is an activity in which Sandia is acknowledged to have made substantial contributions or significant recent progress. Each represents an opportunity for Sandia to learn and to deepen or broaden our capabilities. Moreover, these major initiatives are intended to implement long-term national and DOE agency goals.

2.2.1 Advanced Manufacturing Technology

Established Capabilities

As a consequence of its responsibilities in systems and design engineering, production process development, intelligent machine research and development, and oversight of the performance and reliability of nonnuclear weapons components over the last forty years, Sandia has become the leader among DOE laboratories for advanced manufacturing technologies. Manufacturing support technologies are central to our mission for DOE Defense Programs and constitute a large fraction of our technology base.

The problems facing the DOE nuclear weapons complex presage those that will be faced by the US manufacturing community as a whole. The future operating environment will require manufacturing agility and cost-effectiveness. We will have to design and manufacture to the highest standards of quality. Production will have to be environmentally conscious. The nuclear weapon laboratories must continue to design for the total life cycle, including retirement, dismantlement, and disposal or recycling of components and materials. As a form of deterrence, the complex will need to demonstrate the capability to get new designs into production quickly. The complex must be able to create designs with a minimum of iterations and validate production processes through simulation. Central to achieving these objectives will be an effective information, communication, and management system that integrates the design-to-production-to-disposal process using teamwork to allow concurrent activities.

DOE cannot accomplish this mission in isolation from the nation's manufacturing community. Conversely, the manufacturing community stands to benefit from the DOE laboratories' research and development in manufacturing.

The National Center for Advanced Manufacturing Technology has been established at Sandia/New Mexico to maximize the value of Sandia's technology base to the manufacturing needs of both the DOE nuclear weapons complex and industry. The center will coordinate its efforts with other government agencies and laboratories, universities, and US industry to ensure maximum value to the nation. The center will also help transfer and apply advanced manufacturing technologies developed in Sandia's defense programs to commercial manufacturing, helping to strengthen US industry's competitiveness. Much manufacturing technology transfer is already taking place through many cooperative research and development agreements with industry.

Sandia's California location is strategically important to our advanced manufacturing initiative as a point of contact with the high-technology industries of the US West Coast. The new Integrated Manufacturing Technologies Laboratory focuses on the development and integration of advanced manufacturing technologies. It conducts research and development in materials and processes, process simulation, engineering design, and manufacturing technology support. It also performs research in prototype fabrication and demonstration techniques for agile manufacturing, both for DOE and the domestic industrial sector. Current work focuses on metal removal and welding, weld process simulation, composites fabrication, high-speed communication of manufacturing data, and on-line monitoring and control.

Many of these activities and initiatives will leverage our knowledge in much the same way that machines leverage muscles. Because this initiative cuts across all Sandia's technical capabilities, activities that are of direct value to and supported by advanced manufacturing also appear in other

major initiatives. An example is the recently established National Center for Advanced Information Components Manufacturing, a partnership involving the Advanced Research Projects Agency, DOE, and industry. Industry requires further developments in the manufacturing of optoelectronics and flat-panel displays. This work will be enhanced by activities under Sandia's other defense-related initiatives intended to make the nuclear weapons complex a model of agile manufacturing.

Project Initiatives

Advanced Manufacturing Technology initiatives are described below. Funding requirements are given in Table 2-1 at the end of this section.

Information-Driven Manufacturing

(for the Assistant Secretary for Defense Programs [program GB])

Information technology is a means of achieving the objectives of the modernized DOE Defense Programs design and production complex and of enabling an economically competitive US manufacturing infrastructure. Future DOE manufacturing systems will depend heavily on a range of computing tools, from design at a workstation to real-time computer control of individual production processes.

Recent research and prototyping work at Sandia has demonstrated the feasibility of very tight coupling of design and production processes. Application-specific development of information technologies such as networking and computer science, design analysis, data processing and storage, information surety, and intelligent production systems, processes, and equipment is required for the nuclear weapons complex.

DOE weapons designers have long used computers to design products, manage and process data, and analyze the performance of their designs. Now these methods are being extended to analysis of the producibility of designs, assessment of the environmental consequences of designs, and automated generation of the controls and programs used by the factory production systems. Information technologies will permit designs to be validated in virtual factories before they are approved for release.

In a likely scenario of future manufacturing, designs will be created at computer-aided design workstations and their performance evaluated by integrated computational tools. The same electronic design information will then be coupled with computer models of production processes developed through simulation and limited experimental validation. These models will be available to product designers for assessment of various producibility issues. This process/product assessment is termed manufacturing validation in current literature. Once designers are satisfied with the design, control algorithms for production equipment are automatically generated using the product design database and the computer model of the process. Automated programming of production equipment will be an important element of agile manufacturing. In turn, the plant model permits real-time control of the process based on information sensed from process and product.



Sandian Ted Blacker is shown at a computer-aided design workstation with the mesh generation "paving" algorithm he developed. The algorithm has greatly advanced the science of mesh generation.

Such manufacturing systems will make heavy use of information sciences and technologies; consequently, we use the term information-driven manufacturing. Information-driven manufacturing technologies will make possible many of the desired attributes of DOE's nuclear weapons complex. Weapons system designers will be able to determine quickly if their designs are manufacturable with the available production systems. Production agencies will be able to remove workers from hazardous operations and reduce waste resulting from contaminated protective clothing. Furthermore, because much of the design and production expertise will be embodied in algorithms and software, the cadre of trained engineers and technicians required to operate the complex will be reduced without degrading the ability to respond to national emergencies.

Sandia and DOE will retain a leadership position in information-driven manufacturing as a result of this initiative. These technologies are key elements of US industrial initiatives in agile and intelligent manufacturing.

Sustainable Industries of the Future

(for the Assistant Secretary for Defense Programs [program GB], the Assistant Secretary for Energy Efficiency and Renewable Energy [program ED], the Assistant Secretary for Environmental Restoration and Waste Management [program EW], the Assistant Secretary for Energy Research [program KC07], and the Assistant Secretary for Fossil Energy [programs AA, AB])

The challenges faced by US industry in the increasingly global, rapidly changing marketplace that has developed at the end of the twentieth century are well recognized. The strategies developed to meet these challenges will be conditioned by the requirements of environmental responsibility and constraints imposed by uncertain access to energy resources, as well as by the cost and time-to-market demands of the evolving world market. Technologies that simultaneously address the challenges of economic competitiveness, energy, security, and environmental quality will form the foundation of the emerging manufacturing infrastructure.

This initiative will employ an integrated, interactive partnership. Integration of government activities and programs will reduce duplication of efforts, leverage investments, and obtain the maximum impact possible. Interaction among government agencies and between industry and government will ensure the development and deployment of technologies that contribute to industry profitability while satisfying federal environmental regulatory requirements. Partnerships or strategic alliances of industry, government, and academe will provide the facilitating mechanisms for technology development and deployment and will ensure that the outcomes of this initiative provide significant benefits to all parties. The primary steps necessary for the effective implementation of this initiative are (in temporal order) formation of strategic alliances; identification and prioritizing of critical national needs; identification of routes to success; assignment of authority and responsibility for implementation; and development, demonstration, and deployment of new processes and products.

Successful implementation of this initiative is expected to contribute to the fulfillment of national agendas in economic competitiveness, environmental quality, and energy security. Capture of additional market share by US companies should help the United States reduce its trade and budget deficits and create new jobs. Waste reductions and energy savings will contribute both to reduced costs of goods and to improved quality of life for Americans. Increased industry profits through lower energy costs of goods and enhanced agility leading to the capture of larger market shares will improve our economic climate. Finally, the training our academic institutions will provide through their participation in this initiative will yield a higher quality work force more able to undertake the high-value-added jobs that will make significant contributions to future US economic well-being. Through its focus on industries of the future, this initiative will substantively enhance the value of the US manufacturing sector.

Environmentally Conscious Manufacturing

(for the Assistant Secretary for Defense Programs [program GB] and the Assistant Secretary for Energy Efficiency and Renewable Energy [program ED])

Environmentally conscious manufacturing (ECM) is the deliberate attempt to reduce the ecologically harmful by-products of industrial processes and improve energy efficiency without sacrificing quality, reliability, or performance. ECM technologies and practices optimize manufacturing process decisions about cost, resource utilization, environmental impact, and product reliability and performance. The end result of ECM is a value-added transformation of materials and energy into products in a manner that adds environmental considerations to the manufacturing process.

Successful implementation of environmentally conscious manufacturing requires a total systems approach to very complex problems utilizing engineering, chemistry, information systems, reliability and risk analyses, life-cycle analysis, and advanced manufacturing.

Sandia has led the way in practical applications of environmentally conscious manufacturing through an integrated systems approach for implementing ECM processes and demonstrating the benefits of ECM in DOE programs. In the past, application of a fully integrated approach has focused on weapons components, including prototyping systems, providing analysis tools, and coordinating the first ECM demonstration in the DOE nuclear weapons complex (electronics and electromechanical component fabrication at AlliedSignal in Kansas City).

Over the next five years, Sandia will bring the benefits and techniques of ECM to US industry. We will develop and demonstrate ECM methods and technologies with high dual-benefit payoff. Sandia will develop methodologies for easier ECM implementation, such as expert-system decision tools to allow consideration of environmental impact in product design and manufacturing process decisions. Sandia will collaborate with the Environmental Protection Agency (EPA) to refine prototype life-cycle analysis tools. We will test ECM's feasibility and complete its development into a user-friendly tool for industrial use. We will evaluate available technologies for ECM, identify technology needs, and initiate programs to develop and provide new ECM technologies that have been fully tested and validated (e.g., advanced soldering and cleaning techniques).

We will concentrate on the application of ECM through collaborative programs with partners from US industry and other government agencies. We will develop industry-driven

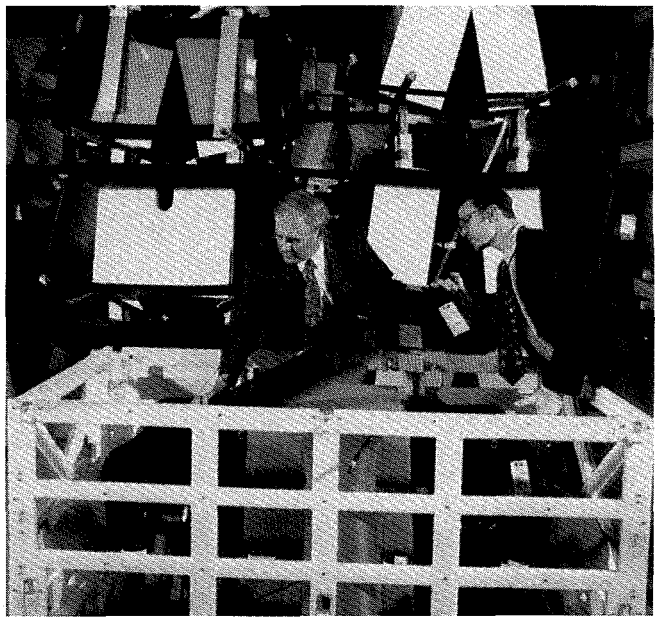
collaborative programs in ECM with the goal of a track record of successful government/industry technology transfers. These programs will emphasize active solicitation of industry's needs, measurement of our effectiveness in meeting those needs, effective dissemination of information on ECM to industry, and identification of opportunities for transfer of industrially developed technologies to the defense complex.

New approaches will be used in these programs, including expanded use of industry advisory groups and market research, adoption of performance metrics accepted by industry, and more active collaboration with industry trade associations for opportunity assessment and information dissemination. We will expand the present work in transferring technology to the microelectronics industry and extend it to other industries (e.g., textile, automotive, chemical, pulp, and paper) with modifications as appropriate. These Sandia programs will cover technologies such as the following: solvent substitution; soldering (no-clean, lead-free, and advanced technologies); polymers engineered for reuse/recycle; "green" printed wiring board fabrication; advanced process monitoring and control; and replacement of hazardous materials in surface coating, metal finishing, and precision machining.

We will initiate new multiple agency collaborative programs, especially with the EPA and the Department of Commerce (DOC), to address regulatory and technology transfer issues more effectively. Programs have been proposed to integrate EPA and DOE techniques for process waste assessment and environmental and energy audits into a single assessment tool. We will collaborate with the EPA and DOC through the Manufacturing Technology Centers of the National Institute of Standards and Technology to evaluate the impact of new ECM processes to make ECM benefits more visible to all US industry. We will coordinate with other DOE offices and DoD to eliminate redundancies and ensure that ECM technology development is applicable throughout the complex.

We will establish Sandia as a national ECM resource by evaluating our current capabilities and developing them accordingly. We will survey commercial ECM resources and develop programs in which Sandia can serve as a focal point, referencing and collaborating with manufacturers to add the ECM dimension. This work will increase emphasis on Sandia as a preferred provider of ECM technology, including evaluation of alternatives, development, feasibility demonstration, assistance in deployment, and dissemination of information.

New programs will be initiated to focus on coordinating state and federal resources to deploy ECM technologies to industry, particularly small businesses. An example is a proposed joint DOE/EPA/DOC Environmental Extension Enabling Program in which Sandia will work with extension entities of the National Institute of Standards and Technology to identify small business needs. We will help develop and commercialize technologies and facilitate technology deployment by training and providing advisors for the National Institute of Standards and Technology, state extension agents, and small businesses. New programs will focus on developing a complete on-line ECM knowledge base and an electronic ECM-information-on-demand network, improving ECM education (via training at Sandia and simulation tools for retraining practicing engineers), and increasing effectiveness of ECM information dissemination through an extensive outreach program that includes a speaker's bureau, videotapes, joint activities with industry trade groups, workshops and exhibitions, and a widely distributed Environmentally Conscious Manufacturing Newsletter.



Using environmentally conscious manufacturing techniques, Sandia helped develop this prototype windshield transport container made from recycled plastic.

Advanced Materials and Manufacturing Technology

(for the Assistant Secretary for Defense Programs [program GB])

Two federal government initiatives, the advanced materials and processing initiative and the advanced manufacturing initiative, have emphasized the importance of materials research and technology development. The intent of Sandia's advanced materials and manufacturing technology initiative is to work with industry to address its critical needs in the areas of materials synthesis and processing. A long-range objective is to improve the flexibility of manufacturing processes and facilitate the application of artificial intelligence to manufacturing operations by

applying tools and concepts of concurrent engineering and computer-integrated manufacturing.

The reconfiguration of the nuclear weapons complex will require development of external industrial suppliers for a large variety of components. Low rates of weapons production and stockpile retrofits will require the design agencies to reduce costs for weapons research by developing and applying new materials and processing technologies. Such technologies will include computer design of advanced materials, computer modeling of materials processing, and development of sensors and real-time diagnostics for materials processing. These technologies can cut costs by accelerating the development of new materials and processes and by reducing the need for prototype hardware. They will enable product design engineers to work concurrently with materials process engineers on component designs. They will permit more rapid prototyping by simulating and validating process options on computers, rather than on the factory floor. Moreover, such technologies will promote computer-integrated manufacturing by furnishing manufacturers with process controllers and process control software.

Planners of advanced materials and manufacturing technology have identified several specific activities for the initiative. These activities include the following: thermomechanical processing; electromagnetic synthesis and processing; development of sensors, process diagnostics, and smart materials; synthesis and characterization of optoelectronic materials; and synthesis, processing, and characterization of composite materials.

Interaction with industry will be facilitated by the recently established Advanced Materials and Processes for Economic Competitiveness Alliance of Sandia, Los Alamos, the Air Force Phillips Laboratory, three New Mexico universities, and the New Mexico Economic Development Department. Industrial interns will be centrally located at the Advanced Materials Laboratory in the University of New Mexico Research Park.

Intelligent Manufacturing Science and Engineering

(for the Assistant Secretary for Defense Programs [program GB])

DOE contractors have found that standard industrial robots, designed primarily for high-volume manufacturing, have limited applicability to their operations, which typically call for small-lot production. However, with a modified approach to robotics research and development, intelligent manufacturing systems can be designed that are specifically applicable to DOE requirements but incorporate standard industrial robotics hardware. Such work will advance the capability of robotic tools available for agile manufacturing in industry.

Sandia's approach is to eliminate entirely the manual process of teaching and programming robots. We are developing algorithmic and software techniques that will let robotic systems generate their own programs. New systems based on these techniques will be able to generate plans of action, program the required devices, and use sensors and instrumentation to react appropriately to changes in the workplace. New sensor and model-based controls are obviating the requirement for precise fixtures and jigs for piece parts. Real-time sensory capabilities will permit flexible production systems to have other desirable features such as automated compensation for tool wear, in-process inspection, and automated error detection and correction.

The intelligent manufacturing science and engineering initiative will draw upon Sandia's robotics technology expertise. During the past several years, Sandia has carried out robotics development for the Assistant Secretary for Defense Programs, the Office of Civilian Radioactive Waste Management, and the Office of Environmental Management. We are currently transferring robotic technologies to several DOE sites, including Pantex, Mound, Y-12, Savannah River, AlliedSignal, and Rocky Flats. Furthermore, we are consulting with several other organizations in the production complex and are performing research and development in advanced manufacturing for DOE mission applications.

In many ways, DOE's design and production activities are a microcosm of the future of commercial manufacturing. The intelligent manufacturing science and engineering initiative will play a key role in reconfiguring and modernizing the nuclear weapons complex and therefore offers an opportunity for DOE to help US manufacturers strengthen their competitiveness.

The initiative will push research in automated programming and planning, geometric modeling and reasoning, and high-speed, sensor-driven control—areas key to the broad application of robotics to DOE problems. In addition, we will construct prototypes of advanced systems targeted for specific applications within defense programs. Managers from across the DOE complex will be consulted regularly on the thrust and scope of developmental activities. Also, engineers from the DOE production plants will help evaluate prototype systems. Sandia developers will continue active participation as full-scale production systems are built and brought into operation.

Virtual Manufacturing Environments

(for the Assistant Secretary for Defense Programs [program GB] and the Office of Energy Research [program KC])

The marriage of two of today's most advanced technology fields, virtual reality and advanced manufacturing, promises significant advances in the emerging discipline of virtual manufacturing. The virtual manufacturing environment will enable designers and others on a dispersed product realization team to interact with a wholly artificial

environment constructed of design and simulation data. This entails sharing and manipulating high-fidelity simulations and three-dimensional, computer-assisted design (CAD) systems in virtual reality space.

Advances in computer and display technologies have made possible the advent of virtual reality, a system that makes it possible for a human to feel immersed in a constructed environment consisting only of computer displays. In such a system, natural human senses can be fully utilized in exploring and understanding the data. In virtual reality space, sound, and touch can be important displays that complement vision.

The most advanced system today is the multidimensional, user-oriented synthetic environment (MuUSE) developed and patented by Sandia researchers. The MuUSE environment is a flexible, modular, device-independent system that takes data or models and provides a highly interactive virtual reality environment in which to explore, examine, and manipulate a user's data. Data may be real-time or stored and may be mapped to represent any variables that the user wishes to investigate.

Advanced manufacturing is characterized by the rational use of human and machine intelligence in the manufacturing process. The integrating factor among world-class manufacturing systems is information. Elements of advanced manufacturing include design tools, process and performance modeling and simulation, sensor-based processes, intelligent machines, automated assembly, and flexibility—which comprise what is sometimes called agile manufacturing. The communications linkages among all the elements of advanced manufacturing are amenable to visualization and simulation. By virtualizing every step of the product realization process, the concurrent team can design an optimal product, establish the most efficient (and agile, lean, and clean) manufacturing processes, prototype the most elegant software, exercise the simplest operational procedures, and set up the best implementing organization simultaneously, without ever hiring a person, building a factory, buying a machine, or making a physical part.

Virtual manufacturing environments, virtual reality, and advanced manufacturing converge in the new paradigm called the virtual interactive environment work space. This work space is the first application package of the multidimensional, user-oriented synthetic environment, and it contains many of the common features required to virtualize the product realization process. Two implementations are being developed: a single-user workstation and a collaborative environment work space.

In single-station mode, the virtual interactive environment work space presents the designer or analyst with a virtual design office. If the site has virtual reality immersion equipment, the office will appear to be an actual room but will have information display and manipulation features that do not occur in physical space. If the work site has other means of display and interaction, such as two-dimensional screens or projection television systems, the same information and the same manipulation are still available, although total immersion will not be possible. A three-dimensional capability is not required; the virtual work space will function on any system that has the proper graphics and computational capabilities, independent of any hardware that inputs or outputs data.

The designer will be able to use voice commands and various input devices to request that electronic data be brought to the design office and displayed there. For a typical designer of electromechanical products using a three-dimensional CAD system, products will appear as real as the local equipment allows. Simulations that predict the rigors of manufacturing and real-world use will be available.

A powerful feature of the virtual interactive environment work space allows many geographically separated persons to meet, see each other, share information, and interact in a virtual meeting room. Each participant will bring along a private office not visible or accessible to others. In that private office, the participant will be able to access all kinds of data and process and manipulate it privately.

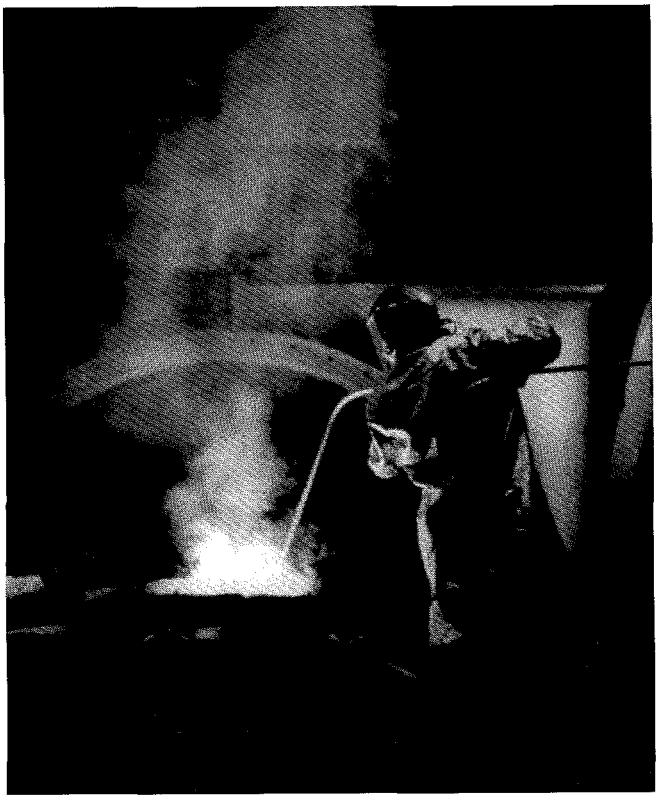
Once displays or data need to be shared with other virtual work space participants, a voice or other command will allow each person to transfer a display for others to see and use. When the concurrent team has reached consensus, the responsible party will download the final design data for further use, perhaps by an information-driven manufacturing system. Advanced communications features will allow many kinds of data transfer, including virtual participation via prerecorded video and audio messages to the virtual work space session.

A virtual video camera feature allows the entire design, analysis, and simulation session to be recorded for further use. Such archives will include the actual computer data, the design intent, and conversations (if required). For future DOE projects, the capability of retrieving archived design sessions will be invaluable. In fact, retrospective design sessions could be convened for existing weapons systems, and the opinions and anecdotes of the original designers could be captured and arranged in hypertext format. By augmenting such sessions with original drawing data and design information and analyses and by including video sessions of assembly and testing, enough manufacturing information could be gathered in one place so that future weapons designers could access and reuse it without having to start from the beginning. Weapons product documentation could conceivably be a file cabinet of CD-ROMs.

Advanced Rapid Manufacturing

(for the Assistant Secretary for Defense Programs [program GB])

Advanced rapid manufacturing is the logical successor to rapid prototyping. Presently, at least thirty fabrication technologies may be called rapid prototyping.



Sandia's FASTCAST™ program has reduced the time of manufactured casting by a factor of ten.

The most mature and interesting of these are classified as solid free-form fabrication, which are additive processes that build solid three-dimensional parts one thin layer at a time. Included in this class are stereolithography, which grows parts from a vat of laser-activated, photo-reactive polymer liquid; selective laser sintering, in which a laser melts together particles of plastic or wax to make solid parts; and direct shell production, also called three-dimensional printing, which sprays binder selectively onto ceramic powder to make prototype parts. Other rapid prototyping processes use combinations or variations of these techniques or utilize rapid prototyping processes as intermediate steps (e.g., producing wax molds for investment casting by selective laser sintering).

Since the invention of stereolithography in the mid-1980s, rapid prototyping has revolutionized the production of physical prototypes. It is now practicable to design a model in three dimensions on a computer-assisted design system and then have it fabricated in hours or minutes at a rapid prototyping facility. Compared to machined or cast prototypes made by conventional means, this procedure can reduce the total procurement time from months or weeks to days or hours. Dimensional scaling of small models to large size and vice-versa is routine for fit checks and detailed design reviews. Additionally, layer-by-layer techniques allow the fabrication of one-piece, seamless assemblies not possible with conventional methods.

An important limitation of rapid prototyping models is existing materials. Most rapidly prototyped models are fragile or structurally sufficient only for display, demonstrations, or fit checks. They lack the strength, wear resistance, and temperature stability of actual engineering materials. Advanced rapid manufacturing refers to the logical next stage in the development of rapid prototyping, namely the rapid fabrication of production-quality parts in a similar time scale. Advanced rapid manufacturing has the potential to revolutionize manufacturing the way rapid prototyping revolutionized prototyping. The Sandia Advanced Rapid Manufacturing Proposal Team has set a goal of making final-quality parts at least one-hundred times faster than possible by current conventional manufacturing. This will involve attention to each element of the product realization process, from initial design through physical fabrication, and the integration of each element by efficient information flow.

Several rapid manufacturing technologies and techniques already exist in prototypical form within Sandia, and it is useful to learn from them. For example, Sandia's FASTCAST™ program utilizes only a few of the elements that advanced rapid manufacturing proposes to use, yet FASTCAST™ has already reduced the time from design to the first manufactured casting by a factor of ten. In addition, FASTCAST™ is the core technology of a new consortium to develop spinoff technology for US industry. One critical element of FASTCAST™ is the ability of rapid prototyping to produce very accurate patterns for castings.

A full complement of rapid-response manufacturing and production will be required to support the nuclear weapons complex vision of a comprehensive dual-benefit industrial base. This capability to meet stringent defense needs by advanced industrial technologies is an exemplar of the dual-benefit concept. Advanced rapid manufacturing promises to expand this concept and speed it significantly. Advanced rapid manufacturing aims for an integrated portfolio of manufacturing technologies (from conceptual design through virtual manufacturing to physical fabrication) that will meet DOE Defense Programs production needs orders of magnitude faster than possible today and at the same time enable US manufacturers to stay ahead in the competition for civilian international markets.

Smart Material Systems

(for the Assistant Secretary for Defense Programs [program GB])

Improvements in manufacturing technologies can be made using smart material systems technology. Smart materials and structures have the ability to respond beneficially to internal and external stimulation through intelligent sensing, processing, and controls. This technology provides

the designer an expanded capability and new design methodology in the materials and structures area that can be employed for a variety of manufacturing tasks, including the design of new products or manufacturing systems.

First, smart material systems enable a designer to use lightweight structural systems for high-precision tasks. Second, smart material systems convey information about the current structural health of the system and use this information to adapt and achieve a desired goal. Third, smart material systems technology facilitates manufacturing process control via embedded sensors. Intelligent material and structural systems often involve flexible structure control problems. These systems have sensory and actuating characteristics that can respond in real time to the environment and modify responses to overcome undesirable and unexpected stimuli. The solution to such problems is directly related to complementary technologies in intelligent process control and intelligent machines.

Cost and time to manufacture can be reduced through application of smart material systems. This is made possible because of recent advances in a number of related technologies, including materials, sensing and actuating, processing, reliable structural modeling and simulation, and microdevices. It is now often less expensive to incorporate sensors, actuators, and computing than to use heavy structures to achieve the accuracy and precision required for a reliable design or manufacturing task. It is a requirement of agile manufacturing that processes be able to adapt to new families of design, and this adaptability is inherent in smart material and structural systems.

To maintain accuracy in precision manufacturing, operations will require an ability to sense and control actively the vibration inherent in many procedures. This use of active vibration control is needed for advanced lithography machines for semiconductors or flat panels to achieve the desired precision. Structural systems and equipment used to produce weapons parts in agile manufacturing operations will require intelligence and adaptability. Also required are very accurate modeling and simulation capabilities to enable virtual prototyping of weapons, thus avoiding costly hardware iterations. On-line system identification is required for control of flexible structural systems, for detection of the onset of chatter and suppression of vibration, for precision machine tool manufacturing systems requiring vibration reduction, and for other precision cutting or grinding operations.

Other manufacturing applications of smart materials include embedded sensors to monitor the cure cycle for composite materials; damage detection and health monitoring of sensitive structural systems; shape memory alloys as clamping devices for automated production line handling to eliminate environmentally damaging hydraulic clamping systems; process control of extruded and injected molded plastics; temperature and wear compensation; precision oscillating equipment; and nonintrusive sensing of manufacturing process parameters internal to material processing.

Current efforts in the field of smart material and structural systems by the private sector and other government agencies have increased significantly in recent years. Sandia has a unique opportunity to bring its resources to bear on a technology of great importance to this country. Advances in this field require the resources of an organization that has both breadth and depth in the individual technologies that make up this multidisciplinary field. Such expertise requires the integration of experimental and analytical research and development in materials, structures, processing, sensors, and controls, plus a capability for prototype device development and systems engineering—skills that are well established at Sandia.

Manufacturing Energy Conservation

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program ED])

Sandia's work in DOE's Industrial Waste Reduction Program is focused on changing the initial processes used in manufacturing to reduce both the waste generated and the energy used in manufacturing. This approach has great potential to help industry because it improves the entire manufacturing process. Industry supports this program because of its potential to yield huge savings and to help protect the environment.

Sandia supports DOE in areas that can enhance advanced manufacturing, such as industrial waste reduction and environmentally conscious manufacturing. Integrating concepts and lessons learned from these projects into the baseline planning for tomorrow's manufacturing programs will enhance US competitiveness by making products less costly and more desirable in worldwide environmental markets.

The waste reduction program has already proved itself of value to US industry. It is currently industry-driven, market-based, and cost-shared with industry, and it leverages investments already made by the federal government in the national laboratories.

In a parallel effort, Sandia has been coordinating demonstrations of environmentally conscious manufacturing in the DOE weapons complex. Sandia uses an integrated systems approach that attempts to reduce the ecological impacts of industrial activity and improve efficiency of energy use without sacrificing quality, reliability, or performance. Over the next five years, our strategy for the program will be to concentrate on the application of energy conserving manufacturing through collaboration and partnership with industry and by making Sandia a national center for the methodology.

Specific support is needed to integrate environmentally conscious manufacturing and energy reduction into the design of advanced manufacturing processes. Known

opportunities for significant energy conservation present themselves, new approaches will be developed.

Technology-Based US Product Reliability Leadership

(for the Assistant Secretary for Defense Programs [program GB])

DOE and commercial industry have similar requirements for high-reliability systems and components. Meeting these requirements, a serious challenge for the nuclear weapons complex today, will become a critical issue as production downsizes and as we move toward agile manufacturing.

Quality will be vital in meeting sponsors' expectations for reliable systems. The key issue will be to achieve high reliability competitively (i.e., to produce extremely low failure rates while producing the product at the lowest possible cost).

Two essential components for performance and leadership are a quality culture and the application of reliability technologies. Quality culture refers to the values and principles of individuals and organizations. Reliability technologies refers to the base of technical competencies required for a practical, competitive implementation of a quality culture. This base includes such competencies as reliability physics, failure analysis, nondestructive testing, process control, and design for manufacturing.

The military and economic security of the United States demands that the nation achieve and sustain competency and leadership in technologies for quality and reliability. This initiative proposes a multiorganizational National Center for Ultra-Reliability Engineering (NCURE). Sandia possesses strong qualifications for leadership in a cooperative NCURE program. The extreme consequences of a nuclear weapon failure have required Sandia to develop and maintain a broad base of expertise in quality and reliability technologies. NCURE will use capabilities from the entire DOE complex and will broadly support US industry and government programs.

Strategies will be identified for ensuring high quality and reliability in the small-lot, high-product-mix environment of downsized defense production and agile manufacturing. We will also define key reliability technology drivers of the future and pursue related research and development.

NCURE will identify key dual-use technologies and work with industry to establish and maintain world-class quality technology capabilities in these areas. For example, NCURE will provide concurrent engineering support for developing advanced electronic technologies such as flat-panel displays, high-speed electronics, and high-temperature electronics.

All organizations are susceptible to the loss of valuable expertise as key technical people retire. This problem has particularly important implications for DOE because it has responsibility for nuclear weapons that have service lives longer than the careers of the original designers. An important goal of NCURE will be to develop practical expert-system methodologies to preserve the knowledge of such individuals.

Concurrent Engineering Practices

(for the Assistant Secretary for Defense Programs [program GB])

Sandia has initiated an effort to create in the near-term a process both to build small quantities of replacement weapon hardware and to mobilize quickly for volume production upon command. This program will develop processes for weapons products realization in the nuclear weapons complex to support DOE's vision of a smaller, more cost-effective complex to support dismantlement, stockpile management, and new weapons development. It is not intended to support direct research and development of new technologies for weapon products but to couple the product cycle tightly from design through dismantlement, resulting in efficient, flexible, and affordable design and production.

The nuclear weapons complex functions with traditional industrial engineering processes for product realization. A more modern approach is needed. This initiative will define and implement concurrent engineering processes for the realization of weapons.

Concurrent engineering (in the context of DOE Defense Programs weapons production) is defined as a process for product realization that improves cycle time by using teamwork from concept to disposal, with special emphasis on up-front engineering of all process and life-cycle requirements. Concurrent engineering offers a systematic approach to the integrated, simultaneous design of products and their associated fabrication processes. This approach is intended to cause weapons developers to consider all elements of the product life cycle from concept to disposal, including quality, cost, schedule, and performance.

To implement this initiative, Sandia will conduct activities in two major areas. First, an integrated systems approach will be employed for weapons design and manufacture that encompasses the entire life cycle of weapons components. Building on the Standardization Enabling Program, Pit Reuse for Enhanced Safety and Security, Focal Point, and other demonstration programs, the initiative will focus on a few pilot product realization projects. These pilot projects will be the vehicles for development cycle activities.

Specific subsystems and components will be selected as pilot projects. The two initial candidates will be a fireset/programmer and the focal point paste explosives system. The entire integrated approach will be exercised on these prototypical applications, including systems management (emphasizing rapid cycle time), design for manufacturability and cost, process characterization (focused on feedback to the design process), continuous improvement of all processes, waste minimization, and demonstration of industrial partnerships. New pilot projects will be selected as the new process gains momentum.

The second major area to be addressed is the formation of multidisciplinary teams to apply concurrent engineering principles to design, manufacturing, and dismantlement processes. These teams will include designers, manufacturing engineers, materials and process scientists, environmental safety and health engineers, waste management specialists, information management specialists, and so forth. By improving the manufacturability of current nuclear weapons components, engineers can generate ideas that may benefit stockpile and dismantlement activities and achieve better designs for future production.

A project management approach will ensure that this initiative develops according to planned strategic intent, that resources are properly aligned with requirements, and that effective linkages are maintained between customers and support groups.

Production Readiness Assurance

(for the Assistant Secretary for Defense Programs [program GB])

Manufacturing is a crucial component of the defense technology base and a principal factor in US economic security. The new weapons procurement strategy calls for ongoing development of advanced weapons systems to retain America's technological edge in military systems. In contrast to past practice, however, these new weapons systems may not be immediately produced in quantity. Instead, the nation will retain the capability to produce them quickly when needed in response to threatening world conditions.

This strategy affects the US military's ability to maintain a substantive fighting capability and a credible deterrent in several ways. First, the concept of readiness will have to be expanded to include the infrastructure that will create weapons systems. This infrastructure includes both captive production facilities and industrial production capacity. These industrial production facilities will require unprecedented flexibility to produce a mix of military and nonmilitary products. The nation will need new methods for monitoring and assuring the readiness of this large production complex to meet its critical, time-limited needs in periods of crisis.

Second, accredited production processes are needed that can operate at low- or no-volume levels for many years and then be turned on for volume production with no loss of quality. The technological implications of this requirement are profound. The manufacturing processes must be validated to high quality standards with only small sample sizes. The corporate memory for those processes must be preserved so that it can be recalled without a lengthy learning curve. In addition, there must be procedures to revalidate (and periodically modernize) the reinstated processes without lengthy pilot production runs. These needs are beyond the current state of the art in manufacturing.

Third, the defense production infrastructure will need an agility that it does not possess today. If a decision to rearm should be made, it is likely that modifications to extant weapons systems will be specified at the same time. Those modifications will be based on an assessment of the specific threat to be countered. The engineering and design functions needed to accomplish these changes will have to exhibit the same agility as the fabrication systems that produce them. Thus, highly integrated, paperless, concurrent design and analysis systems will have to function seamlessly with the rest of the procurement and production infrastructure. It will be a great challenge to make the agile manufacturing concept a reality in the defense procurement arena.

These challenges facing defense manufacturing must also be addressed by DOE, and in some cases the problems will be even more difficult. The production volumes of nuclear weapons will almost certainly be quite small, but the standards for quality will remain uniquely high. Moreover, the ability to resume quantity production must be retained. As actual production experience diminishes, it will become more difficult to sustain our ability to produce a high-quality product unless agile manufacturing technologies and practices are available and have been demonstrated. DOE should become a leader in integrated engineering, design, and production in order to meet its responsibilities in the twenty-first century.

Manufacturing Energy Systems and Energy Efficient Manufacturing

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program BD])

Sandia is working with the domestic renewable energy industry to provide enabling technologies in advanced materials and manufacturing. Our goal is to assist industry in improving the manufacturability, performance, reliability, and cost-competitiveness of renewable energy systems. This new initiative provides an opportunity for Sandia to obtain support for defense programs materials and manufacturing and for applications of these capabilities to our Applied Energy programs.

Sandia's capabilities in advanced manufacturing and materials are relevant to the needs of the domestic renewable energy industry. Some examples include information-driven manufacturing of energy system components, improved materials and encapsulants, improved process controls in casting, welding and joining, improved reliability of solder joints, environmentally conscious soldering processes, advanced mirror and concentrator fabrication processes, electronic components design for robust power inverters, and improved controllers.

Table 2-1. Funding Requirements for Initiative Project Proposals in Advanced Manufacturing Technology (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Information-Driven Manufacturing					
Operating	8.0	20.0	30.0	35.0	30.0
Capital Equipment	5.0	8.0	8.0	7.0	5.0
Total Cost	13.0	28.0	38.0	42.0	35.0
Direct Personnel	30	60	100	120	90
Sustainable Industries of the Future					
Operating	8.0	16.0	24.0	35.0	37.0
Capital Equipment	2.0	4.0	6.0	5.0	3.0
Total Cost	10.0	20.0	30.0	40.0	40.0
Direct Personnel	35	70	100	165	170
Environmentally Conscious Manufacturing					
Operating	10.0	15.0	20.0	25.0	25.0
Capital Equipment	2.0	4.0	5.0	4.0	3.0
Total Cost	12.0	19.0	25.0	29.0	28.0
Direct Personnel	25	30	50	55	55
Advanced Materials and Manufacturing Technology					
Operating	10.0	10.0	15.0	15.0	20.0
Capital Equipment	5.0	10.0	10.0	10.0	5.0
Total Cost	15.0	20.0	25.0	25.0	25.0
Direct Personnel	40	40	60	60	60
Intelligent Manufacturing Science and Engineering					
Operating	6.0	10.0	15.0	15.0	20.0
Capital Equipment	1.0	2.0	2.0	2.0	1.0
Total Cost	7.0	12.0	17.0	17.0	21.0
Direct Personnel	25	40	50	50	50
Virtual Manufacturing Environments					
Operating	1.2	2.5	1.8	1.8	1.8
Capital Equipment	1.0	1.5	1.0	0.8	0.8
Total Cost	2.2	4.0	2.8	2.6	2.6
Direct Personnel	6	10	12	12	12
Advanced Rapid Manufacturing					
Operating	5.0	8.0	10.0	10.0	10.0
Capital Equipment	2.0	3.0	3.0	2.0	2.0
Total Cost	7.0	11.0	13.0	12.0	12.0
Direct Personnel	20	35	40	40	40

Table 2-1. Funding Requirements for Initiative Project Proposals in Advanced Manufacturing Technology (Dollars in Constant FY 1995 Millions; Personnel in FTEs) (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5
Smart Material Systems					
Operating	2.5	5.0	8.0	13.0	14.0
Capital Equipment	0.5	2.0	2.0	2.0	1.0
Total Cost	3.0	7.0	10.0	15.0	15.0
Direct Personnel	10	20	35	50	50
Manufacturing Energy Conservation					
Operating	6.0	10.0	15.0	15.0	15.0
Direct Personnel	10	18	20	20	20
Technology-Based US Product Reliability Leadership					
Operating	5.0	10.0	12.5	12.5	12.5
Capital Equipment	1.0	2.0	2.0	2.0	1.0
Total Cost	6.0	12.0	14.5	14.5	13.5
Direct Personnel	25	40	50	50	50
Concurrent Engineering Practices					
Operating	8.0	8.0	6.0	6.0	6.0
Direct Personnel	32	32	24	24	24
Production Readiness Assurance					
Operating	12.0	25.0	31.0	31.0	31.0
Capital Equipment	2.0	4.0	7.0	7.0	5.0
Total Cost	14.0	29.0	38.0	38.0	36.0
Direct Personnel	50	100	115	115	115
Manufacturing Energy Systems and Energy Efficient Manufacturing					
Operating	12.0	15.0	20.0	20.0	20.0
Direct Personnel	20	25	30	30	30
Total, Advanced Manufacturing Technology					
Operating	93.7	154.2	208.3	234.3	242.3
Capital Equipment	21.5	40.5	46.5	41.8	26.8
Total Cost	115.2	194.7	254.8	276.1	269.1
Direct Personnel	328	520	686	791	766

2.2.2 Electronics Technology

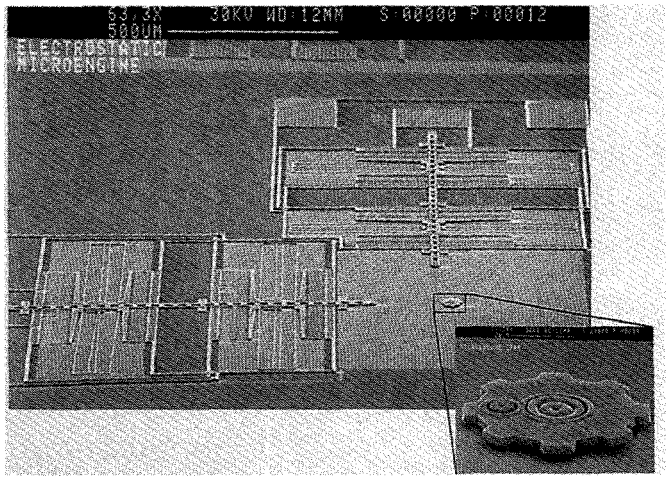
Established Capabilities

Sandia's electronics capabilities and programs embody the entire electronic-component realization process. The depth and breadth of our capabilities are unique among US government facilities. We apply our resources to developing custom components for specialized DOE and other federal agency applications and in precompetitive technology partnerships with the private sector.

Sandia's broad-based activities provide a focus for DOE's response to industry-generated technology road maps such as those prepared by the Semiconductor Industry Association, the Optoelectronics Industry Development Association, and the National Electronics Manufacturing initiative. In addition, we provide a direct mechanism for applying university research to manufacturable electronics products and processes.

Sandia's Center for Microelectronics Technologies provides a unique capability for research and development that is both critical for future defense programs systems and relevant to industry. Sandia established the Center for Microelectronics Technologies by combining the existing Microelectronics Development Laboratory with a major donation of equipment and technology from IBM Corporation. The IBM donation provides a state-of-the-art submicrometer silicon-integrated-circuit research and development capability supporting the total semiconductor development cycle. The Center for Microelectronics Technologies will create a centralized site in partnership with the US microelectronics industry and US universities to develop the technologies, the manufacturing equipment, and the advanced processes upon which the future of both defense and commercial electronics depends. The Center for Microelectronics Technologies will also train US graduate students in the most advanced integrated circuit technologies in the world. The centers' major impacts are on processing methods and equipment (singled out as critical elements of this technology in the DOE Defense Programs Critical Technology Plan) and on US semiconductor manufacturing equipment, another key goal. This capability is being accessed by industry through a five-year, $100 million cooperative research and development agreement with the US semiconductor industry SEMATECH consortium, as well as through cooperative research and development agreements with individual companies. The center is supported by a large range of semiconductor and microelectronics capabilities and includes advanced sensor, silicon micromachine, and advanced packaging technologies.

Activities of the center in support of the US semiconductor industry include the Semiconductor Equipment Technology Center, the Center for Contamination-Free Manufacturing Research, and the Equipment Design Support Center, all joint projects with SEMATECH.



Surface micromachine microengine that will be used to drive a micromachined stronglink (not shown). This microengine can also be used to drive micromachined pumps, valves, sensors, and positioners.

The Center for Microelectronics Technologies conducts joint projection extreme ultraviolet lithography programs with industrial partners to develop the next generation of processes and processing equipment. The center is also the site for developing environmentally conscious manufacturing and environmentally safe and healthful procedures for semiconductor manufacturing. Sandia is working with SEMATECH and US equipment manufacturers represented by SEMATECH to develop a semiconductor equipment design center in the Semiconductor Equipment Technology Center.

Sandia's Microelectronics Development Laboratory is a 74,000-square-foot facility that includes 30,000 square feet of clean-room space with 12,500 square feet of class-1 clean space in twenty-two separate clean room bays. The laboratory's design provides maximum flexibility for new processing equipment and device technologies and is uniquely configurable to support the Center for Contamination-Free Manufacturing Research. The Microelectronics Development Laboratory's equipment supports the total semiconductor development cycle, including research, design, fabrication, packaging, testing, prototype delivery, qualification, and technology transfer. These facilities also support intelligent micromachining, high-density packaging, and intelligent sensor and display research.

Sandia's Electronics Quality and Reliability Center provides staff and equipment to evaluate and verify electrical and mechanical properties of microelectronic materials, design, verification, and construction at the component level. Sandia's reliability physics and engineering efforts draw upon materials science programs that develop basic understanding of failure mechanisms such as electromigration or stress voiding, defects in insulators and metallizations, and defects in semiconductors. Sandia's National Center for

Ultra-Reliability Engineering Program, which focuses on ultra-reliability in electronics components for nuclear weapons, is transferring these techniques to commercial electronics manufacturers.

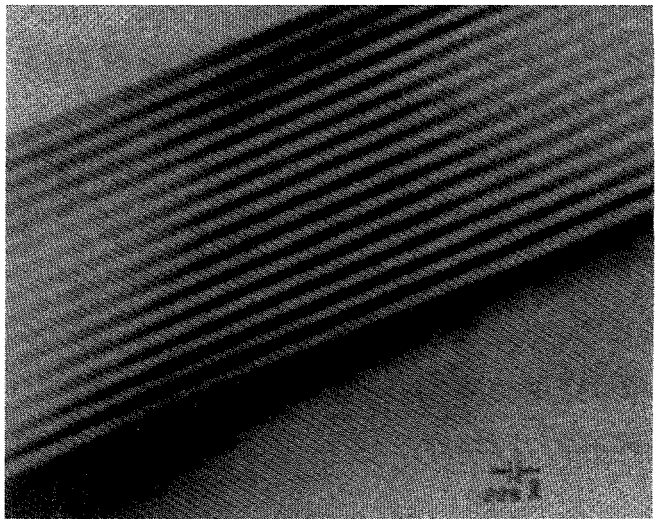
The Center for Contamination-Free Manufacturing Research at Sandia was formalized by a cooperative research and development agreement with SEMATECH in 1992. This center exploits the unique layout of Sandia's Microelectronics Development Laboratory to conduct experiments to advance semiconductor manufacturing concepts and use equipment to reduce contamination that limits the yield of integrated-circuit manufacturing processes.

The center conducts and coordinates research in cost-effective, contamination-free manufacturing technologies involving features as small as 0.2 micrometer and removal of defects as small as 0.01 micrometer. Research focuses on the effects of chemical particulates and electrostatic, thermal, and electromagnetic (including light) radiation contamination on circuit yield and performance. The center also helps develop the following: equipment and processes; improved equipment reliability through software quality, ergonomics, and modeling; and new lithography devices, material components, and equipment. These activities are an extension of Sandia's historic development of the laminar-flow clean room, which made possible the entire microelectronics industry.

Sandia was a pioneer in the development of compound semiconductors. Our Center for Compound Semiconductor Science and Technology pioneered the strained-layer superlattice material and such strained-layer superlattice-based devices as pseudomorphic, high-electron-mobility transistors and circuits, as well as such semiconductor photonic devices as vertical cavity, surface emitting lasers. In this laboratory, Sandia engineers demonstrated the advantages of strained-layer superlattices, which today are responsible for the highest-speed, highest-efficiency, and longest-lived semiconductor lasers, transistors, and integrated circuits in the world. A recent achievement is the fabrication of a vertical cavity, surface emitting laser that achieved 53 percent electrical-to-optical efficiency. This twenty-fold performance improvement over previous vertical cavity, surface emitting lasers makes them useful for both military and commercial applications.

The center supports the full range of theoretical and experimental activities for solid-state physics, materials science, crystal growth, device and circuit design, and fabrication to develop the next generation of compound semiconductor electronic and optoelectronic devices. Facilities include capabilities for extensive molecular beam epitaxy and metallorganic chemical vapor deposition crystal growth, ion implantation, and electron-beam lithography in a 6,000-square-foot, class-100 clean room with state-of-the-art processing equipment.

Sandia's program for sensor development employs more than one hundred technical professionals who extend the state of the art in sensor technologies for next generation weapons technologies, commercial manufacturing, and



This strained-layer superlattice consists of many thin layers of semiconductor materials.

other applications. Unique facilities include the Microelectronics Development Laboratory (described above); the Intelligent Machine/Robot Advanced Sensor and Control Laboratory, consisting of twenty-five different development laboratories containing the latest commercially available computer-controlled robots, five-axis computer-controlled machines, mobile platforms, state-of-the-art research robots, and advanced controllers; the Microsensors Research and Development Laboratory, including fifteen separate research, engineering, and development laboratories that fabricate, package, and integrate new sensors into fieldable subsystems; and the Sensor Test and Modeling Laboratory, which has numerical modeling and equipment characterization facilities for environmental, chemical, electromagnetic, stress, and thermal testing.

The Advanced Manufacturing Processes Laboratory, a facility for advanced prototype manufacturing, is housed in a 100,000-square-foot building featuring equipment for hybrid microcircuits, thin films, printed circuits, ceramics, plastics, and rapid prototyping. The laboratory coordinates its activities with the Integrated Manufacturing Technologies Laboratory at Sandia's California facility.

This design center is chartered to focus on reliability and quality of manufacturing processes through understanding and qualification of manufacturing processes. Particular emphasis is given to automation and robotic handling through complementary programs in both software and robotics hardware.

This facility is also a proving ground for custom sensors for manufacturing processes. Emphasis is placed on developing new approaches to joining and sealing dissimilar materials that have particular relevance to advanced packaging. Collaborations with the Iaccoca Institute at

Lehigh University have led the Advanced Manufacturing Processes Laboratory to support empirical investigations of higher-level manufacturing issues such as control, optimization of material flow, and work space organization.

To provide custom designs for its customers, Sandia has developed an integrated approach to the design of microelectronic components and systems. As part of these activities, Sandia writes custom support software for commercial vendors, which has become the basis for multiple commercial design packages. Sandia's integrated software environment combines circuit-level simulators, logic-level simulations, and both analog and digital system-level simulators—with complete verification from chip to multichip module to the printed circuit board.

Sandia's capabilities and facilities in electronics are comprehensive and span the development cycle from research to manufacturing support. This competency is certainly unique among US government facilities and is competitive with the best electronics research and development facilities in the world. The following package of initiative project proposals is designed to exploit these capabilities for maximum benefit to both defense and civilian needs.

All the above capabilities are enabled by the strong science and technology base at Sandia. Fundamental understanding of solid-state physics, chemistry, optics, semiconductor technology, photonics, computing, modeling and simulation, and materials science are the foundation of our world-class research staff's competence in electronics.

Project Initiatives

Electronics Technology initiatives are described below. Funding requirements are given in Table 2-2 at the end of this section.

Electronics Technology Center

(for the Assistant Secretary for Defense Programs [program GB])

Electronic components are at the heart of every weapons system and of many commercial products.



RAYBOT, a telerobotic vehicle developed at Sandia, uses a hierarchical control system that allows it to be upgraded without major changes to software or hardware.

Electronic products range in complexity and sophistication from the portable radio to very sophisticated computers, smart bombs, and life-support systems. Electronics has revolutionized the ways in which the nation defends itself and has affected nearly every aspect of our lives. Our automobiles now go 30,000 miles without needing a tune-up because of electronic fuel delivery systems, and our homes include electronically controlled appliances, entertainment devices, security systems, and in some cases life-support systems.

Sandia is DOE's electronics design and test laboratory. For more than forty-five years, Sandia has designed manufacturable electronics systems that meet the stringent surety requirements of nuclear weapons. Sandia's successful fulfillment of this mission has created a world-class capability to design, model, test, and prototype electronic subsystems. Yet outstanding though it is, this capability needs to undergo continuous improvement and maintain a state-of-the-art infrastructure to meet DOE's evolving needs and ensure the availability of components for future DOE systems through technology partnerships with American industry.

The Electronics Technology Center needs to be established at Sandia to meet the dual needs of fulfilling DOE's requirements and helping to ensure the availability of weapons components from American industry. The center would meet these needs by dramatically improving electronic product realization processes and technologies. The success of the center would be measured by its technological capabilities to shorten the concept-to-product development cycle, reduce development and manufacturing costs, and minimize the product's environmental impact simultaneously through the production, use, and disposal of life-cycle elements.

The near-term focus of the center's work would be on improved design and performance modeling tools. At present, the best design and modeling tools for electronics products require an experienced, well-trained designer and often a significant capital investment in hardware and software. Even under the best conditions, very few common ties exist in data input formats among the various tools. Consequently, the product designer must enter design data in the initial computer-aided design file in one format, then reenter the design data in a second format for circuit electrical performance modeling, then a third time for thermal and mechanical analyses, and a fourth time for circuit board physical layout for fabrication, and so on.

One initial thrust of the Electronics Technology Center would develop overlay expert systems that obviate this duplication of effort. These multiple entries are costly both in the time and talent consumed and also in the errors introduced and propagated at each data entry point. These errors often lead to multiple prototyping and slow the entry of the product to the market, which could lead to lost market share.

Recently, Sandia designers were able to demonstrate a dramatic decrease in development cost and cycle time. They successfully brought a complicated, high-value defense product from concept to product without ever building a physical prototype. The prototype existed only as bit patterns in a computer memory. The use of such virtual prototyping resulted in a well-characterized design and robust product. The development period was characterized by rapid design iteration cycles and tremendous savings in cost and development time. This work exemplifies the promise and payoff of the proposed Electronics Technology Center.

The development and use of advanced product realization technologies in the Electronics Technology Center would ensure Sandia's capability to meet DOE's changing needs. This initiative would enable the delivery of manufacturable designs in much less time, at a reduced development cost, and with higher product surety than at any time in the past.

Another thrust of the electronics technology initiative would be the development of a design assistant to lead engineers through the concept-to-product cycle. This computer-based design assistant would facilitate the skilled engineer's use of various tools while simultaneously augmenting the less skilled engineer's ability to select and use the best and most appropriate design tools and processes. This capability is viewed by many in the electronics products industries as a critical differentiator for American industry. At the conclusion of this phase of the initiative, the technologies of the Electronics Technology Center truly would be a dual-benefit capability to meet DOE needs while providing a strategic advantage for the nation's electronics industry.

This initiative would require partnerships with both industrial consortia and other federal agencies. The National Institute of Standards and Technology National Information Infrastructure initiative and the National Center for Manufacturing Sciences' Environmentally Conscious Manufacturing programs are examples of potential synergistic relationships, and the SEMATECH Semiconductor Equipment Technology Center is a successful model of an industry-government partnership currently in operation.

Defense Microelectronics Technology Program

(for the Assistant Secretary for Defense Programs [program GB])

Although all electronic components are important to electronics systems, the exponential growth in performance of microelectronics has enabled the enhanced capabilities, smaller volumes and weights, and lower costs of today's consumer and defense electronics. Microelectronics is also the core technology of information systems, with applications ranging from high-performance complementary-metal-oxide-on-silicon microprocessors to photonic (gallium-arsenide) fiber optic communication driver circuits. Competition within the global semiconductor industry has

forced domestic integrated circuit manufacturers to focus on near-term research and to emphasize very large volume products.

Under these pressures, the US semiconductor industry has drawn together in unprecedented fashion. Recently, the US Semiconductor Industry Association released a technology plan for the US microelectronics industry through the year 2010; the plan was assembled by two hundred top US semiconductor experts from industry, government (several from Sandia), and universities. The plan, known as the National Technology Roadmap for Semiconductors, identifies opportunities for government laboratories to help industry address generic technology needs. Through its cooperative research and development agreement with SEMATECH, Sandia is already helping the domestic semiconductor industry meet the goals of the National Technology Roadmap for Semiconductors. This will in turn help ensure the availability of many semiconductor components needed for future DOE Defense Programs systems and will also support DoD, NASA, and other government agencies.

However, another effect of the semiconductor industry's near-term, high-volume focus is the diminishing availability of commercially manufactured microelectronics that meet special needs of government military and space systems. Radiation-hardened microelectronics, small-quantity application-specific integrated circuits, military temperature-range circuit operation, integrated microelectromechanical and sensor components, optoelectronic/photonic components, and high-density packaging are among government needs not addressed by the National Technology Roadmap for Semiconductors and for which there is a diminishing or nonexistent domestic supplier base. The DoD, NASA, and DOE are the federal agencies most at risk.

In response to this threat, Sandia has proposed the Defense Microelectronics Technology Program. The goal is to establish an integrated, cooperative microelectronics program with DOE, DoD, NASA, and industry, working to maintain a state-of-the-art capability for future defense and space needs by fostering a healthy, competitive, onshore integrated circuit industry through support for the National Technology Roadmap for Semiconductors. DOE participants will be the Sandia, Los Alamos, Lawrence Livermore, and Oak Ridge national laboratories, with Sandia serving as the lead laboratory. The Defense Microelectronics Technology Program will support the vitality of the US microelectronics industry by emphasizing research on intermediate objectives and by maintaining the availability of special defense and space semiconductors.

Currently, the National Technology Roadmap for Semiconductors near-term research objectives are being met by industrial research and development, while the long-term objectives are the focus of Advanced Research Projects Agency and university research. Because the first thrust of the Defense Microelectronics Technology Program emphasizes intermediate objectives for the National Technology Roadmap for Semiconductors, it is complementary to existing federal and industrial research programs and will help fill a critical void in research that supports the National Technology Roadmap for Semiconductors. An equally important result of this alignment between the National Technology Roadmap for Semiconductors and DOE research is the knowledge transfer of industrial processes and components to Sandia, the DOE laboratory responsible for the design of the electronics components and systems in nuclear weapons. This will enable designers of future DOE Defense Program weapons systems to take maximum advantage of commercial processes and components and to identify readily shortfalls that must be addressed through alternative means.

Because partnerships that emphasize intermediate objectives of the National Technology Roadmap for Semiconductors will include research and development of next-generation semiconductor processing equipment, these partnerships will maintain Sandia's microelectronics equipment at the state of the art. This will occur because Sandia keeps the semiconductor processing equipment associated with industrial partnerships as part of the industrial cost share. Such a strategy has been successfully employed through SEMATECH and other industrial partnerships and has helped us keep our technology current.

The Defense Microelectronics Technology Program will also emphasize research that supports special military and space needs not available from commercial sources. The preferred procedure will be to transfer semiconductor processes used on a commercial semiconductor line to yield components that meet special government requirements. In cases where this cannot be done, the Defense Microelectronics Technology Program will serve as a supplier of last resort.

The Defense Microelectronics Technology Program will draw from existing Sandia programs and facilities, including the three joint SEMATECH/Sandia centers (Semiconductor Equipment Technology, Contamination-Free Manufacturing Research, and the Equipment Design Support Center), the Extreme Ultra-Violet Lithography Program, the Electronics Quality and Reliability Center, and most importantly the Center for Microelectronics Technology. Because the above programs maintain a state-of-the-art capability through industrial partnerships, the Defense Microelectronics Technology Program will preserve its ability to serve as a supplier of last resort for custom defense and space microelectronics using commercially compatible manufacturing processes and design tools.

The federal government is the major beneficiary of this work through custom products for government applications and through support for the domestic manufacturing base that provides these products. Industry will benefit through specific projects, which will be cost-shared by government and the private sector, that focus on gaps in current semiconductor research in support of the intermediate National Technology Roadmap for Semiconductors. Initial government support should be $100 million per year, with $65 million from DOE and $35 million from other federal agencies. Additional funding will be provided by industry and industrial consortia.

National Optoelectronics Initiative

(for the Assistant Secretary for Defense Programs [program GB])

Optoelectronics will provide the hardware for the information highways that will carry the United States into the twenty-first century. Optoelectronic elements will provide the high-data-rate communication links among remote manufacturing sites to create agile enterprises in the DOE nuclear weapons complex for cost-effective realization of future weapon systems. Over shorter distances, optoelectronics will become the means by which computers communicate with storage and output devices and even among multichip modules that will provide the intelligence within computer workstations in the future. Optoelectronics are also critical to the next generation of self-surveilling nuclear weapons.

In the private sector, optoelectronics information networks will pervade the lives of citizens by providing access to vast quantities of data for commerce, information, education, and entertainment. Information highways based on optical components may soon become as critical to our commercial and defense infrastructure as bridges and highways.

Despite having pioneered the components responsible for this revolution, the US optoelectronics industry's market share is eroding. Japan has increased optoelectronics production from $700 million in 1980 to $32 billion in 1990. During this decade, US producers saw their world market share decline from 50 percent to less than 15 percent. If foreign producers establish a dominant position in optoelectronics, it is unlikely that US producers will ever recapture sufficient market share to sustain domestic production of these critical components.

Similar to the US Semiconductor Industry Association for integrated-circuit technology, the US Optoelectronics Industry Development Association (OIDA) is creating a technology road map to chart a course for common action. OIDA selected five critical areas: displays, optical communications, optical data storage, optical interconnection and switching, and hard copy output. Sandia has been an active partner in charting the course with the OIDA. In addition to participating in OIDA road-mapping activities, Sandia has hosted two OIDA workshops on optical sensors, one to perform a market needs assessment and one to develop a technology road map.

Advances in the four other critical areas depend on two key competencies: optoelectronic materials and optoelectronic manufacturing (especially processes and production equipment). These are areas of particular strength at Sandia. We propose applying the resources of the Compound Semiconductor Science and Technology Center to support a national optoelectronics initiative in a dual-use partnership with the US optoelectronics industry.

Optoelectronics manufacturing relies on expensive facilities with specialized production equipment. Sandia's Compound Semiconductor Science and Technology Center provides the ideal facility at which cost-leveraged partnerships of US industry, universities, and government researchers will perform the precompetitive development of the design tools, processes, and related production equipment essential for US optoelectronics manufacturers.

An advisory board will recommend projects that combine teams of researchers from multiple organizations. These teams will include major industry partners who will commercialize the results. This initiative will have major impacts on processing methods and equipment and on manufacturing equipment, which are as critical for production of optoelectronics as they are for silicon integrated circuits.

Electronics Packaging

(for the Assistant Secretary for Defense Programs [program GB])

Electronics packaging is a key technology for defense applications. As packaging requirements have become more stringent and the number of interconnections within systems has multiplied, the success of complex electronic assemblies is increasingly dependent on the development and implementation of robust packaging technologies. Because high-reliability electronic assemblies underlie our military, medical, communication, and transportation infrastructures, packaging failures can have a direct impact on individual health and safety and the national defense and commercial infrastructure. The strength of advanced electronic packaging can provide US industry with a competitive advantage over international competitors (as demonstrated by IBM's mainframe computer packaging during the 1980s).

Sandia is unique among the national laboratories in having design and production oversight responsibility for all electronics components in DOE systems, with the corresponding responsibility for development, maintenance, and evaluation of packaging technologies. To meet its mission requirements, Sandia has developed a broad-based competency in electronics packaging with the associated infrastructure in facilities and personnel. Sandia's capabilities cover the full spectrum of packaging-related technologies, from fundamental research to prototyping and evaluation. To meet customer requirements, we draw upon a wide range of scientific and engineering disciplines within Sandia.

Our competency in electronics packaging includes the following areas:

- package prototyping, including single-chip, printed circuit boards, hybrid microcircuits, multichip modules, and photonic packaging;
- multichip modules, including deposited thin film, ceramic, and laminate technologies;
- computer modeling, including thermal, mechanical, and electromagnetic analyses;

- materials analysis and synthesis;
- design tools, including design for test, auto-layout, and design rule checking;
- assembly research and development;
- failure analysis and reliability;
- qualification;
- test chips and smart substrates;
- three-dimensional packaging;
- optoelectronics packaging and interconnects;
- mixed-mode packaging; and
- flat-panel display packaging.

Sandia conducts packaging-related research and development for DOE and other federal agencies. Many projects are ongoing under the work-for-others arrangements: packaging test methodologies and materials research for the DoD Reliability without Hermeticity Program; advanced packaging development for a miniaturized DoD synthetic aperture radar and multiprocessor computer; high reliability packaging for NASA deep space probes; use of Sandia's assembly test chip by several federal agencies for package qualification and package assembly monitoring; and secure multichip module design and manufacture for several federal customers.

US industry values Sandia's unique integrated capability in electronics packaging. Sandia is working on electronics-packaging-related cooperative research with the auto industry for under-the-hood electronics, with the National Center for Manufacturing Sciences for advanced printed circuit board interconnect technology, and with approximately fifty semiconductor and electronics companies on projects ranging from supplying test chips for electronics packaging qualification to large-scale cooperative research and development with industrial consortia (e.g., the semiconductor industry SEMATECH consortium). Sandians serve on technical advisory boards for the packaging programs at SEMATECH and the Microelectronics and Computer Corporation and have participated in the development of packaging road maps for the Semiconductor Industry Association. US industry recognized the value of our electronics packaging program through a 1993 Research and Development 100 award for our assembly test chip technology.

We think that partnerships with universities are critical to the success of our packaging program. Sandians have been active on university technical advisory boards for electronics packaging programs and have served as mentors and postdoctoral sponsors for students specializing in electronics packaging. Sandia sponsors packaging-related research at several academic institutions and is engaged in cooperative packaging-related research with approximately ten universities.

The broad-based competency in electronics packaging and the associated infrastructure in facilities and technologies developed at Sandia since 1949 has served the nation well by contributing to the mission of DOE and supporting the missions of other federal agencies. More recently, the breadth and depth of our competency in packaging has allowed us to contribute to the nation's economic well-being through partnerships with industry. We are actively expanding the number and scope of industrial partnerships because such partnerships help us maintain our competency in packaging for our DOE and other federal customers while benefiting the nation's economic competitiveness. To make our packaging resources more accessible to industry and academe, we will seek designation of our packaging infrastructure as a national user facility.

Communications Hardware Development Center

(for the Assistant Secretary for Defense Programs [program GB])

By directly supporting technologies that will lead to smaller, higher-speed computers, this initiative will address several critical DOE defense technologies. It will enhance signal processing and data fusion for synthetic aperture radars engaged in real-time imaging for DOE defense applications. This hardware will allow nuclear weapons and containers to communicate over wireless links for real-time monitoring of the stockpile. Size reduction will enhance embedded computer systems for flight demonstrations of next generation intelligent weapons. This initiative also supports DOE's technology base by employing microelectronics, photonics, and engineered materials technologies.

The Electronics Industries Association road map predicts that future integrated circuits and high-density multichip-module packaging will contain thousands of interconnects resulting in data rates of tens to hundreds of gigabits per second. Current interconnect schemes cannot accommodate the packing densities, size reduction, signal timing, and low crosstalk required by high-density, high-data-rate signals. To resolve these issues, multichip-module-to-multichip-module and board-to-board interconnects will employ ribbon-fiber optics and free-space photonic interconnects. Terrestrial and space-based communications as well as local and long-distance networks between workstations will employ similar high-bandwidth technology.

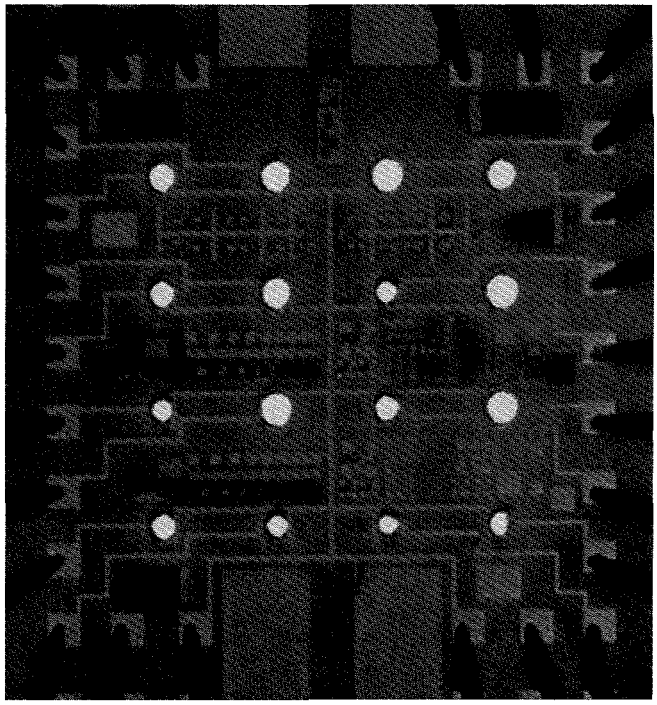
Future defense and commercial communication systems will obtain their performance from compound-semiconductor devices and circuits, including photonic devices; optoelectronic integrated circuits; high-speed digital integrated circuits; microwave- and millimeter-

wave devices and circuits; and photonic interconnects. Because of the combined requirements of high speed, high frequency, and high density, future communication systems will require low-power devices and circuits with device feature sizes below 0.25 micrometer.

Sandia proposes to employ prototype communications hardware as platforms for insertion of far-reaching, high-impact, compound-semiconductor technology into future defense and commercial systems. Sandia will exploit the capabilities of its Center for Compound-Semiconductor Science and Technology (CCST) to partner with US industry in developing the design, processing, and manufacturing infrastructure essential for developing and manufacturing these critical communications components. Sandia will serve as the neutral site for technology test beds for fiber-optic and free-space interconnects, for workstation networks for both local areas and long distance, and for microwave and millimeter-wave terrestrial and space-based communications.

Sandia's CCST pioneered the strained-layer-superlattice (SLS) material, such SLS-based devices as pseudomorphic high-electron mobility transistors (P-HEMTs) and circuits, and such semiconductor photonic devices as vertical cavity surface emitting lasers (VCSELs). Ongoing Sandia efforts on compound-semiconductor complementary digital circuits will create novel components and systems for applications requiring low-power, high-speed computing and communication, including the chip sets for driving 10-gigabyte-per-second optical networks. Sandia pioneered the complementary strained-layer logic that will enable very-high-speed, low-power complementary digital circuits in compound semiconductors. Sandia recently invented a red VCSEL ideal for plastic-fiber-based networks of interest both for military applications (ruggedness) and commercial applications (low cost). Sandia pioneered other important vertical cavity devices such as reflection amplitude modulators for both 1.06-micrometer and 1.32-micrometer optical wavelengths. As in the case of the high-speed P-HEMTs and the vertical cavity lasers, Sandia inventions are critical for these proposed communication technologies. This communications hardware initiative also will leverage Sandia's pioneering work in switched multimegabit data service/asynchronous transfer mode (ATM) links. ATM has been endorsed by the international standards community and has been chosen by Sandia as the technology for establishing national computing and communications leadership within DOE.

Combining high-impact compound semiconductor technology and advanced hardware technology, Sandia will address next-generation computer architectures and communications hardware issues. Results will benefit the national information infrastructure by addressing high-capacity computer networks as well as satellite communications (using Sandia's 60 gigahertz satellite cross-link) for advanced transportation initiatives and wireless communications.



Sandia's Center for Compound-Semiconductor Science and Technology has pioneered many semiconductor components, such as this vertical cavity surface emitting laser.

Sensors

(for the Assistant Secretary for Defense Programs [program GB])

Advanced sensors are the means by which intelligent (computer-controlled) processors monitor and control the operation of systems and manufacturing processes. Sandia has developed families of novel sensors that sense a range of chemical, thermal, electrical, physical, and mechanical properties for defense and commercial applications, including monitoring environmentally hazardous chemicals and controlling production processes.

Such sensors, fabricated with Sandia's unique microelectronics and materials technologies, have broad new applications in remote monitoring, manufacturing process improvement, and real-time control. Commercial applications include assessing the quality of vehicle engine oil, identifying the presence of environmental pollutants, monitoring the electrical charge in lead-acid batteries, tracking physical features in manufacturing processes, and indicating the presence and concentrations of explosive gases.

Other applications of Sandia's sensor technology have direct impact on the nuclear weapons stockpile, weapons surety, advanced weapons designs, and process sensing/

control for the nuclear weapons complex. One envisioned application is advanced, chemically selective sensor arrays integrated with radiation sensors to detect very low levels of corrosion by-products to monitor the integrity of the stockpile and indicate potential problems. Chemical sensors are now used to monitor weapons production processes by providing real-time control of possible chemical emissions into effluent streams at DOE manufacturing facilities. This is an application for which laboratory-sized analytical instruments are not cost-effective or suitable because of power, space, and time limitations.

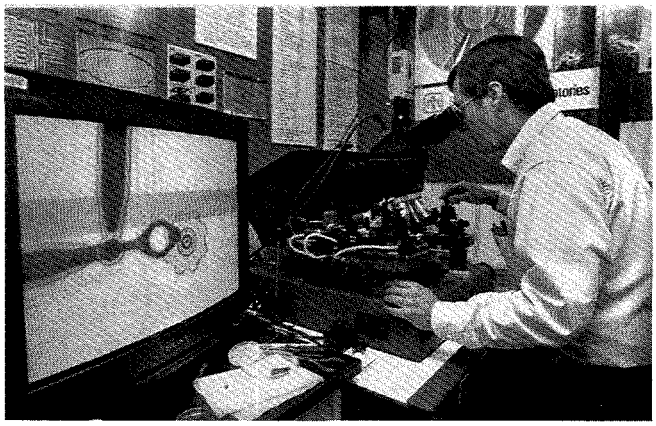
The suite of Sandia sensor technologies is being continuously refined and augmented with related Sandia microelectronic, materials science, signal processing, packaging, and subsystem technologies to expand the range of applications. We propose to integrate these sensor activities into a unified program for maximum synergy with a multitude of government, university, and industrial partners. By forming partnerships with industry to develop sensor manufacturing methodologies and leverage development costs, Sandia will serve as the nucleus around which the US sensor industry can generate new technologies and produce the next generation of sensor components. These advances will be needed to make the production and operation of future commercial and defense systems more efficient and competitive.

These sensor technologies have significant dual-use interest for manufacturing-oriented applications, particularly for the semiconductor, automotive, machine tool, textile, and petroleum industries. Sandia's novel transducer developments, based on ultrasonic, fiber-optic, and solid-state technologies, have solved characterization, monitoring, and control problems for improved manufacturing yield, functionality, quality, and environmental compliance.

Intelligent Micromachines

(for the Assistant Secretary for Defense Programs [program GB])

Micromechanics is an emerging field that uses microelectronic fabrication techniques to build ultraminiature mechanical structures with micrometer- dimensioned feature sizes. The small size, low power requirements, and ruggedness of micromachined elements are highly attractive in modern systems and applications. Consequently, micromachining is truly a dual-use enabler. Enormous markets for micromachined components are likely in the automotive, biomedical, aerospace, and robotics industries, as well as in environmental monitoring and restoration. The same families of micromachined structures are important for such DOE Defense Programs applications as ultrarugged, ultraminiature clock structures for use in weapons systems and a micromechanically fabricated version of a stronglink switch.



Sandia's Ernie Garcia uses a microscope to observe the micromachine that he and Jeff Sniegowski developed. The toothed gear shown on the screen is thinner than a human hair.

Micromachining technology is still in its infancy. A major advance in the evolution of micromachined components will occur when micromachines are integrated with low-power, complementary metal-oxide semiconductor (CMOS) integrated circuits on a single chip. The benefits of integrating CMOS integrated circuits with mechanical microstructures are the greater accuracy, performance, and functionality derived from improved signal processing and reduced noise and parasitics.

Although it is widely recognized that most applications would greatly benefit from the ability to integrate control electronics on the same chip as the micromachines, few micromechanical efforts in the United States have the infrastructure, capacity, or capability to develop this integrated technology and make it available to industry. Sandia proposes to collaborate with US industry to revolutionize the manufacturability, functionality, and applicability of micromachined devices through on-chip integration of micromachines with control electronics. This activity will exploit our unique Microelectronics Development Laboratory for submicrometer-dimension integrated-circuit technology.

The proposed intelligent micromachine initiative will allow US industry, DOE, other federal agencies, and universities to pursue specific projects that require an integrated micromechanics technology. This initiative will be operated by a government/industry/university partnership for cooperative development and highly leveraged fabrication. This activity would lead to low-cost, manufacturable intelligent micromachine technology and demonstration platforms that can be applied to both the defense and commercial sectors.

Center for Microtechnology Science

(for the Director of the Office of Energy Research [EW 20])

Miniaturization has led to major performance enhancements for most microelectronic, photonic, and sensor technologies. Miniaturization has made possible many of the products that we take for granted today: smaller transistors led to the integrated circuit; miniature optical light-emitting diode arrays resulted in small displays; and smaller sensors led to common smoke and carbon monoxide detectors. Many past advances were incremental improvements in existing manufacturing processes. However, in the mesoscopic regime materials properties are neither those of bulk materials nor of single atoms or molecules. Therefore, new physical regimes that permit fundamentally different and more powerful electronic, mechanical, optical, and sensor technologies are becoming accessible. The Center for Microtechnology Science will permit us to exploit new approaches.

The Center for Microtechnology Science is a multi-institution research and technology development center to develop the mesoscopic science base and apply it to the future generation of microdevices. Using this new scientific understanding to tailor the optical, electrical, chemical, and mechanical properties through control of the structure at the mesoscopic level will enable dramatic reduction in size with increased functionality of devices having broad applicability to DOE's missions. This distributed center will link national laboratory, university, and industrial partners, and will provide access to unique facilities for microelectronic, optoelectronic, microsensor, micromechanics, and nanotechnology processing at Sandia. These facilities, valued at more than $100 million, are key to the success of the center.

There are four primary scientific thrusts of the Center for Microtechnology Science. The first is nanophotonics, which includes approaches to photonic lattices that offer the promise of zero threshold lasers. The second is nanoelectronics, which explores such fundamental issues as single-electron interference and one-electron transistors. The third is mesosensors, which emphasizes the molecular design of active chemical coatings tailored to identify specific chemical compounds and the fusion of these sensors with integrated circuit technologies. The fourth is micromechanics, which applies the technologies for high-volume integrated circuit manufacturing to micromachines and microsensors integrated with high-performance integrated circuits for intelligent microelectromechanical systems.

Specific project details and goals were defined in an August 1995 workshop organized by Lawrence Berkeley Laboratory, Ames Laboratory, and Sandia. The workshop was hosted by Sandia and included eighty participants from other DOE national laboratories, universities, and industries.

In addition to advancing the science and technology base of DOE laboratories and the nation, potential applications of this technology include: processes that can dramatically reduce the need for chemicals, water, and energy during the manufacture of components for mass-market and high-performance products; greatly reduced energy requirements for the operation of new products; and real-time sensing and feedback control systems for environmentally-conscious manufacturing and environmental restoration. Moreover, unforeseen applications will result as the scientific knowledge of mesoscopic technologies is expanded.

The Center for Microtechnology Science will be initiated by combining existing Basic Energy Sciences projects at DOE national laboratories and universities with enhanced funding to support facility usage and limited new starts by the various participants.

Table 2-2. Funding Requirements for Initiative Project Proposals in Electronics Technology (Dollars in Constant 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Electronics Technology Center					
Operating	4.5	8.0	8.0	8.0	6.5
Capital Equipment	1.0	3.0	2.0	2.0	1.0
Total Cost	5.5	11.0	10.0	10.0	7.5
Direct Personnel	20	35	35	35	30
Defense Microelectronics Technology Program					
Operating	55.0	60.0	65.0	70.0	75.0
Capital Equipment	10.0	10.0	10.0	12.0	15.0
Total Cost	65.0	70.0	75.0	82.0	90.0
Direct Personnel	100	110	120	130	140
National Optoelectronics Initiative					
Operating	25.0	33.0	45.0	60.0	70.0
Capital Equipment	10.0	13.0	16.0	18.0	20.0
Total Cost	35.0	46.0	61.0	78.0	90.0
Direct Personnel	50	66	90	120	140
Electronics Packaging					
Operating	13.5	18.0	24.0	30.0	35.0
Capital Equipment	4.5	4.5	6.0	6.0	6.0
Total Cost	18.0	22.5	30.0	36.0	41.0
Direct Personnel	27	36	48	60	70
Communications Hardware Development Center					
Operating	7.0	8.5	10.0	12.0	14.0
Capital Equipment	3.0	4.0	5.0	5.0	3.0
Total Cost	10.0	12.5	15.0	17.0	17.0
Direct Personnel	13	15	18	18	18
Sensors					
Operating	12.3	14.1	15.5	16.8	18.1
Capital Equipment	1.2	1.7	2.3	2.6	3.1
Total Cost	13.5	15.8	17.8	19.4	21.2
Direct Personnel	52	60	65	70	76
Intelligent Micromachines					
Operating	13.5	18.0	24.0	30.0	35.0
Capital Equipment	4.5	4.5	6.0	6.0	6.0
Total Cost	18.0	22.5	30.0	36.0	41.0
Direct Personnel	27	36	48	60	70

Table 2-2. Funding Requirements for Initiative Project Proposals in Electronics Technology (Dollars in Constant 1995 Millions; Personnel in FTEs) (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5
Center for Microtechnology Science					
Operating	35.0	38.0	42.0	46.0	50.0
Capital Equipment	5.0	7.0	9.0	11.0	15.0
Total Cost	40.0	45.0	51.0	57.0	65.0
Direct Personnel	70	72	75	77	80
Total, Electronics Technology					
Operating	165.8	197.6	233.5	272.8	303.6
Capital Equipment	39.2	47.7	56.3	62.6	69.1
Total Cost	205.0	245.3	289.8	335.4	372.7
Direct Personnel	359	430	499	570	624

2.2.3 Advanced Information Technology

Established Capabilities

Advanced information technologies are playing an increasingly important role in virtually every aspect of our DOE missions. These technologies enable ubiquitous connectivity, which in turn provides immediate access to highly distributed information sources and supports real-time collaborations between geographically separated team members. Advanced information technologies also facilitate decision making by enabling computational modeling and simulation of physical systems and by supporting efficient evaluation of trade-offs in highly complex decision environments. These capabilities yield significant benefit in terms of reduced cost and cycle time across a diverse set of mission-related problem areas.

Sandia's research foundation in computational and information sciences provides the basis for many of our differentiating capabilities in advanced information technologies. Computational simulation has historically been important to Sandia's national security and energy missions and is also vital to the future of Sandia and DOE. The advent of massively parallel and distributed hardware, software, and communications capabilities in high-performance computing (in which Sandia played a contributing role) is increasing the importance and viability of simulation and modeling. More than five hundred Sandia engineers and scientists are involved in the development and application of computational technologies. One of our distinguishing strengths in this area is the ability to develop and integrate theoretical models, advanced numerical methods, and computing technology to create robust, state-of-the-art tools for simulating complex systems and processes. These capabilities have positioned us for leadership in the area of knowledge-based engineering, which consists of efficiently implementing processes employed throughout the product realization life cycle.

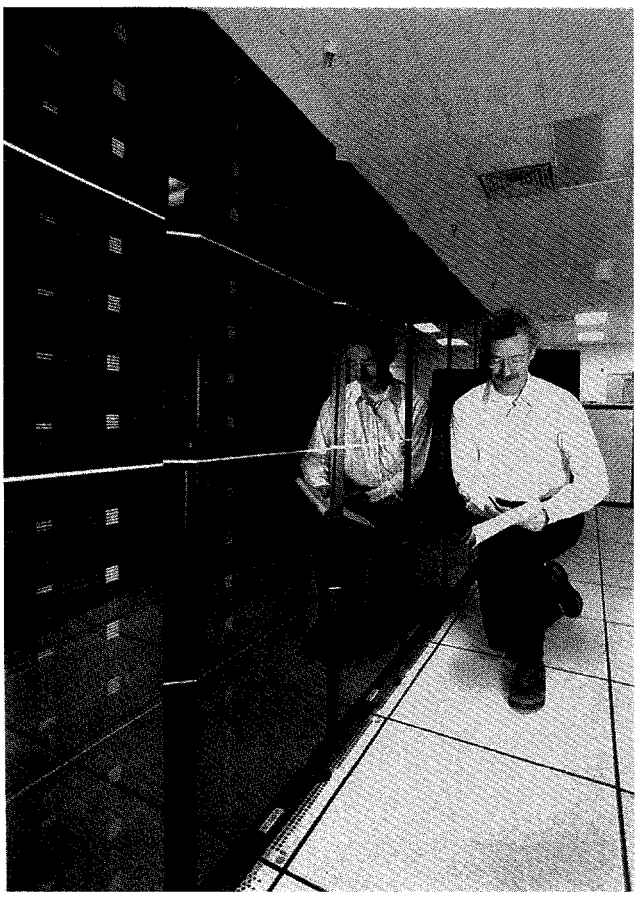
The Massively Parallel Computing Research Laboratory (MPCRL) at Sandia is a national resource for research in high-performance computing and its application to problems in science and engineering. An interdisciplinary team of more than sixty research staff members carries out projects in computational and computer science and in discrete and numerical mathematics. These staff members have access to unique massively parallel computers, including an Intel Paragon (with nearly two thousand processors and 40 gigabytes of memory), a 1,000-processor nCUBE2, and a 16,000-processor connection machine.

The MPCRL has led the development of algorithms since its award-winning introduction of massively parallel techniques for real engineering applications in 1987. During the past year, a team from Sandia and Intel regained the world record for computational speed. The record of 280 billion floating point operations per second (gigaflops per second), set in December 1994, surpassed the record of 170 gigaflops per second established a few months earlier by a Japanese consortium. A Sandia-led team also won the prestigious Gordon Bell Prize for performance in large-scale scientific computing at the Supercomputing '94 Conference. Major thrusts of the MPCRL include the DOE Grand Challenge in Computer Design of Catalysts and Biocatalysts and development of a broad spectrum of massively parallel applications, including turbulent fluids, chemical vapor deposition, Knudson flows, porous media, quantum Monte Carlo calculations for molecules and multiparticle systems,

massively parallel electromagnetics, and signal processing.

In developing these strategic applications, Sandia researchers have invented massively parallel linear algebra methods, new algorithms for molecular mechanics and dynamics, highly scalable methods for quantum chemistry, automatic finite-element adaptive mesh-generation techniques, powerful domain-decomposition and load-balancing techniques, and data visualization methods. Advances in systems technology include portable parallel and distributed operating systems, virtual reality environments, new multithreaded architectures, object-oriented C++ constructs for massively parallel applications, and new routing algorithms. Numerical research at the MPCRL is complemented by research in discrete mathematics that includes algorithms for difficult combinatorial optimization problems. This work also involves new communications algorithms for parallel and distributed computing.

In response to a request from the DOE Office of Scientific Computing, we have broadened the scope of our discrete mathematics research to include computational biology. The goal of this effort is to develop robust computational techniques that can be used to validate biological data. We are currently using data obtained on short segments of DNA to reconstruct the order in which these segments occurred in the DNA sequence, and we are developing techniques for jointly constructing evolutionary trees and multiple sequence alignment to predict more accurately protein folding and function.



Bob Benner is shown with Sandia's Intel Paragon massively parallel supercomputer, which won the Gordon Bell Prize.

The Center for Computational Engineering at Sandia's California site has an interdisciplinary team of physicists, chemists, biologists, mathematicians, computer scientists, and engineers who interact with a broad external community. The center focuses on applications and works directly with customers to help find the most cost-effective solutions to their problems. One major thrust of the Center for Computational Engineering is chemical and biochemical modeling. Work in this area ranges from quantum chemistry representation of small molecules (less than fifty atoms) through molecular diffusion processes involving molar quantities of atoms. Significant results include understanding the binding of cyclophosphamide (a cancer drug) to cell DNA and using advanced genetic algorithms to determine the molecular structures of biologically interesting proteins. One realizable product of this computational chemistry expertise is rational drug design, by which biologically active chemicals can be designed from first principles to reduce the high cost of developing pharmaceuticals. Other work at the Center for Computational Engineering includes modeling to assist in the development of plasma flat-panel displays and to understand the movement of contaminated groundwater through geological media. In addition, manufacturing operations and health care delivery systems are simulated. Each of these activities is accomplished in conjunction with a different external customer.

A major driving force in the information age is the development and networking of low-cost, high-performance workstations. The availability of these workstations is stimulating the growth of multimedia technology (merging voice, video, and data) that will form the basis for a wide spectrum of applications linking people electronically. Sandia has been concentrating on object-oriented design to develop a fully integrated system that ties together the factors required to solve a problem: computational analysis, communication (multimedia and mail), storage, and access. When developing our capabilities in this area, we consider three distinct levels of connectivity: machine-machine (networking), people-people (collaborative environments), and people-machine (human/machine collaboration).

Networking issues include both communication links and interoperability. We have established a heterogeneous environment and test bed consisting of linked workstations from each of the five major workstation vendors. The test bed enables the development of techniques for implementing clustered heterogeneous computing and network

optimizations required to increase the applicability of this technology. We have also developed metacomputing tools, such as the parallel object-oriented environment and tool kit and the distributed audio-video environment, as intelligent system interfaces to enhance the productivity of users. In both cases, our efforts have focused on applications to assure that requirements are met for collaborative engineering in support of our DOE missions.

Collaborative environments are now feasible primarily because of the significant increase in performance and capability of wide-area networks during the past few years. One consequence of this improvement has been a rapid transition to computing environments distributed over long distances; in these environments, users working at powerful but relatively inexpensive workstations can remotely access large supercomputers and database servers at a few centralized locations. These environments are leading to versatile new approaches to multiple party interactions in which people can participate from afar in collaborative engineering projects, scientific experiments, education, and training. Such environments are serving as the model for information dissemination nationwide.

Sandia, uniquely positioned with two widely separated major locations, has already moved to such a model by centralizing its supercomputers in Albuquerque under the supercomputer consolidation project. This effort, which provides ready access to Sandia's supercomputers and storage servers from both the California and New Mexico locations, has enhanced the technology base needed for a robust information infrastructure both within and outside Sandia. For example, we developed a DS3 (45 megabits/second) delay and error simulator that was used to design and test our intersite network in the laboratory. Our capabilities in networking and communications have been acknowledged by the Interop Achievement Award for excellence in implementing the most sophisticated multivendor corporate internetwork and for making the most effective use of internetworking technology to further our business goals.

Human beings have long used tools to accomplish tasks that could not be performed well with only hands and feet. Similarly, we have used computers to aid in cognitive processes. "Training" the tools has always been a challenging activity with the tool responding only to the most precisely phrased "commands." However, computer system performance and human understanding of complex computer-based systems have improved at remarkable rates. It now seems possible that we can go beyond training and eventually collaborate with machines to accomplish many tasks. Sandia is investigating the many beneficial applications of this phenomenon to its future DOE Defense Program objectives.

Some of the processes related to human/machine collaboration include autonomous agents and brokers, high-speed communications, adaptive controls, advanced visualization, and virtual reality. Extraordinary technical challenges must be met to realize collaborative capabilities. The issues of ontology, agent-based architectures, data fusion, human factors, and visual realism are all significant.

We are building on our existing expertise in human factors, high-performance computing, data visualization, and information surety to obtain a suite of highly robust and advanced information technologies that can be applied to nuclear weapons product realization in the future. These capabilities will parallel the human/machine collaboration technologies that will become available in industry but will be applied to the special needs of nuclear weapons stockpile stewardship.

Decision-making in large complex systems is a daunting task. This results from such factors as fragmented or conflicting data, large uncertainties, and significant impacts of potential outcomes. The problem is further compounded when multiple decision-makers must arrive at a collective decision. In addition, decisions in which large amounts of resources are at stake often demand an integrated, consistent, and defensible basis. Although theoretical approaches to decision-making have been studied for many years, sound approaches to practical implementation of the decision sciences are rare. Decision-directed information technologies are advanced information technologies that enhance the quality of decision-making processes. A complete decision support process can be viewed as the integration of five elements: information gathering, environmental abstraction, quantitative modeling and analysis, elicitation of beliefs and values through iterative dialogue between decision-maker and analyst, and communication of analysis and recommendations.

Decision support can also include implementation of a decision once it has been made. Decision-directed information technologies can address each of these elements. Enabling technologies such as data fusion systems, smart databases, and advanced networking technology can assist information gathering. Environmental abstraction, including issue identification and problem framing, can be made more efficient by automating decision analysis tools such as decision trees and influence diagrams. Many different modeling approaches (such as decision and risk analysis, dynamic system simulation, optimization, and gaming simulations) are enhanced through advances in computer architectures and algorithms, including distributed computing and programming languages. Technologies such as interactive querying systems and multimedia systems can facilitate analyst/decision-maker dialogue. Finally, presentations can be made more accessible and meaningful through the careful integration of user-friendly interfaces, geographic information systems, multimedia systems, and networking technologies.

The above suite of decision-directed information technologies can help improve decision-making quality in numerous problem areas of national importance. Examples include new approaches to nuclear weapons design and manufacturing, control of excess fissile material, research and development resource allocation, waste management, contaminated site

remediation, and responses to the threat of global warming. Difficult decisions are being faced in each of these areas, especially in light of increasingly constrained budgets.

Sandia maintains an active effort to develop decision-directed information technologies in a wide variety of business areas. The tools are developed at various levels of hardware/software and analytical sophistication, which are tailored to the needs of the customer. Decision-support systems, which generally integrate quantitative modeling with at least one of the five other elements, are being developed to aid decision-making in environmental remediation, waste disposition management, health-care facility management, and stockpile maintenance. For these tools, object-oriented programming, uncertainty analysis, and risk management strategies are deployed in a rich user-interface environment. Information-gathering systems under development include a database that allows external customers to search available cleanup technologies for specific site remediation. Another system allows industrial manufacturers to leverage Sandia's expertise in modeling and analysis when designing parts for applications. In addition, expert systems have been developed that allow people to conduct life-cycle analyses for manufacturing processes and check their firm's compliance with EPA hazardous materials regulations. These software products have been developed for use with commercial software on personal computers. They utilize a graphics-rich, user-friendly environment to facilitate user comprehension.

Sandia's ability to maximize the realized benefits from our use of advanced information technologies depends on effective implementation of information surety processes. Information surety involves the balancing of information integrity, privacy, and availability. Key elements include protection of information from unauthorized access, accidental or unauthorized modification, and loss of access. This field has been and will continue to be an essential discipline for Sandia's responsibilities in command and control of nuclear weapons. As we move toward a more highly interconnected complex (involving laboratories, other agencies, and industry), the ability to assure the integrity and privacy of information while providing on-line availability is becoming an increasingly important challenge.

We have developed extensive capabilities in information surety at Sandia. These capabilities include design and analysis of cryptographic algorithms and protocols; adversarial analysis of hardware, software, and total systems; design and analysis of access control systems; development of high-speed communication network security systems; development and fielding of use control systems; development and testing of tamper-resistant and tamper-detecting technologies; testing of biometric identification techniques; and development of computer security techniques.

Project Initiatives

Advanced Information Technology initiatives are described below. Funding requirements are given in Table 2-3 at the end of this section.

Information Technologies for the Next Generation Nuclear Weapon

(for the Assistant Secretary for Defense Programs [program GB])

The application of human/machine collaborative technologies will be essential to the development and realization of the next generation of nuclear weapons. These devices will be able to assess their operational environment, state of health, and any threats to their proper function as well as autonomously (but with great surety) respond to a change in state. Many issues (from sensor integration to data fusion to information surety) will require resolution before the next generation system is feasible.

This initiative will examine the potential application of advanced information technologies, especially human/machine collaboration and information surety, to the design, development, product realization, deployment, and stockpile support of the next generation weapon system. Certain of the advanced technologies will be imbedded in the weapon itself. All elements of the project are characterized by their high potential benefit and technical challenge.

Virtual Reality

(for the Assistant Secretary for Defense Programs [program GB])

Virtual reality establishes synthetic environments that enable human interaction with simulated objects, scenes, or conditions that would otherwise be beyond human capabilities. The tools of virtual reality can be used for weapon development by allowing a human observer to "experience" events or processes such as explosions and to observe component or system behavior in these environments. In addition, virtual reality can simulate environments in which training is required but which would be either impossible or prohibitively expensive to provide (areas contaminated with radioactive material, weapon applications in space or in high-performance flight regimes, etc.).

Agent-Based Manufacturing Architecture

(for the Assistant Secretary for Defense Programs [program GB])

Agent-based manufacturing architecture uses computer programs that employ knowledge about the system in which they exist to perform autonomous functions. Intelligent agents can provide highly secure, safe, and reliable functions in software-based systems because they respond both to

direct instructions and to changes in state. In DOE weapons complex manufacturing, an agent-based architecture would be highly agile and reconfigurable. The system could operate a very complex manufacturing enterprise and could also sense and respond to work flow interruptions, safety hazards, or security alarms. Responsible software agents would signal other agents to perform specific activities. Because communication between agents is standardized, functional additions or deletions from the system could be made without system disruption or redesign, minimizing the life-cycle cost of weapon-related manufacturing.

Center for Science and Technology Investment Decisions

(for the Assistant Secretary for Defense Programs [program GB])

Investment decisions are often complex and difficult, especially in the DOE Defense Programs environment because of the changing threat, complex economics, volatile technology, and evolving policy. The center would employ the very best information technologies to obtain relevant data, integrate the data into comprehensible and coherent forms, perform related analyses or simulations, and ultimately provide viable options to the decision-maker. The applications would be primarily to long-range investments in defense-related science and technology to ensure that research and development programs are convergent with future DOE Defense Program needs.

Special Multi-Level Security Needs of the DOE

(for the Assistant Secretary for Defense Programs [program GB])

DOE programs to manage nuclear weapons and nuclear materials in the complex require a unique type of multilevel security for the handling of critical information. Currently available or planned systems do not adequately address the special surety needs for these systems. Devices used for such systems must be compatible with the safety requirements of their nuclear environment while providing modern information security controls. In these applications, there is a need to segregate access, not along the traditional lines of classification but along more uniquely defined groupings, thus enforcing "need to know" and "right to modify" with strong cryptographic techniques. Solutions must also allow application of some of these techniques to systems for use by international agencies involved in treaty compliance. This will require attention to the use of cryptographic techniques normally falling under export controls. Sandia can apply its outstanding capability in cryptology and command and control to these problems. The resulting solutions will likely find application in many information surety problem areas, but they will also provide a unique solution for DOE needs.

Software Surety

(for the Assistant Secretary for Defense Programs [program GB])

Because software pervades products today, the special surety concerns of nuclear weapons can be largely at odds with software approaches. Sandia can provide leadership for the nation in developing new methods for assuring that software produced for critical nuclear weapon applications can be safely applied. Sandia will address all aspects of this problem, including the development of innovative software methodologies, metrics to measure the effectiveness of these methodologies, new techniques for assessing the reliability of software, and tools for practical implementation of the techniques developed. Innovative interactions between hardware and software in critical systems will also be explored, giving rise to an entirely new paradigm for the development of sure software-based systems.

Information Navigation for Knowledge-Based Engineering

(for the Assistant Secretary for Defense Programs [program GB])

Knowledge distinguishes one culture from another, and a high price is paid for it. Capturing that knowledge is critical for eliminating reinvention and preventing unnecessary iterations. The result is considerable cost and time savings.

The unique environmental and technical requirements of Sandia's traditional role in the development of nuclear weapons systems has created a need for models beyond those available in industry. We have created unique test strategies and tools to measure performance, and we have synthesized the data for design decisions. In addition to the full system design, Sandia has gained an understanding of the dependencies and interactions among each part of a product—from systems to subassemblies to components to parts.

With the enormous amount of information on the Internet, in databases, and in reports, an engineer may spend a great deal of time trying to find relevant information and never succeed. Therefore, a need exists for techniques for navigating and directing engineers to relevant information. Such techniques should include standard English queries and full text searches using intelligent software to understand context and identify associated words, names, abbreviations, and phrases.

Computational Manufacturing

(for the Assistant Secretary for Defense Programs [program GB])

Realistic simulation of product, process, and production is one of the key capabilities for information-driven manufacturing. The nuclear weapons complex will require increased use of computational systems design, simulations of prototyping and manufacturing processes, and simulations of system performance and reliability under design conditions and in response to abnormal environments. Thus, the development of rapid prototyping and agile manufacturing techniques must build on emerging simulation capabilities so advanced that they enable virtual prototyping and processing and, ultimately, computational design of entire systems. These technologies depend on Sandia's new thrusts in developing engineering simulation environments.

New user-friendly, powerful environments are beginning to combine solid modeling, automatic mesh generation, and domain decomposition for parallel processing with algorithms for heat transfer, materials mechanics, fluid flow, and chemistry. Techniques being developed for real-time, desktop visualization of simulation data will be important additions to the engineer's computational tool kit.

The needs of the nuclear weapons complex are mirrored in US industry, where requirements for ever-diminishing product development cycles demand constant innovation. Today and tomorrow, one of the most important advantages will come from the use of computational virtual prototyping of processing tools. Sandia's leading-edge, high-performance computing simulation capabilities are already being transferred to US industry in partnerships facilitated by cooperative research and development agreements. Our computational simulation capabilities are a major research and development resource for American industry.

Metacomputing Environment and Tools

(for the Office of Energy Research [program KC07])

The next major phase of Sandia's distributed computing and networking program will expand to include optimization of the communications stack and development of a software super-architecture to integrate the distributed components into a transparent system. In this next phase, we will apply the experience gained from our current work to the design of a communications stack optimized at all levels: protocols, message passing libraries, and the underlying hardware.

This work will increase the range of applications that will achieve optimal performance in a distributed environment. Simultaneously, we will investigate methods for supporting an architecture that incorporates the elements of our distributed infrastructure in an object-oriented framework to permit rapid prototyping and flexible support of information science applications. The environment will contain tools to process a problem. Networking software and communication capabilities will allow the rapid and transparent movement of data among software tools.

By utilizing object-oriented techniques, these software tools will be suitable for a wide range of applications. This environment will reduce costs by accelerating software development, increasing the reuse of software, and decreasing software maintenance. The metacomputing environment will be used for distributing and controlling software, assigning multiple computers to a task, and obtaining information from multiple sources for a task.

Our technology transfer activities range from applications with partners such as Alcoa and Ellery Systems Software to technology infrastructure with such partners as Fore Systems, Digital Equipment Corporation, Hewlett-Packard, Sun Microsystems, IBM, and AT&T. We are collaborating with industry to ensure the highest quality and broadest applicability of the resulting products.

Wireless

(for the Assistant Secretary for Defense Programs [program GB])

Wireless communications can replace hard-wired connections between people, between computers, and between people and computers. For defense programs, wireless communications would enable persons to participate in design processes and decisions supported by high-performance computing without the need to also provide high-capacity, expensive communications links. Access to computing resources would not be restricted to specified locations, times, or previously installed hard-wired links.

Hardwired connectivity is expensive and inflexible, but wireless communications are much less expensive to install and to operate. However, performance and security issues related to the use of wireless communications must be investigated.

Table 2-3. Funding Requirements for Initiative Project Proposals in Advanced Information Technology (Dollars in constant FY 1995 millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Information Technologies for the Next Generation Nuclear Weapon					
Operating	2.5	3.5	4.0	4.5	5.0
Capital Equipment	0.5	0.5	0.5	0.5	0.5
Total Cost	3.0	4.0	4.5	5.0	5.5
Direct Personnel	10	12	14	16	18
Virtual Reality					
Operating	1.5	1.8	2.0	2.0	2.0
Capital Equipment	1.0	1.0	0.5	1.0	0.5
Total Cost	2.5	2.8	2.5	3.0	2.5
Direct Personnel	5	6	7	7	7
Agent-Based Manufacturing Architecture					
Operating	1.0	1.3	1.5	1.5	1.5
Capital Equipment	0.5	1.0	0.5	0.5	0.5
Total Cost	1.5	2.3	2.0	2.0	2.0
Direct Personnel	3	4	5	5	5
Center for Science and Technology Investment Decisions					
Operating	2.0	2.0	3.0	3.0	3.0
Capital Equipment	0.5	0.5	0.5	0.5	0.5
Total Cost	2.5	2.5	3.5	3.5	3.5
Direct Personnel	10	10	15	15	15
Special Multi-Level Security Needs of the DOE					
Operating	3.0	3.0	2.0	2.0	1.0
Capital Equipment	0.5	1.0	1.0	0.5	0.5
Total Cost	3.5	4.0	3.0	2.5	1.5
Direct Personnel	12	12	8	8	4
Software Surety					
Operating	8.0	8.0	8.0	8.0	8.0
Capital Equipment	1.0	1.0	1.0	1.0	1.0
Total Cost	9.0	9.0	9.0	9.0	9.0
Direct Personnel	30	30	30	30	30

Table 2-3. Funding Requirements for Initiative Project Proposals in Advanced Information Technology (Dollars in constant FY 1995 millions; Personnel in FTEs) (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5
Information Navigation for Knowledge-Based Engineering					
Operating	2.0	4.0	6.0	6.0	5.0
Capital Equipment	0.5	1.5	1.5	2.0	1.0
Total Cost	2.5	5.5	7.5	8.0	6.0
Direct Personnel	5	10	15	15	10
Computational Manufacturing					
Operating	4.0	6.0	8.0	8.0	8.0
Capital Equipment	1.0	0.5	1.0	0.5	0.5
Total Cost	5.0	6.5	9.0	8.5	8.5
Direct Personnel	12	15	20	20	20
Metacomputing Environment and Tools					
Operating	7.0	9.0	10.0	10.0	10.0
Capital Equipment	1.0	1.0	1.0	1.0	1.0
Total Cost	8.0	10.0	11.0	11.0	11.0
Direct Personnel	25	30	35	35	35
Wireless					
Operating	4.0	4.0	4.0	6.0	8.0
Capital Equipment	0.5	0.5	0.5		
Total Cost	4.0	4.5	4.5	6.5	8.0
Direct Personnel	10	10	10	20	20
Total, Advanced Information Technology					
Operating	35.0	42.6	48.5	51.0	51.5
Capital Equipment	7.0	8.5	8.0	7.5	6.0
Total Cost	42.0	51.1	56.5	58.5	57.5
Direct Personnel	122	139	159	171	164

2.2.4 Pulsed Power Technology

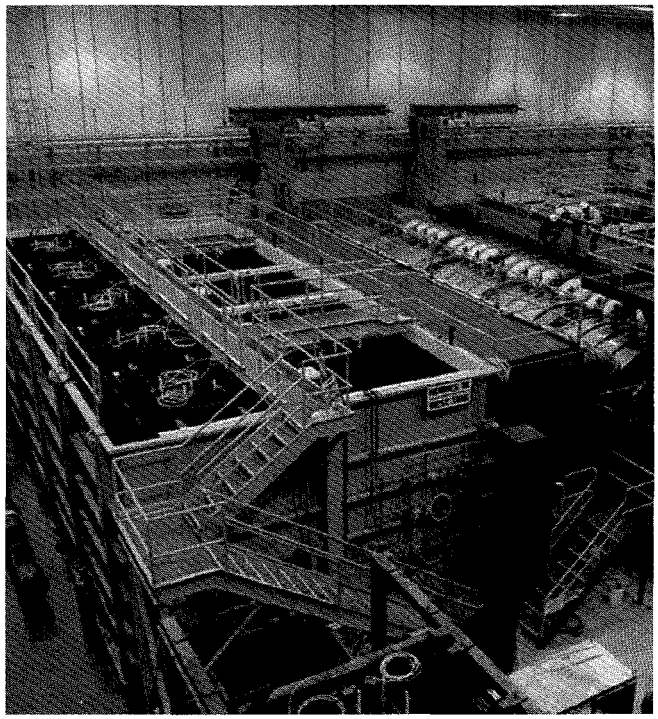
Established Capabilities

Sandia, in its role as the DOE Center for Pulsed Power Research, has been a leader in developing fast pulsed power technology. Pulsed power has its origins in the 1960s, and during the past two decades it has matured into a flexible and robust discipline capable of addressing key physics issues of importance to DOE Defense Programs. Pulsed power can generate and deliver high energy and high power at low cost and high efficiency, which are important because of the large capital investment required for multimegajoule ignition-class systems. High efficiency is also important for potential commercial applications of repetitive pulsed power. The pulsed power effort has led to the development of unique multipurpose facilities supported by highly capable diagnostic, calculational, and analytic capabilities.

The Sandia Particle Beam Fusion Program applies to the longer-term goals of the national Inertial Confinement Fusion Program. Sandia's program builds on technologies initially developed for radiography and for the generation of bremsstrahlung radiation. A separate effort has applied nanosecond pulsed power to the generation of intense, high-energy laboratory x-ray sources for application to x-ray lasser and radiation-effects research. The Saturn, High-Energy Radiation Megavolt Electron Source (HERMES) III, and Particle Beam Fusion Accelerator II are, respectively, the world's most powerful accelerators for the generation of x-rays, gamma rays, and charged particle beams. Pulsed power research and development, inertial confinement fusion, and radiation effects science programs at Sandia are highly interdependent. These programs have benefited greatly from this strong linkage.

Sandia is also a leader in the development and application of laboratory x-ray sources using fast z-pinch implosions. Magnetically driven implosions using fast pulsed power generators form the basis for a growing international collaboration on high-power, high-energy laboratory x-ray sources. The technology has proven capable of converting energy stored in Marx generator capacitors into x-ray energy with an overall efficiency of 15 to 20 percent. Experiments on Saturn at Sandia by a collaboration among US, United Kingdom, and former Soviet Union scientists will be extended to include approximately 2-megajoule z-pinch experiments in the Particle Beam Fusion Accelerator II-Z during FY 1996. Saturn, the most powerful of these sources to date, produces approximately 500 kilojoules of x-rays. These experiments will provide us with the technical confidence required to proceed with the Jupiter Pulsed Power Facility, which will provide an approximately 20-megajoule x-ray capability and a hohlraum temperature greater than 200 electron volts.

Sandia is building strategic relationships with other national laboratories on existing programs such as weapons physics and on new initiatives such as NIF, Atlas, APT, and Jupiter. We will apply our capabilities and competencies to benefit DOE and the nation. We are developing high average (repetitive) pulsed power for DOE and DoD programs and are exploring the potential for a number of commercial applications.



The HERMES III accelerator produces 20 trillion watts of power in each pulse. It is used to test military hardware and satellite systems.

Project Initiatives

Pulsed Power Technology initiatives are described below. Funding requirements are given in Table 2-4 at the end of this section.

Jupiter Pulsed Power Facility

(for the Assistant Secretary for Defense Programs [program GB])

The scope of DOE's Stockpile Stewardship Program was established through a Presidential Decision Directive. The stewardship program's strategy is to use past nuclear test data, future nonnuclear test data, computational modeling, experi-

mental facilities, and simulators to gain a comprehensive understanding of nuclear weapons and the effects of radiation on military systems. Congress also directed DOE to establish a stewardship program to preserve US core intellectual and technical competencies in nuclear weapons. The Jupiter Pulsed Power Facility is a proposed 15 mega-joule x-ray laboratory that will address Sandia's mission accountability in stockpile system and subsystem validation and certification.

The Jupiter Pulsed Power Facility will provide an x-ray environment otherwise achievable only in an underground nuclear explosion. It will provide a source of at least 20 kiloelectronvolt photons necessary for experimentation and modeling of the underlying science and for development of protocols to certify the reliability and survivability of the nuclear weapons stockpile. Jupiter will enable unique experiments for examining material equations-of-state, radiation opacities, radiation flow at high temperatures, densities and pressures with relevance to nuclear weapons physics, and high energy density science. Jupiter will also enable unique inertial confinement fusion experiments relating to radiation flow and symmetrization, internal radiation pulse shaping, and high-power hydrodynamic target implosions. Jupiter will provide a necessary experimental platform to validate the increasingly complex computational modeling required in lieu of underground nuclear testing.

Particle Beam Fusion Accelerator II-Z Modification

(for the Assistant Secretary for Defense Programs [program GB])

The Particle Beam Fusion Accelerator II-Z represents the key technical step toward the Jupiter Pulsed Power Facility. The Particle Beam Fusion Accelerator II-Z Project will provide z-pinch drive options for the Particle Beam Fusion Accelerator II by redirecting the output of the thirty-six pulse forming lines through a vacuum feed section similar to the one used on Saturn. It will significantly enhance capabilities for weapons physics, inertial confinement fusion, and radiation effects science experiments of importance to the Stockpile Stewardship Program. Modification of the Particle Beam Fusion Accelerator II-Z will provide up to a 25-mega-ampere driving current for the generation of ultrahigh-intensity energy densities and high-temperature hohlraums.

The Particle Beam Fusion Accelerator II-Z is recognized by the international scientific community as a unique facility. Los Alamos National Laboratory, Lawrence Livermore National Laboratory, the Atomic Weapons Establishment in Aldermasten, United Kingdom, and scientists from the former Soviet Union have participated in atomic physics and plasma physics experiments at the Sandia Saturn facility. Plans are being made to extend this collaborative effort to the Particle Beam Fusion Accelerator II-Z, which represents a factor of approximately four times the energy delivered by Saturn. The Particle Beam Fusion Accelerator II-Z Project is scheduled to complete the pulsed power modifications and begin testing in June 1996.

Repetitive High-Energy Pulsed Power

(for the Assistant Secretary for Defense Programs [program GB])

The Repetitive High-Energy Pulsed Power Project is directed at developing and validating the technology for producing 100-megawatt-class, high-average power systems with potential application to the accelerator production of tritium, the processing of chemical and mixed waste, the transmutation of nuclear waste, and the use of megawatt electron and ion beams to improve manufacturing processes. Repetitive pulsed power technology is also important to the energy application of inertial fusion research.

Repetitive high-energy pulsed power technology employs solid state switching, which leads to very robust accelerator systems that are modular and flexible. They have the potential to scale cost effectively to very high levels. Repetitive high-energy pulsed power technology can produce peak dose rates that exceed 10^{13} rads per second and deliver total doses of 10^{13} millirads per second to the target material. The Repetitive High-Energy Pulsed Power II system is a 2-megaelectronvolt, 300-kilowatt electron beam industrial-scale accelerator for applications such as organic compound destruction. Additionally, with the Repetitive High-Energy Pulsed Power I accelerator, a significant program of ion beam surface treatment is being developed. Surfaces treated with an ion beam demonstrate properties ranging from increased hardness to improved corrosion resistance. This program continues to develop enhanced scaling and the practical applications that may be transferred to industry.

Table 2-4. Funding Requirements for Initiative Project Proposals in Pulsed Power Technology (Dollars in constant FY 1995 millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Jupiter Pulsed Power Facility					
DOE Cost	0.8	5.8	8.4	43.8	99.2
Direct Personnel	5	10	14	25	25
PBFA II-Z Modification					
DOE Cost	6.0	1.5	1.0	1.0	
Direct Personnel	7	3	3	3	
Repetitive High-Energy Pulsed Power					
DOE Cost	3.0	3.0	3.0	3.5	3.5
Direct Personnel	10	10	10	10	10
Total, Pulsed Power Technology					
DOE Total Cost	9.8	10.3	12.4	48.3	102.7
Direct Personnel	22	23	27	38	35

2.2.5 Post-Cold War Defense Imperatives

Established Capabilities

The collapse of the Soviet Union has diminished the strategic threat to the United States. However, we continue to face two strategic security challenges as a nation. First, the threat posed by the continuing existence and spread of technologies of mass destruction challenges us to sustain a credible nuclear deterrent and to preserve the national capability and capacity to rebuild our forces in response to unforeseen circumstances. Second, the impact and effect of an increasingly competitive global economy challenges us to ensure that our concepts of national interest and security remain current, realistic, and sufficiently comprehensive to encompass the full range of potential threats to our national integrity.

The following set of coordinated nonproliferation and other defense-related proposals respond aggressively to the evolving challenges facing DOE in its enduring responsibilities in defense and intelligence. Care has been taken to avoid unnecessary mission expansion. In each case, these initiatives extend established responsibilities and capabilities. Each initiative expands benefits to the nation and serves to exercise, sustain, and build on core competencies essential to meeting programmatic requirements. Therefore, these initiatives have been developed to reap further value from existing assets and resources.

Project Initiatives

Post-Cold War Defense Imperatives initiatives are described below. Funding requirements are given in Table 2-5 at the end of this section.

Former Soviet Union Cooperative Measures

(for the Assistant Secretary for Defense Programs [program GB] and the Office of Nonproliferation and National Security [program GB])

Sandia's cooperative measures with the former Soviet Union support the US government's policies on nonproliferation, support emerging democracies, and foster defense conversion and commercialization. We also support the DOE's Safe and Secure Dismantlement Working Group in its activities under the Nunn-Lugar and Freedom Support Act authorizations, now totaling about $1.4 billion through FY 1995. Sandia has been actively involved in a government-to-

government agreement to allow unclassified technical exchanges on nuclear warhead safety and security. We anticipate working with Russian design experts in this activity.

Sandia has been very active in the development of the two-phased newly independent states partnership, which will enable collaboration between Sandia and former Soviet Union military institutes whose stability is important to nonproliferation. This will also facilitate commercialization partnerships between US industries and former Soviet Union defense institutes. During the first phase, we have already established about seventy individual projects with former Soviet Union institutes, principally in the areas of nonproliferation, reactor safety, materials, environment, energy, and manufacturing. During the second phase, we will develop partnerships with US industry to foster commercialization of these projects. We have signed one cooperative research and development agreement and translated several others into English this year.

Sandia expects to support fully the pending agreement between the US and Russian governments on the technical exchange of nuclear warhead safety and security information. This technical exchange involves unclassified information on topics related to nonproliferation, safety, security, and physical protection and will provide a forum for exploring important issues of mutual interest and benefit. We expect to support actively the technical working groups in this exchange.

Sandia is the lead organization in the physical security aspect of DOE's material protection, control, and accountability initiative, which is intended to help safeguard nuclear material with modern methods. We have projects in place at sites containing large quantities of weapons-capable nuclear material and already have completed a first project at the Kurchatov Institute in Moscow. This project used modern methods to safeguard two nuclear reactors and a significant amount of weapons-capable material.

Accelerated Strategic Computing Initiative

(for the Assistant Secretary for Defense Programs [program GB])

The United States' commitment to end underground nuclear testing, in combination with associated constraints on nonnuclear testing, is forcing us to seek new means of verifying the safety, reliability, and performance of the nuclear stockpile. Built on the core nuclear weapons program, the Accelerated Strategic Computing initiative is one of four DOE Defense Programs initiatives designed to support the stewardship of the enduring nuclear stockpile without the benefit of nuclear testing. The Accelerated Strategic Computing initiative will support the prompt shift from traditional testing and other empirical approaches to the computational methods that must form the basis for stockpile stewardship in the future.

We are facing equally severe constraints on our ability to manufacture new weapons and replacement parts for existing weapons. Many of the original manufacturing processes for stockpile weapons components are no longer acceptable because of new standards for efficiency, waste minimization, or environmental impact. In addition, some processes and suppliers are simply no longer available. Although new weapons production has ceased, the ability to design nuclear weapons, analyze their performance, predict their safety and reliability, and certify their functionality remains essential to the conscientious management of the enduring stockpile, particularly as these weapons age past their originally intended service lives.

Fortunately, we are experiencing dramatic improvements in computer hardware and software technologies. These technologies offer the promise of virtual testing and virtual prototyping methods as practical alternatives to traditional testing and other empirical approaches used for the design, manufacture, and certification of nuclear weapons in the past. Virtual testing and prototyping rely primarily on validated computational models and numerical simulation tools for weapons design and manufacture and for certifying weapons performance, safety, and reliability. Rudimentary versions of virtual testing and prototyping exist and are in use; however, to meet our stockpile stewardship needs in the year 2010, virtual applications must achieve high-resolution, full-physics, full-system capabilities.

This level of simulation will require computing power far beyond our current levels of performance. Current simulation and modeling applications still rely heavily on costly and environmentally problematic empirical testing and validation, and they are not adequate for detailed independent analysis of new designs or for dealing with unanticipated changes in existing designs. In addition, these current applications were not designed to operate efficiently on the massively parallel processing computer architectures that will be required for later generation virtual testing and prototyping. Our current applications must thus be rewritten to incorporate refined physics algorithms, three-dimensional capabilities, and massively parallel processing efficiency.

By 2010, the Accelerated Strategic Computing initiative will

- develop high-performance, full-system, full-physics predictive codes to support weapons design, production analysis, and certification;
- stimulate the US computer manufacturing industry to create the powerful, high-end supercomputers required by these applications; and
- create a computational infrastructure and operating environment that makes these capabilities accessible and usable.

In addition, the Accelerated Strategic Computing initiative will promote interlaboratory cooperation in project management, working level collaboration across laboratories, and openness to the ideas and solutions of the industrial and academic communities.

The Accelerated Strategic Computing initiative has four main objectives:

- The performance objective will create "seamless" simulations (highly credible virtual tests) to analyze the performance and predict the behavior of nuclear weapons.
- The safety objective will predict, with high certainty, the behavior of full weapon systems in complex accident scenarios.
- The reliability objective will achieve validated capabilities to predict failure mechanisms and reduce routine maintenance.
- The renewal objective will use virtual prototyping to reduce production and testing facilities for stockpile requalification and replacement work.

Each objective calls for computational capabilities that do not currently exist. Five strategies have been identified for meeting these program objectives, and together these strategies compose a balanced program that will create the needed virtual test and virtual prototyping capabilities.

The first strategy is to create a single seamless management program for the three weapons laboratories by operating the Accelerated Strategic Computing initiative as a three-laboratory, single-program activity with seamless management and execution across the laboratories. We will collaborate on development and share hardware and software resources to take maximum advantage of standard tools, common system structures, and code portability.

The second strategy is to focus on advanced applications development. This will provide three-dimensional, full-physics, full-systems simulation capabilities; accelerate code performance; and validate simulations by rigorous correlation with constrained experiments and archival data.

The third strategy will focus on high-end computing. This will accelerate the development of scalable architectures as we develop partnerships with multiple vendors to ensure appropriate technology development and worldwide leadership.

The fourth strategy will provide applications development support, high-performance computing access, and a distributed computing environment.

The fifth strategy will encourage openness and collaboration by sponsoring biannual workshops; partnering with other DOE departments, agencies, universities, and industries; and leveraging other national initiatives.

Sandia, Los Alamos, and Lawrence Livermore national laboratories will all play key roles in implementing these five strategies through collaboration and resource sharing and by leveraging other national initiatives in related areas.

In the area of high-end computing, Sandia will have lead responsibility for a research partnership with the computing industry. This partnership will focus on the development of a new massively parallel computer composed of thousands of processors and providing teraflop performance and terabyte memory capacity. This effort will capitalize on Sandia's expertise and leadership in computer science and high-performance computing and will deliver a new computing capability to support the development of Accelerated Strategic Computing initiative application codes.

In advanced applications development, Sandia has proposed four projects that will provide advanced simulation capabilities for three important classes of problems. In the area of virtual testing and safety, we have proposed simulating accident environments, predicting full weapons system response, and assessing nuclear detonation safety for complex, combined-environment accident scenarios such as aircraft crashes followed by jet fuel fires. The aircraft crash/burn scenario is the risk-dominant event for most stockpile weapons. In the area of material aging, we have proposed a project to develop a capability for predicting grain-scale microcracking in solder joints, which occurs because of thermal fluctuations during normal weapons storage and transportation scenarios and has led to electrical component failures. Another proposed material aging project is to develop a capability for predicting the dominant factors in the oxidation and deterioration of the Kevlar polymeric material used in parachute strapping for laydown bombs. Only limited data exist on Kevlar aging because of its relatively recent development, and these proposed simulation methods will be useful for predicting the lifetime of a parachute and for identifying the environmental factors that can be controlled to prolong its service life. In the area of virtual prototyping, we have proposed to develop computational methods for specifying forging and welding process variables for the remanufacture of limited-life components in gas transfer systems, thus allowing standard industrial practices to provide the required performance for these manufactured parts. These research and development efforts will merge our expertise in high-performance computing and engineering sciences to develop advanced capabilities that will address important defense program problems.

Finally, Sandia will also play an important role in the development of the infrastructure required to support the use and availability of the high-end computing platforms developed by the Accelerated Strategic Computing initiative. This infrastructure includes operating systems, high-speed networking, and high-speed storage. This effort will also capitalize on Sandia's expertise and leadership in high-performance computing and networking.

Project Straight-Line

(for the Assistant Secretary for Defense Programs [program GB])

Project Straight-Line is a new initiative in the materials protection area, specifically for weapon material accountability in anticipation of future treaty monitoring requirements. Sandia is developing a comprehensive systems approach to the challenges faced in the management and control of nuclear materials and weapons. Straight-Line will include all aspects of hardware, logistics, and national and international controls leading to an internationally inspectable system that will also serve to enhance the maintainability and management of nuclear materials and weapons. This effort will demonstrate leadership on important national and international problems while encouraging greater integration of DOE's efforts in defense programs, national security, and nonproliferation. Straight-Line will parallel and extend major ongoing initiatives that include a transporter for the protection of nuclear weapons and materials during transfer from site to site; the AT-400A pit container for enhanced safety during transportation and long-term storage at the Pantex facility; the Stage Right effort for the storage, retrieval, and monitoring of pits in magazines; and the work in plutonium disposition systems integration and technical development for DOE material disposition.

Straight-Line is an integrated system of sensors providing information to enhance the safety, security, and international accountability of stored nuclear material. The goals of this remote monitoring program are to

- promptly provide the right sensor information to the right user;
- reduce the expenses, risks, and frequency of human inspection of the material; and
- provide trustworthy data to international inspectors to minimize their need to make intrusive, on-site inspections.

Straight-Line unites technology from DOE Defense, National Security, and Non-Proliferation programs to communicate the authenticated status of the monitored item back to central magazine receivers.

Straight-Line incorporates several important features not found in previous systems. The first feature addresses information security. Sensors, monitoring components, or materials may produce classified and unclassified data. Straight-Line will handle both simultaneously while ensuring dissemination of the information on a strict need-to-know basis. The second feature concerns multiple and diverse users. Straight-Line provides a single system that integrates the remote monitoring needs of safety, security, and international accountability. The third feature is the incorporation of analog sensors. Earlier systems provided only switch closure data—on or off. Straight-Line sensors will provide a range of data; for example, they will monitor temperature rather than merely indicate variations above or below an established set point.

A prototype system is scheduled for installation in a nuclear storage magazine at the Pantex Facility by June 1995. Additional empty nuclear materials containers will also be installed and monitored during this time at the Sandia Cooperative Monitoring Center in Albuquerque and at Sandia/California. Plans for FY 1996 include a fully engineered system to be in operation at the Pantex Facility.

Straight-Line gathers sensor information from stored nuclear material and distributes the data to authorized users. Installation is simplified by the use of wireless communication for sending data from sensors to a magazine data unit. Door switches and volumetric motion detectors monitor for intrusion into the room. Item sensors placed on the materials or containers can monitor one or more of the following parameters:

- container and ambient temperature,
- motion,
- gamma radiation-dose and spectrum,
- tampering,
- fiber-optic seal status, and
- pressure.

The sensor pack has a standard sensor interface that allows for a wide variety of sensors. Sensors being developed include acoustic sensors for monitoring material cracks and gas sensors for detecting hydrogen or helium.

Video cameras connect to the magazine data unit by cable to provide another layer of monitoring, allowing the user to determine if the material is in place, stable, and unaltered. The sensor information is sent via modem to the National Data Unit server, which provides appropriate data to a wide variety of users. Thus, Straight-Line can provide the right sensor information to the right user to enhance the safety, security, and international accountability of stored nuclear materials.

Although Straight-Line is being developed for storage configurations, the basic concepts could be deployed to the entire life-cycle of nuclear materials. Monitoring for safety, security, and accountability during material generation, transportation, storage, and final disposition will be addressed in future efforts. Funding for this effort has been initiated by DOE Defense Programs; however, a successful program will provide opportunities for funding from other organizations within and outside the DOE.

Advanced Design and Production Technology Initiative

(for the Assistant Secretary for Defense Programs [program GB])

Recent changes in national security requirements, the elimination of nuclear testing, and reduced budgets require significant changes in the nuclear weapons complex. DOE will transition to a smaller, more cost-effective, and environmentally benign complex that will support post-Cold War priorities and expectations while ensuring the safety and reliability of the nation's nuclear stockpile.

As the drawdown of nuclear forces progresses and as stockpiled weapons continue to age, deterrence will be provided by capabilities to maintain, modify, and reconstitute our nuclear forces. A credible technological capability will require innovative thinking and careful planning. Otherwise, DOE's capability for nuclear weapons maintenance, surveillance, modification, remanufacture, and certification will decrease. DOE, Sandia, other defense program laboratories, and the remaining production plants are currently developing, acquiring, and using a broad spectrum of advanced design and manufacturing technologies. However, the implementation of these improved capabilities must be focused and accelerated.

The Advanced Design and Production Technology initiative will accelerate the development and deployment of cost-effective and environmentally acceptable product realization technologies, processes, and methods required to maintain an affordable, effective, safe, and reliable nuclear stockpile. The Advanced Design and Production Technology initiative will focus on four key objectives:

- Performance, which will focus on developing technologies and processes needed to ensure that both weapons products and manufacturing processes meet military requirements and design intent.
- Reliability, which will develop computational models, characterization methods, and process controls needed to assure the continued safety and reliability of stockpile weapons systems.
- Affordability, which will demonstrate the technologies and methods that will enable the cost-effective and environmentally benign development and production of weapons.
- Responsiveness, which will develop technologies and strategies allowing the nuclear weapons production system to respond rapidly and effectively to changing national security needs.

The Advanced Design and Production Technology initiative will focus on five strategies tailored to meet the above objectives.

The first strategy will integrate product and process design. We will develop and deploy concurrent engineering methods and practices. Design tools to support the rapid optimization of product design for performance and manufacturability will be validated and integrated into advanced nonnuclear weapons component product design.

The second strategy will develop and qualify advanced processes. Efforts will concentrate on the development and understanding of manufacturing processes to enhance flexibility and cost efficiency. Environmentally conscious processes will be qualified for production use. Technologies and methods for monitoring and control of all key production processes will be developed and deployed.

The third strategy will characterize and improve materials. Emphasis will be on detailed predictive understanding of material performance and reliability. Some activity will be directed at development and qualification of replacements for unavailable or expensive materials.

The fourth strategy will develop agile manufacturing. We will develop the technologies, processes, and methods needed to provide maximum flexibility and responsiveness in production. Efforts will include development of system and machine models to allow simulation and optimization of complete production systems.

The fifth strategy will integrate the enterprise. This work will focus on technologies and processes needed to integrate the entire extended nuclear weapons enterprise to meet our national security mission more efficiently . We will develop the communication and information systems needed to allow ready access to essential information. Improved communication systems and software will allow ready access to a distributed design and production system.

The Advanced Design and Production Technology initiative will partner with appropriate commercial sector organizations to accelerate further the development and deployment of advanced product realization technologies and methods in the weapons complex. Such partnerships will provide an infusion of industrial skills by building on the common need between Sandia and the private sector to produce cost-effective, highly reliable products in limited volume. These arrangements will also lead to the development of suppliers who will be available to meet our product needs.

Predictive Stewardship

(for the Assistant Secretary for Defense Programs [program GB])

The end of the Cold War has brought fundamental changes to the nuclear weapons stockpile, the nuclear weapons complex, and Sandia's role in stockpile stewardship. The enduring stockpile will contain a greatly reduced number of weapons and fewer types of weapons systems, and these weapons will remain in service beyond their original design lifetimes. In addition, with the smaller

overall stockpile, each of the remaining weapons in the stockpile may have increased individual strategic importance. Sandia's experience with older (twenty-five years or older) weapons is limited. Most of our weapons have been retired before eighteen years. As the weapons in the stockpile age, we expect to encounter more age-related problems. Because the production complex responsible for the maintenance of the stockpile has been significantly downsized, the ability of DOE to respond will depend on our ability to anticipate a significant number of those problems.

To meet our responsibilities for the nation's stockpile, we must augment the traditional methods of maintaining the reliability and surety of the nuclear weapons stockpile, which were largely based on testing randomly selected samples from the active stockpile. The smaller stockpile will reduce our opportunities to sample without depleting the stockpile itself. We must develop methods and techniques to predict reliability, performance, and surety of weapons as they age, without traditional sampling and test-oriented approaches. The Predictive Stewardship initiative seeks to predict accurately the condition and reliability of the stockpile with minimal inspection and testing.

Our understanding of the stockpile condition will increasingly be supported by a fundamental understanding of the individual materials used in nuclear weapons and the long-term stability and performance of these materials. The effects of the stockpile environment on individual materials and combinations of materials can then be quantitatively predicted as a function of time. Model-based understanding of time-dependent materials behavior will be coupled with the development and deployment of sensors that can offer early detection of material deterioration by-products. The sensors will be supported by a new series of redesigned and custom-targeted stockpile surveillance tests. The data from these sensors and tests will provide critical information for material model development and verification. Models of performance and reliability for existing materials will also provide the bases for designing or selecting new materials and designs to improve the reliability of the stockpile as components are replaced and systems are upgraded.

These data are crucial for forecasting the service fitness of weapons components and systems. Such forecasting of weapons and component reliability and performance will allow a more effective planning process and enable the systematic and efficient replacement and upgrade of weapons components before they fail or reduce weapon reliability. This type of forecasting is critical if high reliability is to be maintained in a smaller stockpile supported by a smaller production capability.

Table 2-5. Funding Requirements for Project Proposals in Post-Cold War Defense Imperatives (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Former Soviet Union Cooperative Measures					
Operating	5.6	6.0	6.0	6.0	6.0
Capital Equipment	0.1	0.2	0.2	0.2	0.2
Total Cost	5.7	6.2	6.2	6.2	6.2
Direct Personnel	15	15	15	15	15
Accelerated Strategic Computing Initiative					
Operating	18.5	44.7	46.8	46.8	46.8
Capital Equipment	0.3	0.5	0.5	0.5	0.5
Total Cost	18.8	45.2	47.3	47.3	47.3
Direct Personnel	34	107	127	127	127
Project Straight-Line					
Operating	5.0	4.0	3.0	3.0	3.0
Capital Equipment	0.3	0.5	0.5	0.5	0.5
Total Cost	5.3	4.5	3.5	3.5	3.5
Direct Personnel	16	13	10	10	10
Advanced Design and Production Technology Initiative					
Operating	10.0	40.0	45.0	45.0	15.0
Capital Equipment	0.3	0.5	0.5	0.5	0.5
Total Cost	10.3	40.5	45.5	45.5	15.5
Direct Personnel	40	160	180	180	60
Predictive Stewardship					
Operating	11.7	13.7	14.4	16.6	17.9
Capital Equipment	0.1	0.2	0.3	0.4	0.4
Total Cost	11.8	13.9	14.7	17.0	18.3
Direct Personnel	16	13	10	10	10
Total, Post-Cold War Defense Imperatives					
Operating	50.8	108.4	115.2	117.4	88.7
Capital Equipment	1.1	1.9	2.0	2.1	2.1
Total Cost	51.9	110.3	117.2	119.5	90.8
Direct Personnel	121	308	342	342	222

2.2.6 Energy Research and Technology Development

Established Capabilities

Energy research and technology development encompasses Sandia's technical capabilities, facilities, and industry relationships. Sandia supports DOE's Global Climate Change Plan and its mission of an integrated approach to improve the competitiveness of US industry, of ensuring the energy security of the nation, and of improving environmental quality. We actively seek opportunities to transfer our expertise and the results of our work to US industry and to the international arena through partnerships with appropriate entities.

A major part of our work is in collaboration with industry to develop system-level solutions to energy and environmental challenges. Sandia has for decades been one of the premier contributors to energy technology in the areas of renewables, fossil energy, and energy efficiency. Sandia's technical competencies and systems orientation have traditionally driven our responsibilities in energy technology. For this reason, our chemical sciences effort has focused on developing tools and fundamental knowledge that relate directly to our work with engine, furnace, and fossil fuel combustion. Similarly, our geosciences staff provides basic tools and knowledge to improve our effectiveness in reservoir characterization and repository design. Our materials sciences engineers have a major component of advanced electronic materials design to support other efforts, such as photovoltaics, advanced semiconductors, and environmentally conscious manufacturing. Sandia uses its technical knowledge and its facilities to help US industry and government agencies improve their energy efficiency, quality, reliability, and cost. We apply these same strengths to energy use, to the sources of energy, and to the technologies related to them.

We are at a threshold of significant new thrusts in renewables, building on our historic strengths in this area. For many years, we have operated the National Solar Thermal Test Facility for DOE. We provide support for the development of Solar Two, a utility-scale solar power tower in California. Sandia's Photovoltaic Systems Design Assistance Center has helped US manufacturers compete in this emerging international market. We are also collaborating with industry and the Bonneville Power Administration to expand commercial utilization of geothermal resources in the Pacific Northwest. Renewable energy technologies rely on Sandia's contributions of reliable, well-engineered system designs to make the leap from laboratory novelties to manufacturable, high-volume commercial products.

Our fossil energy programs have already made numerous breakthroughs in combustion research, coal liquefaction, oil and gas exploration, and reservoir characterization and production. We plan to use our oil recovery technology partnership as a model for involving industry in other partnership endeavors.

Sandia's nuclear energy program is largely built around our Nuclear Regulatory Commission experience in severe accident phenomenology and risk assessment. We have drawn extensively upon these capabilities and Sandia's broader competencies to assist DOE in its programs in reactor design and in plant life extension. Sandia will continue to help DOE address plant life problems, and we intend to begin a new program in decommissioning and decontamination of plants whose design lifetimes have expired.

Project Initiatives

Energy Research and Technology Development initiatives are described below. Funding requirements are given in Table 2-6 at the end of this section.

Photovoltaics Industry Development

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EB])

Sandia has provided the engineering design, testing, and evaluation that have been significant in the development of today's solar energy industry. Important new thrusts are now possible based on this work. The photovoltaics initiatives below will help industry overcome current barriers in manufacturing and infrastructure that keep photovoltaics from becoming a sustainable technology.

Federal, State, and Regional Government Agency Photovoltaics Initiative

(for the Office of Utility Technology)

This initiative will develop photovoltaic applications for government agencies. Sandia's technical competencies can enable DOE to demonstrate how photovoltaic systems can improve the operational economy of federal and other government agencies. If successful, the initiative will stimulate the local and regional infrastructure for photovoltaic systems, thereby creating jobs and markets for the industry.

For example, cost-effective applications exist today in federal agencies such as the Bureau of Land Management, DoD, Department of Agriculture, and Department of the Interior (parks and remote facilities).

Sandia's Photovoltaic Systems Design Assistance Center, with its proven record of success, will work with agencies to ensure that applications are developed for appropriate needs. In addition, the center will support and complement activities in the established Photovoltaics for Utilities

organization of state working groups. This work will initiate fielding of systems with wide-scale repeatability. It involves state energy officials, representatives from the photovoltaics industry, and staff from utility companies working cooperatively to foster the use of photovoltaics.

Photovoltaic Collector Manufacturing Process Development

(for the Office of Solar Electric Conversion)

A goal of the DOE National Photovoltaic Program is to provide a clean, renewable, and economical source of electric power that will reduce fossil fuel consumption while improving the competitiveness of US industry. To remain internationally competitive, industry must both reduce manufacturing costs and continuously improve the quality of photovoltaic systems.

Manufacturing development for photovoltaic collectors will improve products and manufacturing processes by collaborating with industry to address manufacturing issues affecting collector durability and cost. Industry has expressed interest in leveraging its limited research and development resources through the analytical services and photovoltaics fabrication capabilities at Sandia. Sandia's photovoltaic collector lifetime project is already working with several major photovoltaic collector manufacturers to identify mechanisms limiting durability under operating conditions.

Under the proposed initiative, Sandia will investigate issues involving collector design and reliability, collector manufacturing and cost, and environmentally conscious manufacturing of collectors. We will use our laboratory capabilities to fabricate and evaluate collector design and process alternatives, especially in the areas of soldering, encapsulation materials, and bonding.

In addition to using the resources of Sandia's Photovoltaics Laboratories, we will leverage other Sandia centers of expertise including environmentally conscious manufacturing, robotics, and advanced manufacturing processes.

This initiative will provide a flexible, industry-oriented support capability that will be responsive to industry's needs as the technology develops and matures.

Photovoltaic Balance-of-System Manufacturing Technology

(for the Office of Solar Electric Conversion)

Approximately one-half the cost of a utility-interconnected photovoltaic energy system is in photovoltaic modules. The other half is in such balance-of-system items as interconnections, power conditioning, control systems, support structures, and installation.

This initiative addresses balance-of-system technology improvements that will reduce costs and develop hardware to allow US industry to compete successfully in larger markets. A cost-shared, balance-of-system manufacturing initiative will reduce manufacturing costs for photovoltaic power conditioning and control systems. Balance-of-system cost reductions and reliability improvements, coupled with decreases in module costs, will encourage utilities to include photovoltaic generation in grid support, demand-side management, remote power, and other specialized applications.

In addition, development of manufacturable power conditioning and control systems for diesel generator/photovoltaic hybrid systems greater than 100 kilowatts is necessary if photovoltaics is to expand into the diesel replacement market. This market includes systems for village-scale power in developing countries and systems that can meet environmental requirements while supplying power for military and other government applications. This option will be especially attractive in environmentally sensitive areas.

Sandia has collaborated with the US photovoltaics industry to develop systems hardware that has reduced costs, improved performance, and opened new markets both domestically and internationally. This $50 million initiative will develop the manufacturing capability of the US balance-of-system industry over a five-year period so it can continue to compete in world photovoltaic systems markets. The balance-of-system initiative has strong support from the US photovoltaic industry, which would share program costs.

The DOE Office of Solar Electric Conversion is funding a Photovoltaic Manufacturing Technology Program to reduce the manufacturing costs of photovoltaic modules. This program is addressing photovoltaic module manufacturing technology problems through cost-shared contracts with photovoltaic module manufacturers and is also beginning a phase that addresses the entire cost of a photovoltaic system. The photovoltaics industry now recognizes the need to reduce balance-of-system costs to foster large-scale utility adoption of photovoltaic technology.

Photovoltaic Systems Lifetime Improvement

(for the Office of Solar Electric Conversion)

Ten years of field data from a variety of photovoltaic systems and components show that power loss from balance-of-system degradation typically ranges from 10 to 15 percent and that irreversible module degradation and mismatch losses add another 10 to 15 percent. Because the success of photovoltaic technology will depend on its reliability, the photovoltaic system lifetime improvement effort is aimed at assisting the industry in achieving a photovoltaic technology with a thirty-year lifetime that degrades in performance by less than 10 percent in that period.

A team of representatives from industry, DOE, and users

of photovoltaic technologies will work to eliminate the failure mechanisms responsible for power losses in five- to ten-year-old systems. The team will also establish an evaluation program for current manufacturing processes aimed at early mitigation of reliability problems.

The program's working group will perform field evaluations of installed systems and identify causes of observed degradation. Degradation typically includes browning, high resistance in solder bonds, interconnect corrosion, changes in balance-of-systems components performance, module delamination, cell metallization adhesion, cracks in the back surface polymer, and electrical mismatch.

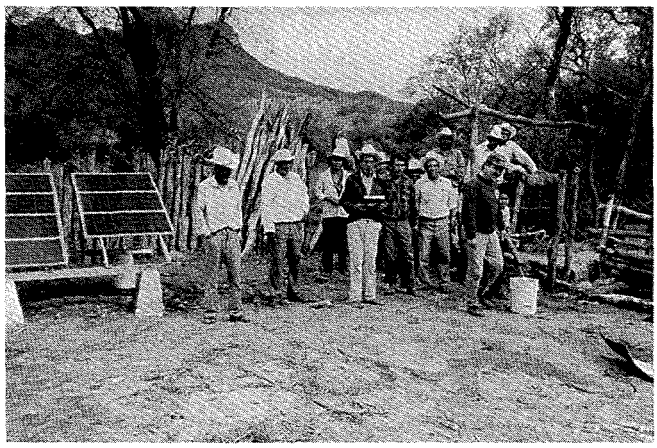
The working group will recommend improvements in manufacturing processes or in developing new materials to solve reliability problems. It will also recommend utilization of DOE capabilities in photovoltaics testing, materials and process sciences, and nondestructive testing.

The evaluation program will require a long-term commitment from both DOE and industry. It will begin with a minimum commitment of $20 million over a five-year period to address degradation issues.

Utility Photovoltaics

(for the Office of Solar Electric Conversion)

Because utility companies are major suppliers of electricity for the nation, they could be a major customer for photovoltaic systems, using them to supply energy where grid connection is expensive or impossible. This initiative is important in ensuring that utilities use photovoltaics. Sandia can add its technical experience and expertise to demonstrate that photovoltaic systems can be used in a number of ways to help utilities and save the customer money.



Sandia helped install this photovoltaic energy system in Mexico. The system uses solar power to pump irrigation water.

This initiative is a cooperative partnership. The partners in this effort include the photovoltaics industry, the established utility photovoltaic group, utility representative organizations (such as the Electric Power Research Institute), and individual utility companies.

Objectives are to identify and maximize the benefits of photovoltaics in applied systems for utilities or their customers. Building on Sandia's established network of relationships with utilities and the photovoltaics industry, higher-value remote and grid-connected applications will offer the photovoltaics industry market entry into the utility sector. The ability of photovoltaic systems to serve remote locations will be the foundation for the transition to larger and significant fuel-offset systems and eventual specialized grid-connected applications. These applications will capitalize on the technology's characteristics of no fuel use, low operating costs, modularity, reliability, and sustainability.

The initiative will be based on the needs of the utilities and their customers. Starting with analyses of feasibility and opportunity, applications will be developed based on current hardware and the ability of photovoltaics to uniquely meet customer requirements for energy in an environmentally acceptable way. Furthermore, the systems will to a certain extent bypass traditional means of electricity delivery. Grid-connected systems owned by customers offer a means of demand-side supply. Successful implementation of systems will be communicated to stakeholders, and the economic advantages (including job creation) will be determined.

Advanced Materials for Energy Conversion

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EB] and the Assistant Secretary for Fossil Energy [programs AA, AB])

Government and private studies have concluded that new materials will drive advances in many industrial sectors. The need for government-sponsored research and development leading to advances in materials technology has been clearly delineated. The National Energy Policy Act of 1992 mandates a five-year national advanced materials program plan.

The need for materials with higher performance in extremes of temperature, pressure, and corrosive environments, coupled with the need for energy savings and environmental sensitivity, require major advances in structural and functional materials. Research and development in structural materials includes ceramics, intermetallics and alloys, coatings, and joining. Functional materials research and development includes catalysts, membranes, filters, insulators, and adsorbents. This initiative focuses on research and development in both structural and functional materials for energy applications.

Advanced structural materials that can operate at higher temperatures and pressures and that are more corrosion-resistant will allow the use of new higher-efficiency energy conversion and industrial processes. However, these high-performance materials often have drawbacks, including high cost and difficulty of forming and joining parts. Proposed research and development in structural materials includes new processing methods for increasing ductility and workability of high-temperature chromium-niobium alloys, synthesis of nanometer-sized silicon nitride and carbide powders for high-temperature ceramics with enhanced sintering performance, novel joining technologies for advanced ceramic and alloy structural materials, computer-driven processes for induction hardening, thermal spray technology for corrosion and impact resistance, and high-temperature coatings. In each area, we are building on expertise resident at Sandia and on specific structural materials requirements in the DOE Fossil Energy and Energy Efficiency and Renewable Energy programs.

Because catalytic processes account for 20 percent of the US gross domestic product, research and development leading to improvements in catalysts and catalytic processes can have a substantial positive impact on the economy. Catalytic research and development areas addressed in this initiative include emissions control, catalytic membrane reactors, conversion of hydrocarbon resources, and fuel cells. This effort combines established strengths at Sandia in computer-aided molecular design, massively parallel computation, process chemistry and reaction engineering, materials science, and catalyst characterization and evaluation to focus on an integrated theoretical, experimental, and engineering approach to the design of advanced catalytic materials.

Porous materials technology also broadly impacts industrial processes. Porous materials often replace more expensive, energy-intensive processes in such energy conversion applications as membranes and adsorption media for separations, ion exchange, storage, and purification; environmental and industrial process sensors; electrodes for battery and fuel cell applications; supports for catalysts; insulators; and lightweight structural materials. Porous materials research and development areas addressed in this initiative include

- corrosion- and impact-resistant high-temperature filters for gas filtration,
- unique catalytic membrane reactors,
- other micro- and meso-porous catalyst support materials,
- controlled-pore-size membranes and coatings for light gas separations,
- extremely high selectivity crystalline silicotitanate ion-exchange materials for industrial and radioactive waste,
- porous electrodes for fuel cells, and
- fast-cycle, high-capacity hydrogen and methane storage media.

Solar-Dish-Stirling Systems for Utility Applications

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EB])

Modular solar-dish/engine systems can effectively address near-term, high-value utility applications such as remote generation and end-of-line capacity additions. To accelerate the introduction of this technology, several dish/engine system development and commercialization projects have been initiated. These activities are patterned after our successful remote-power dish-Stirling joint venture with Cummins Power Generation.

These new joint ventures are developing distributed solar thermal systems of approximately 25 kilowatts per module suitable for utility markets. Like the Cummins Joint Venture, the utility-scale joint venture program includes equal cost-sharing between DOE and industry. An industrial partner capable of marketing and supporting commercialization of the technology is required, as is participation by utility companies. Significant industry direction in developing marketing plans, product development, and program planning and execution is required. To meet the goal of prototype system demonstrations at utility sites, large-scale demonstrations are planned.

This initiative includes non-Stirling cycle converters in one case. Technical advances and manufacturing cost reductions suggest a Brayton-cycle-based system may be economically competitive in the projected time frame of the Utility-Scale Joint Venture Program.

Integrated Utility Systems Energy Storage

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EB])

The integrated utility systems energy storage initiative will address generation, transmission, distribution, and end-use energy storage needs. The nation's total energy use is projected to increase from 85 quads today to between 102 and 112 quads by 2010. The share of primary energy consumed to produce energy is projected to increase from 36 to 39 percent. This estimate corresponds to expanding generating capacity by as much as 245 gigawatts. During this period, to optimize baseload capacity and substation transformer loading, energy storage will become an essential capability in an integrated electrical network.

This initiative matches Sandia integrated systems capabilities in storage technologies (such as batteries,

superconducting magnets, and capacitors) with the needs of industry and DOE. Although energy storage technology programs are under way in the private sector and elsewhere in the federal government, there is a major need to be met. First, to formulate long-range energy policy, a comprehensive and integrated understanding of energy storage technologies and their applications is required. Second, a balanced research portfolio that accelerates the incorporation of present technologies and identifies new storage technologies should be developed. Finally, joint demonstration programs involving industry, DOE, and the national laboratories are needed to move these developing technologies to the private sector.

This initiative will help maintain the continued growth of US industry by keeping the cost of electricity down, improving the utilization of fossil energy resources, and minimizing the environmental impact of sustained industrial growth.

Wind Turbine Manufacturing

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EB])

A wind turbine manufacturing initiative will identify and support advanced manufacturing technologies that can foster economic growth, energy efficiency, and competitiveness in the wind industry. Breakthroughs in wind turbine manufacturing will provide the extra boost needed to make wind energy competitive with conventional power sources. Technical improvements in several areas can impact wind turbine manufacturing. They include composite design, advanced materials, structural design, systems integration, robotics, cost/performance trade-off analysis, serviceability and inspectability, and airfoil design. Application of modern concepts of agile manufacturing will improve production.

The Wind Turbine Manufacturing initiative is divided into two phases. Phase one is for integrated rotor analysis and concentrates on ways to improve the manufacturing of rotors and blades. Phase two is for integrated system manufacturing and will seek ways to impact the manufacturing of nonrotor components and the wind turbine system as a whole.

Natural Gas and Oil Technology Partnership

(for the Assistant Secretary for Fossil Energy [program AB, AC])

The Natural Gas and Oil Technology Partnership is based on the successful model of the Oil Recovery Technology Partnership, which has matched Sandia capabilities with industry needs on a limited scale since FY 1989. This partnership paradigm features industry-driven technology transfer, joint industry/national laboratory projects, flexible agreements and cost-sharing arrangements, and short proposals reviewed and prioritized by industry. The DOE Fossil Energy Program has selected the partnership as its preferred way of involving the national laboratories with this industry.

This program has seen significant expansion; in FY 1995 nine multiprogram laboratories participated, and a large advanced computational technology effort was initiated. Expansion into technology areas such as oil and gas processing and refining are expected.

Successful implementation of the partnership will have a positive impact on the petroleum industry by providing a versatile technology base and helping to create jobs. The partnership will also maintain a leading technology base within DOE's national laboratories.

Funding is based on industry review of proposals. Past experience indicates that Sandia can expect a significant share of current and future funds. Funding will gradually increase during the remainder of the decade to permit the laboratories to conduct a full range of research and development identified by industry.

Hydrogen Storage and Utilization

(for the Office of Energy Efficiency and Renewable Energy [program AL])

The environmental impacts of contemporary energy utilization and national dependence on foreign supplies are a source of concern. This concern highlights the importance of developing alternative energy sources for transportation, utility, and industrial utilization. Hydrogen, an abundant and versatile energy carrier, offers significant advantages over other alternative fuels, including the potential to reach zero pollutant emission levels and burn without carbon dioxide production.

There are significant challenges to hydrogen utilization, including cost-competitive energy production, efficient storage, effective conversion systems, and an infrastructure for distribution. These problems cut across several technology areas, and solving them will require the application of many disciplines. Development and demonstration of critical technologies for a hydrogen energy system is a high-risk, long-term effort well suited to a national laboratory.

Sandia is the recognized leader in hydrogen isotope systems (developed as part of our nuclear weapons mission). Weapons programs will benefit from the dual-use aspects of this technology and the synergistic maintenance of our core technical expertise. The hydrogen energy program will be leveraged by our existing programs and facilities. Sandia's Combustion Research Facility, which has a complete spectrum of hydrogen combustion experimental and modeling capabilities, will play a central role in this program in basic and applied research.

This initiative will work toward an integrated demonstration of a complete storage, delivery, and conversion system. The storage element will develop alternative storage concepts aimed at maximizing energy density and engineering those concepts into storage device subsystems that can supply an internal combustion engine or fuel cell. Specific storage concepts will be high-pressure, lightweight tanks, adsorption systems, and a lightweight hydride. Other storage system components (such as sensors, filters, and valves) will also be developed and integrated into the subsystem design.

We will focus on internal combustion engine modeling and testing and development of a hydrogen-burning internal combustion engine optimized for efficiency and clean emissions specifically suited for hybrid vehicle applications.

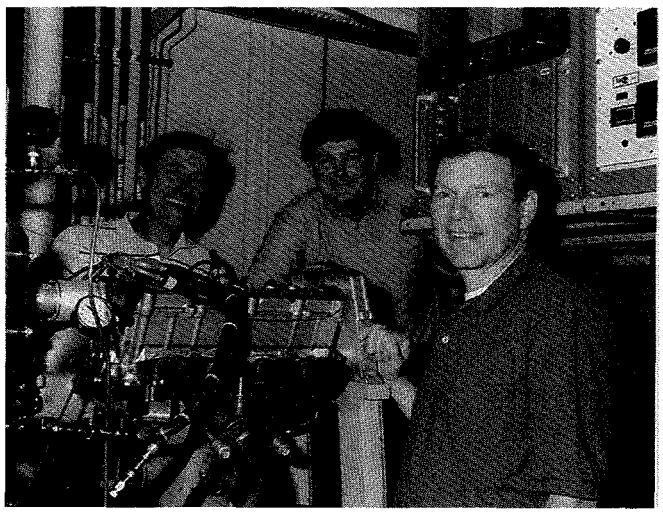
In the short term, research and development will focus on vehicle applications. In the long term, activities will focus on full conversion of utility systems to the use of hydrogen.

Combustion Dynamics

(for the Office of Energy Research [program KC])

The combustion dynamics initiative is a joint proposal by Sandia National Laboratories and the Lawrence Berkeley Laboratory in support of DOE's national role in combustion research. The initiative will improve the efficiency of combustion processes while minimizing pollutants.

The combustion dynamics initiative depends on completion of the unfinished Combustion Research Facility, Phase II project at Sandia/California and construction of the Chemical Dynamics Research Laboratory at Lawrence Berkeley Laboratory.



Combustion researchers Bob Greene, Pete Witze, and Bob Carling (left to right) with emissions study equipment.

Research at the facilities will produce predictive combustion models using data from experimental and theoretical studies. These models could be very useful to US industry in designing next-generation combustion systems. Work at the Combustion Research Facility will develop optical diagnostics for combustion, study chemical kinetics and reacting flows, and conduct studies in chemical physics. In collaboration with researchers from universities and industry, Sandia and Lawrence Berkeley will develop and apply instrumentation for combustion studies.

These activities will result in new insights into the elementary reactions involved in hydrocarbon combustion, the structure and dynamics of highly excited molecular species, and molecular energy flow processes, all of which are critical for advancing combustion technology. Results from fundamental studies of chemical reactivity and fluid mechanics will be incorporated into computer models to improve the design of engines, burners, boilers, furnaces, and gas turbines. The proposed modeling effort already has several industrial participants, including Allison Gas Turbine Company and Cummins Engine.

The combustion dynamics initiative will offer superior resources for users to study fundamental and applied combustion processes. Researchers at Sandia's Combustion Research Facility will be able to utilize advanced laser systems to study ultrafast processes in chemistry and combustion and perform two- and three-dimensional imaging of the physical and chemical properties of turbulent reacting flows.

Proposed Application of Nuclear Reactor Capabilities for Medical Radioisotope Production

(for the Office of Nuclear Energy, Isotope Production, and Distribution [program ST])

The US nuclear medicine industry will benefit from Sandia participation in the production of medical isotopes using our nuclear facilities and expertise in reactor engineering and associated technologies and our expertise in sensor technology and robotics.

There are several advantages to designating Sandia as a major production source for radioisotopes for nuclear medicine. First, a US supply has been mandated by Congress because the current foreign supply has no backup and the US radiopharmaceutical industry will benefit from the establishment of a US-based supply. Second, the DOE Office of Nuclear Energy, Isotope Production, and Distribution has determined that there are no suitable commercial reactor facilities and has recommended Sandia as a DOE option. Third, Sandia has multiprogram flexibility and a nuclear technology infrastructure. Extant reactor and hot cell facilities require only minor modifications to irradiate and perform postirradiation processing of fission targets, and no

over-the-road transport is required between the reactor and the Hot Cell Facility. Sandia also has substantial radioactive waste management expertise to minimize and otherwise manage the production waste stream. Sandia can be an essential supplier of radioisotopes and provide a national focal point for US research in nuclear medicine. This initiative will include medical radioisotope production, processing, research, and development, as well as radio labeling for therapy, diagnosis, or imaging. Compatible initiatives include production of radioisotopes for industrial applications such as gauging and tool wear measurement, and use of reactor neutrons for fusion reactor first-wall radiation damage studies.

Nuclear medicine has become a very important part of the health care system in the United States and in the rest of the world. Nuclear medicine requires a reliable and continuous supply of radioisotopes such as technetium-99m, which results from the decay of molybdenum-99. Technetium-99m is involved in 85 to 90 percent of all nuclear medicine procedures in the United States, and its use is expected to increase at a rate of 10 to 15 percent a year. It is currently supplied almost exclusively by Nordion International, Inc. of Canada. The House Government Operations Committee has charged DOE to fill an urgent need for a US supply of molybdenum-99 for medical applications within two years. The Office of Nuclear Energy, Isotope Production, and Distribution has responsibility for meeting this requirement. We propose to make the nuclear facilities and associated technologies of Sandia Technical Area V available to achieve this important national goal. The molybdenum-99 would be produced in the Annular Core Research Reactor by the fission process, separated from other fission products, and prepared for shipment in the Hot Cell Facility.

As presently envisioned, the project involves two phases. The facilities preparation phase involves modifying the Annular Core Research Reactor and the Hot Cell Facility and meeting Food and Drug Administration and environmental safety and health regulatory requirements. The production phase includes a transition from the current Annular Core Research Reactor fuel to a less expensive, more readily replaceable fuel. A third phase, decontamination and decommissioning, is not scheduled at this time. Other activities, such as support for development of optimized production and processing, technology transfer, and transitioning to private industry will be considered. The first two years of the project are the preparation phase; the production phase follows.

Table 2-6. Funding Requirements for Initiative Project Proposals in Energy Research and Technology Development (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Photovoltaics Industry Development					
Federal, State, and Regional Government Agency Photovoltaics Initiative					
Operating	2.0	3.0	4.0	4.0	3.0
Direct Personnel	4	5	6	6	5
Photovoltaic Collector Manufacturing Process Development					
Operating	2.5	3.0	4.0	4.5	5.0
Direct Personnel	4	5	6	7	8
Photovoltaic Balance-of-System Manufacturing Technology					
Operating	5.0	6.0	7.0	6.0	5.0
Direct Personnel	5	7	8	8	7
Photovoltaic Systems Lifetime Improvement					
Operating	2.0	3.0	4.0	3.0	2.0
Direct Personnel	4	5	6	5	4
Utility Photovoltaics					
Operating	2.0	3.0	4.0	5.0	6.0
Direct Personnel	4	5	6	6	5
Subtotal, Photovoltaics Industry Development					
Operating	13.5	18.0	23.0	22.5	21.0
Direct Personnel	21	27	32	32	29
Advanced Materials for Energy Conversion					
Operating	10.0	14.0	17.0	19.0	22.0
Direct Personnel	30	40	45	50	55
Solar-Dish-Stirling Systems for Utility Applications					
Operating	10.0	12.0	15.0	15.0	15.0
Direct Personnel	9	9	9	9	9

Table 2-6. Funding Requirements for Initiative Project Proposals in Energy Research and Technology Development (Dollars in Constant FY 1995 Millions; Personnel in FTEs) (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5
Integrated Utility Systems Energy Storage					
Operating	3.5	10.0	20.0	20.0	20.0
Construction	0.5	5.0	5.0		
Total Cost	4.0	15.0	25.0	20.0	20.0
Direct Personnel	10	25	50	50	50
Wind Turbine Manufacturing					
Operating	1.0	4.0	5.0	5.0	2.4
Direct Personnel	2	5	7	7	10
Natural Gas and Oil Technology Partnership					
Operating	3.0	9.0	12.0	13.0	13.0
Direct Personnel	12	36	48	52	52
Hydrogen Storage and Utilization					
Operating	2.0	2.5	3.0	3.0	3.0
Direct Personnel	5	7	10	10	10
Combustion Dynamics					
Operating	5.0	5.0	5.0	5.0	5.0
Construction	10.0	9.8			
Total Cost	15.0	14.8	5.0	5.0	5.0
Direct Personnel	25	25	25	25	25
Proposed Application of Nuclear Reactor Capabilities for Medical Radioisotope Production					
Operating		6.8	10.8	14.5	15.0
Capital Equipment		0.8	1.2	0.5	
Total Cost		7.6	12.0	15.0	15.0
Direct Personnel		22	32	38	45
Total, Energy Research and Technology Development					
Operating	48.0	81.3	110.8	117.0	116.4
Capital Equipment		0.8	1.2		
Construction	10.5	14.8	5.0		
Total Cost	70.5	111.9	137.0	137.0	136.4
Direct Personnel	114	196	258	273	285

2.2.7 Environmental Technology

Established Capabilities

Environmental issues are a growing national and international concern. Unfortunately, technologies for dealing with environmental problems are often immature or costly. DOE has a major responsibility for developing and applying environmental technologies and sharing solutions with industry and other agencies. DOE needs new and improved technologies to meet its cleanup requirements within expected budgets. Seeking to support DOE and the nation, Sandia has initiated a program to apply its wide range of technical competencies to environmental issues.

Sandia has extensive experience in environmental technologies, particularly with systems for transporting and storing radioactive waste. For many years, Sandia has been responsible for testing and performance assessment for the Waste Isolation Pilot Plant. We also serve as DOE's lead laboratory for conducting the assessment of compliance for Greater Confinement Disposal at the Nevada Test Site. Several DOE offices share research expertise for these assessments. Sandia also conducts research and performance assessment for the Yucca Mountain Site Characterization Project.

Since 1978 Sandia has been the DOE center for research and development for packaging and transporting radioactive materials. These efforts have been associated chiefly with waste management aspects of DOE programs, but the technology has found application in DOE Defense Programs, Naval Reactors, and Nuclear Energy programs as well. In addition, other agencies have funded aspects of the program such as design of packaging for moving chemical munitions to demilitarization sites, development of routing guidelines, evaluation of safety program operations, and development of package performance standards for toxic inhalants.

In 1990 Sandia assumed a lead role in moving the DOE production complex toward environmentally conscious manufacturing for nonnuclear components. We have developed and introduced suitable substitutes for materials and processes that required or generated hazardous materials.

For many years, the DOE Combustion Research Facility at Sandia/California has investigated the mechanisms that create pollutants in combustion processes and has developed concepts for cleaner energy conversion processes. The solar thermal programs at Sandia/New Mexico have helped develop an innovative process for destroying organic compounds in wastewater using solar energy. Competencies developed in defense and energy programs form a useful foundation for environmental research and technology development.

Sandia has been involved in the development and commercialization of site remediation technologies via the Mixed Waste Landfill Integrated Demonstration, which uses technologies from Sandia, other laboratories, and commercial sources. DOE has also asked Sandia to provide technical management for a new joint DOE and Environmental Protection Agency program investigating a streamlined process for innovative cleanup technologies for contaminated sites. This program is being viewed as a model cooperative effort among industry, regulators, and federal agencies. Plans call for extending this partnership to many DOE site cleanup problems and a variety of waste management issues.

Project Initiatives

Environmental Technology initiatives are described below. Funding requirements are given in Table 2-7 at the end of this section.

Subsurface Flow and Transport Laboratory

(for the Office of Energy Research [program KC])

Understanding of the fundamental processes involved in fluid flow through rocks and soils is essential to many DOE programs, including those in nuclear waste disposal and management, environmental restoration, and energy resource exploration (oil, gas, and geothermal). Sandia will use the Subsurface Flow and Transport Laboratory for systematic experimentation with fluid flow processes in real materials using bench- and field-scale experiments and numerical modeling. The bench-scale experimental facilities will include state-of-the-art quantitative flow and transport visualization via high-resolution image acquisition and analysis. Large-scale field studies will incorporate sensor arrays for monitoring subsurface flow and transport. Numerical modeling capabilities will range from continuum-based modeling to nonstandard percolation theory techniques. The laboratory will also serve an educational purpose by bringing together students, postdoctoral scientists, researchers from other national laboratories and universities, and Sandians. We are broadening the customer base for this facility and envision it as a DOE user facility and center of excellence serving the needs of both basic and applied programs within DOE.

Waste Management

(for the Assistant Secretary for Defense Programs [program GB], the Assistant Secretary for Energy Efficiency and Renewable Energy [program ED], and the Office of Environmental Management [program EW])

New waste management technologies are needed to

address both regulatory and technical requirements. In partnership with industry and other national laboratories, Sandia is actively involved in developing treatment and disposal processes and recycling techniques. These activities address both Sandia's obligations for handling its own wastes from current and past operations, and technologies for application to national needs. The nation faces a growing need to handle municipal wastes and hazardous chemicals with diminishing resources. Also, government agencies such as DOE and DoD will have to handle radioactive wastes, high explosives, and propellants. Issues of public acceptance, regulatory compliance, treatment options, health and ecological risk, liability, and cost must be addressed. Sandia will solve these problems by applying expertise in robotic systems, radioactive and hazardous materials safety, chemical and thermal processing, risk assessment, and sensor systems.

One set of problems involves disposal of electronic packages resulting from weapons dismantlement. Extending our waste-management technologies for these components to commercial electronics is a major goal. We will support DOE's new focus-area initiatives in waste management for underground storage tanks and mixed waste. Sandia is the lead technical integration manager for stabilization and closure for the underground storage tank effort and we have proposed using transportable treatment units for selected mixed waste streams.

Sandia is investigating how regulatory policy can be improved through scientific risk assessment. We are also working with local environmentalists.

Because so many waste management problems facing DOE are similar to those faced by the nation as a whole, we hope to use our technologies to help municipalities and industry. The nation's increasing need to deal with municipal wastes, hazardous chemicals, and obsolete electronics will require advanced waste management technologies.

Environmental Restoration

(for the Assistant Secretary for Defense Programs [program GB] and the Office of Environmental Management [program EW])

Environmental restoration focuses on the cleanup of contaminated sites. Technologies and systems that lead to quicker, safer, and more efficient remediation of sites are needed. Tens of thousands of suspected contaminated sites are the responsibility of DOE and DoD, in addition to problems resulting from metal, mineral, oil, and gas production on lands administered by the departments of agriculture and the interior. Similar situations exist in many municipalities that must deal with contamination from industry or mining.

More efficient ways to stabilize, contain, and clean up contaminated sites will be needed in the future. Advanced airborne sensors and rapid sampling and analysis to provide real-time data on the extent of contamination may be used. Because the cost of cleanup will continue to rise, more cost-effective solutions will be needed to stabilize waste and provide reliable barriers. Technologies to verify the integrity of in situ containments will be needed. Long-term, subsurface dosimetry instrumentation for leak detection will be needed to minimize risk to the public

The restoration initiative will also focus on problems beyond DOE's scope, such as those associated with mining operations, landfill leakage, septic tank drain fields, and agricultural pollution. As more military bases are closed, techniques for identifying and containing contaminants and performing site cleanup will need to become more efficient and be acceptable to regulators and the public. Finally, a growing concern about contamination and restoration of ports, harbors, and marine estuaries will require advanced technologies for characterizing and cleaning up ocean sediments.

Solutions to these problems that balance public health and safety against cleanup costs will become a national priority. Sandia's capabilities in sensor systems, physical and chemical analysis, and systems integration, together with our geophysical experience and knowledge, can directly support such activities.

Hazardous Materials Transportation

(for the Assistant Secretary for Defense Programs [program GB], the Office of Environmental Management [program EW], and the United States Department of Transportation)

Growing public environmental awareness and risk consciousness focus on governmental activities that have the potential to produce harm. One of the most visible of all such activities is the packaging and transportation of all hazardous materials, not just radioactive wastes.

DOE will be challenged to demonstrate safe transportation of unprocessed spent fuel from the nuclear weapons program, as well as research reactor spent fuel that DOE has committed to accept under the Research Reactor Spent Fuel Return Program. Also, programs in site decontamination and decommissioning are expected to produce large quantities of waste to be moved to repositories.

A growing need exists for careful consideration of the systems aspects of proposed solutions to these challenges. Also needed are innovative package designs, new package materials, and demonstrations of package and operations safety—all of which are key strengths of Sandia's program.

As DOE remediates sites, Sandia proposes to develop containers to store and transport hazardous waste. This effort builds on current expertise but is more demanding because of the requirement to maintain container integrity and elastomeric materials attacked by corrosive and organic solvents that may be components of the waste.

Applications of geographic information systems as an enabling technology are proposed in risk assessment,

routing, and emergency management as an important addition to our existing capabilities. Increased emphasis in DOE on interactions with stakeholders during cleanup campaigns requires the development of geographic information system tools to illustrate actions to be taken and provide the software interface in guiding activity.

Spent fuel from DOE weapons production and from research reactors will probably not be reprocessed. Instead, interim storage and geological disposal are options. We propose to evaluate the multipurpose container as a means of avoiding multiple handling of the fuel, as a consolidation measure, and to facilitate robotic operations in the repository. This evaluation may lead to a systems study and development of an optimized package. Technologies of benefit to DOE and potential commercial interim storage of civilian reactor spent fuel are likely to result from this work.

We also propose development of a group of rugged, cost-effective sensors to detect accidents, store information about accidents, summon response teams, and provide information and direction to responders. Given the increased risk-aversion of the public toward hazardous material in the environment, this technology will provide hazardous materials operations with effective tools to help protect the environment in the event of accidents.

Table 2-7. Funding Requirements for Initiative Project Proposals in Environmental Technology (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Subsurface Flow and Transport Laboratory					
Operating	1.0	4.0	4.0	4.0	4.0
Capital Equipment	1.0	1.0	1.0	1.0	1.0
Total Cost	2.0	5.0	5.0	5.0	5.0
Direct Personnel	3	12	12	12	12
Waste Management					
Operating	7.0	8.0	9.0	10.0	12.0
Direct Personnel	20	25	30	35	40
Environmental Restoration					
Operating	4.0	6.0	8.0	10.0	14.0
Direct Personnel	10	15	20	25	40
Hazardous Materials Transportation					
Operating	3.0	4.0	6.0	8.0	10.0
Direct Personnel	6	8	10	12	15
Total, Environmental Technology					
Operating	15.0	22.0	27.0	32.0	40.0
Capital Equipment	1.0	1.0	1.0	1.0	1.0
Total Cost	16.0	23.0	28.0	33.0	41.0
Direct Personnel	39	60	72	84	107

2.2.8 Transportation Energy Technology and Infrastructure

Established Capabilities

For four decades Sandia has conducted lead functions in transportation for DOE. These functions are broad, serving several DOE customers and benefiting from synergy in several areas.

Since its inception, Sandia has been the lead laboratory for transportation technologies associated with the safe, reliable, and monitorable movement of defense hardware. This historical role includes infrastructure issues in geographic information system tracking of trucks, full vehicle system design and production oversight, and reliability and safety integration. For nearly twenty years, we have held a similar lead role for transportation systems for radioactive and hazardous materials for both DOE and the Department of Transportation (DOT). Our responsibilities have included geographic information system development, cask design and certification, safety analysis, performance assessment, and manufacturing coordination. These two functions have also allowed Sandia to play important roles internationally in transportation of special materials in the former Soviet Union and in ocean and air transport of reactor fuel around the world.

Sandia's energy-related transportation responsibilities have been focused on engine combustion technology and advanced batteries. The engine program is a model government/university/industry partnership and has demonstrated to industry the valuable contributions the national laboratories can make. Because of these successes, the US auto industry is seeking Sandia's participation in its recent thrusts for improvement. In the past year, numerous cooperative research and development agreements have been placed by Sandia and the auto industry.

Because of these broad system successes at Sandia (information systems, propulsion systems, storage systems, vehicle system design and manufacture, reliability and safety integration, and multilaboratory coordination), we intend to play an even larger role in the US transportation infrastructure and vehicle system technology development. Our historical competency in systems integration and our experience in transportation should be utilized by DOE and DOT to maximize mission successes. Sandia's core competencies can be used to obtain practical solutions to transportation problems.

Project Initiatives

Transportation Energy Technology and Infrastructure initiatives are described below. Funding requirements are given in Table 2-8 at the end of this section.

Transportation Energy and Environment Technology

(for the Assistant Secretary for Energy Efficiency and Renewable Energy [program EE])

Sandia's existing Advanced Transportation Energy and Environment Technology Program is focused on improving the energy efficiency of the US transportation system, thus improving the country's economic competitiveness while protecting the environment. To this end, Sandia has entered into a number of cooperative research and development agreements with industries connected with transportation, notably the United States Council for Automotive Research and the United States Advanced Battery Consortium, which is developing an improved battery for electric vehicles.

Sandia's existing Engine Combustion Technology Project works to develop new technologies to improve efficiency, increase fuel flexibility, and reduce emissions in automobile and truck engines. The project includes catalysts for emission reduction and fuel cell applications, lightweight structural materials, hydrogen storage materials, and other new engineered materials for transportation applications.

Sandia has considerable expertise in energy storage development, which includes carbon materials for double-layer capacitors and lithium polymer electrolyte, sodium/sulfur, and zinc/air batteries. Much of this expertise is being applied in supporting the United States Advanced Battery Consortium (USABC), with participation by the Electric Power Research Institute and industry. USABC was formed to develop advanced batteries for commercial use in electric vehicles by 1998. The California initiative requiring 2 percent of vehicles sold in 1998 to produce zero pollution was a stimulus for formation of the group. Sandia's role with the USABC includes materials development, battery design, and testing.

Hybrid vehicles powered by batteries or fuel cells in conjunction with each other or with an internal combustion engine also will contribute to fuel substitution and environmental protection. Sandia's battery technology base, combustion expertise, sensor expertise, and systems engineering capabilities provide the tools necessary for this initiative.

Optimizing engine designs for emissions control and high efficiency is important to the expanded use of hydrocarbon fuels. Wider use of natural gas or multifuel engines will also support expanded use of such fuels. Sandia's Combustion Research Facility supports this work and can play a key role in solving these problems. In addition, our expertise in catalysis can contribute to the direct use of alternative fuels in fuel cells, and our experience in storing and transferring hydrogen isotopes (gained in the nuclear weapons program) can contribute to the practical utilization of hydrogen as a fuel.

Transportation Infrastructure Technologies

(for the United States Department of Transportation)

The Department of Transportation is beginning a program to improve the safety and efficiency of surface transportation by applying the latest technology in sensors, data fusion, communications, information, and control. The interconnections among various modes of transportation will become increasingly important in future systems. The Intelligent Transportation System initiative envisions "smart" highways and vehicles that will improve safety and reduce congestion, energy consumption, and pollution. The technology involves vehicle tracking systems, collision avoidance sensors, traffic control centers, automatic vehicle control systems, and roadside sensors.

In addition, new programs to enhance public transit systems, railroad systems, and commercial vehicle operations can be uniquely supported by Sandia's system integration capabilities. Research and development will be conducted in several areas in conjunction with the private sector and universities to foster rapid development and commercialization.

Future transportation systems will need to balance the interrelated issues of energy security, environmental quality, cost, and efficiency. It will be prudent to perform systems analyses before making major commitments or allocating resources to technology development and commercialization. Sandia's experience in modeling and analysis will help to analyze all levels of system design. The current study to examine the technical and economic feasibility of the proposed Santa Teresa Intermodal Facility is a prime example of this type of effort. This facility would cover approximately ten square miles near the border of New Mexico and Mexico and could dramatically improve the efficiency of moving commercial vehicle freight across the border.

Sandia has established a partnership with the University of New Mexico, New Mexico State University, Los Alamos National Laboratory, and the New Mexico State Highway and Transportation Department for transportation research. The alliance is a unique combination of partners with wide-ranging technical capabilities and facilities and a thorough understanding of current problem areas and future needs for the nation's transportation infrastructure. The alliance is dedicated to solving the nation's transportation needs by teaming with other research organizations and industry in application-oriented research and development.

The selection of tomorrow's transportation systems involves a thorough understanding of risks associated with the introduction of new fuels and energy storage elements into the system. The extensive use of combustible fuels in the United States leads to a variety of safety and security concerns. To ensure against abnormal occurrences, misuse, or sabotage, systematic risk assessment and testing should be conducted on every step of the combustible fuel system: extraction, transportation, storage, processing, and consumption/disposal. Each step is subject to environmental, safety, and health (ES&H) risks because dangerous work sites such as offshore oil platforms, pipelines, transport vehicles, storage tanks, processing plants, and disposal facilities are all part of the process of preparing fuel for consumption. Sandia is well-positioned to conduct risk assessment studies and testing from a systems point of view, addressing both safety and security. As the originator of probabilistic risk analysis methodologies for nuclear power systems and nuclear weapons, we can apply these techniques to economic issues and risk-related scenarios.



The Safe Secure Transport Program has developed reliable, secure systems for transporting nuclear weapons and materials.

Much of the technology for the Intelligent Transportation System is an extension of work already under way at DOE laboratories. The Safe Secure Transport Program has developed reliable, secure systems for transporting nuclear weapons and materials. DOE has developed a command and control system called STARBASE to operate and manage the fleet and provide emergency response. The Department of Transportation has expressed interest in using our experience base to develop a geographic information system for transportation to collect and manage the vast amount of information that will be generated by the legally mandated upgrades to the transportation infrastructure. These technologies are also important to managers of large truck or bus fleets.

Sandia has developed many types of robust, unattended ground sensors. This technology may be important to the Intelligent Transportation System in developing roadside sensors for monitoring commercial vehicle safety, assessing the weight of passing trucks, and automatically assessing tolls. We have also developed many versions of teleoperated and autonomous vehicles.

Partnership for a New Generation of Vehicles

(for the Assistant Secretary for Defense Programs [program GB])

The Partnership for a New Generation of Vehicles, the

official name for a program also called clean car or super car, was announced in September 1993 by President Clinton and the chief executives of Ford, General Motors, and Chrysler. The program enables a new partnership between the US government and the domestic automobile industry to improve economic competitiveness, the energy supply, and the environment. Automobiles were selected because of their role in personal transport, environmental cleanliness, and economic competitiveness.

The program focuses on technologies that can reduce the time and cost for moving new automotive product ideas into the marketplace—technologies that will enhance the safety and efficiency of the present designs of automobiles and that will be required to develop production prototypes of vehicles with up to three times greater fuel efficiency than today's vehicles.

Sandia has established capabilities in combustion analysis and instrumentation, sensing, analysis and control of manufacturing processes, development and application of lightweight materials, supercomputing, structural analysis, fluid dynamics, mesh generation, and visualization. These capabilities have been nurtured primarily to meet the requirements of our nuclear ordnance mission, but they have also been supported by the Basic Energy Sciences, Energy Efficiency, and Environmental areas of DOE. Building on these capabilities, we have used the technology transfer initiative process to open new programs with the auto industry.

The US Council for Automotive Research (USCAR) is the US automobile industry's body for performing and sharing precompetitive, cooperative research of mutual interest to Ford, General Motors, and Chrysler. USCAR is organized into about fifteen consortia that address various technical areas. For example, emissions control technologies are addressed by USCAR's Low Emissions Partnership, and advanced, lightweight materials are addressed by USCAR's Advanced Materials Partnership. Other consortia consider the technical issues related to recycling, supercomputing, computer-aided design/computer-aided manufacturing, emissions measurement, painting, and advanced batteries for electric or hybrid automobiles. USCAR is the industry's organization for participation in the Partnership for a New Generation of Vehicles. The three major areas of emphasis in Sandia's automotive initiative, which correspond to the major areas selected by USCAR, are

- advanced emissions control technologies,
- lightweight materials for automotive applications, and
- advanced supercomputing.

Sandia's Advanced Manufacturing Technology Program has major applications to the automotive industry. Many of the projects in process analysis, quality, reliability, and environmental areas find important automotive application. Other Sandia efforts that contribute to the initiative are

- advanced design techniques for tire design and manufacture,
- improved combustion systems, and
- fuel cell development and manufacture.

Table 2-8. Funding Requirements for Initiative Project Proposals in Transportation Energy Technology and Infrastructure (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Transportation Energy and Environment Technology					
Operating	10.0	15.0	20.0	20.0	20.0
Direct Personnel	25	37	50	50	50
Transportation Infrastructure Technology					
Operating	10.0	15.0	20.0	20.0	20.0
Direct Personnel	15	20	25	25	25
Partnership for a New Generation of Vehicles					
Operating	25.0	30.0	40.0	50.0	60.0
Direct Personnel	60	70	80	90	100
Total, Transportation Energy Technology and Infrastructure					
Operating	45.0	60.0	80.0	90.0	100.0
Direct Personnel	100	127	155	165	175

2.2.9 Biomedical Systems Engineering

Established Capabilities

Health care costs in the United States are increasing rapidly. These costs are a major concern of the public and contribute to the decline in US economic competitiveness. The proper application of advanced technologies through biomedical engineering could significantly reduce some costs without compromising health care.

The national laboratories possess a wealth of engineering and scientific expertise that can be applied to this critical need. However, this expertise has not yet been used to develop technologies to help reduce health care costs. Research in biology (e.g., the human genome project) is under way at several DOE laboratories, but little focused effort in the United States is directed at developing biomedical technologies that have the potential to reduce health care costs.

Project Initiatives

Biomedical Systems Engineering initiatives are described below. Funding requirements are given in Table 2-9 at the end of this section.

National Biomedical Engineering Collaboration

(for the Assistant Secretary for Defense Programs [program GB], the Office of Health and Environmental Research, and Advanced Research Projects Agency)

Development of affordable technologies to drive down health care costs requires both technical innovation and a thorough understanding of the medical community's requirements. We propose to establish the National Biomedical Engineering Collaboration to lead the country's efforts in applying technology to reduce health care costs. The collaboration will be facilitated by a nonprofit consortium.

This collaboration would allow formation of interdisciplinary teams with members from the national laboratories, university medical schools, and industry to guide technology development. These teams, dispersed throughout the United States and connected via an information infrastructure, would identify the largest cost drivers in health care delivery, define areas where technology could impact those costs, conduct focused research and development programs, and arrange for the transfer of resultant technologies to industry. A multidisciplinary approach will combine state-of-the-art technology development by the national laboratories and industry with insight from the medical community.

The major emphasis will be on a systems engineering approach to defining the role of technology in reducing health care costs. A comprehensive study has begun to identify areas in the health care delivery system where technology can reduce costs. This study will produce a road map to guide technology development.

Sandia has already developed several biomedical applications that could reduce costs and improve diagnosis and/or treatment. For example, a set of computer algorithms developed by Sandia computer scientists to find mobile targets in combat operations has been used to interpret digitized mammograms. These algorithms have increased tumor detection rates. In collaboration with the Baylor University Medical Center and the Albuquerque Veterans Administration, Sandia is applying massively parallel computational techniques to enhance the utility of magnetic resonance imaging in diagnosis of breast cancer and brain disorders. We plan to continue dual-use improvement of target recognition algorithms to serve both military and civilian needs for image processing.

High-performance computing is also enabling great advances in the field of computational biology. In cooperation with a major pharmaceutical company, Sandia is applying massively parallel computing to unravel the interactions between DNA molecules and drug molecules. This work provides insight into drugs that might eventually cure cancer and AIDS.

One of the most promising new developments in the field of medicine is that of minimally invasive diagnostics and procedures. Sandia has already demonstrated competence in the development of noninvasive sensors. For example, a spectroscopic blood monitor has been demonstrated to measure blood glucose noninvasively, making it possible for people with diabetes to manage the disease more easily. This technology has now been licensed for commercial development. It uses computer software originally developed with DOE Defense Programs funding for evaluating explosives in the stockpile. Further advances in image processing technology are making it possible to obtain ultrasonic images with a resolution comparable to that of x-rays. This ultrasonic technology will provide a low-cost, nonionizing source of imaging. The Advanced Research Projects Agency is supporting development of this technology.

DOE's Office of Health and Environmental Research is developing a strategic plan for a research program in biomedical technology. Sandia is working with them to help define this program. In addition, DOE's technology partnerships have defined a health care technology advisory coordinating team to form projects at the DOE Defense Programs laboratories. The biomedical technology research program has led to the formation of seven biomedical cooperative research and development agreements at Sandia. These Sandia initiatives form the technical foundation for our future program.

A new trend in medicine is toward more home health care to reduce the average length of hospital stays and to allow infirm people to remain at home while being monitored. To facilitate this trend, small, low-cost sensors with communications capability are desirable for monitoring the state of health of outpatients, postoperative patients, and home-bound patients. Such devices are also of interest to the military for monitoring the health of troops on the battlefield. We are discussing a program in this area with the Advanced Research Projects Agency and several private companies.

Development of biologically compatible materials is an increasingly important area of medical research. Sandia's role in the nuclear weapons program has provided a strong capability in engineered materials. Applications of this capability to the field of biomedical engineering will lead to new, biologically compatible materials for implantable sensors, bone and hip replacements, and skin grafts. Specifically, microcellular foams, long used for packaging nuclear weapons components, are being evaluated for applicability in bone replacement. Adhesives for permanently repairing meniscal tears have been proposed for funding through our Laboratory-Directed Research and Development program. In addition, the combination of the bioactivity of silicate glasses with the mechanical properties of structural materials may lead to the development of more useful prosthetic devices.

National Medical Information and Communications System Design

(for the Office of Health and Environmental Research, Advanced Research Projects Agency, and the Veterans Administration)

Many studies have shown that one of the major contributors to rapidly growing health care costs is the lack of timely, accurate information on patient records. This lack of information frequently results in redundant medical tests that add to health care costs.

In conjunction with major medical research institutions, the Advanced Research Projects Agency, the Veterans Administration, and the National Library of Medicine, Sandia is exploring the application of its capabilities in data and network surety, high-speed communication links, and high-performance computing to a program for designing a national medical information infrastructure. In addition to patient records, the system could also provide high-speed image processing capability to increase the utilization of expensive equipment such as magnetic resonance imaging instruments. Substantial cost reductions appear to be possible if such a system is developed.

Table 2-9. Funding Requirements for Initiative Project Proposals in Biomedical Systems Engineering (Dollars in Constant FY 1995 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
National Biomedical Engineering Collaboration					
Operating	2.0	1.0	1.0	4.0	5.0
Direct Personnel	10	5	5	20	25
National Medical Information and Communications System Design					
Operating		0.5	0.5	0.5	0.5
Direct Personnel		2	2	2	5
Total, Biomedical Systems Engineering					
Operating	2.0	1.5	1.5	4.5	6.0
Direct Personnel	10	7	7	22	30



Programmatic Activities

3.1 Programs for the Department of Energy

Three quarters of Sandia's operating budget is derived from programs for DOE. The remainder is reimbursable funding provided by other federal agencies, principally DoD, for work in national security and other national need programs.

3.1.1 Weapons and Waste Cleanup Programs

Although dramatic changes in the world have significantly reduced the threat of global nuclear conflict, nuclear deterrence will remain a vital part of the US defense strategy as long as technologies of mass destruction pose a threat to our national interests. The urgency of the Cold War has passed; however, Sandia's atomic energy defense programs must continue to ensure that the United States remains capable of fielding a viable response to any future challenges.

Our nation must remain capable of facing an uncertain and possibly hostile world with the confidence that comes from a safe and reliable nuclear deterrent under the assured control of appropriate national authorities. In addition, our allies may perceive less need to acquire nuclear weapons because the United States will retain its nuclear weapons capabilities. Sandia's responsibilities for the long-term surety (safety, use-control, and security) and reliability of the deterrent are made more difficult by several new challenges, including the lack of new weapons in development, the dramatic restructuring of the nuclear weapons complex, increased stockpile weapon lifetimes, and the cessation of nuclear testing.

Weapons being retired from the stockpile in response to changes in national security requirements continue to be dismantled safely, securely, efficiently, and with sensitivity to public concerns about risk, security, and environmental protection. Both near- and long-term issues associated with the configuration, storage, and final disposition of nuclear-weapons-capable materials must be addressed. Ensuring sufficient security and emergency response capabilities for the substantially increased movement of weapons and materials resulting from the stockpile drawdown remains essential.

Because of the reduction in nuclear weapons production, the nation's fiscal realities, and the greater emphasis on environment, safety, and health (ES&H), the nuclear weapons production complex is being dramatically downsized,

modernized, and reduced in cost of operation. This must be accomplished while retaining a capacity to design and build replacements for current weapon components as those components reach the ends of their service lives. Also, the capability must be preserved to design and produce new nuclear weapons in response to unforeseen world events.

To meet our ES&H responsibilities, many sites within the nuclear weapons complex are undergoing environmental stabilization and restoration. Ongoing operations within the complex are being improved from the standpoints of worker safety and waste minimization.

Possible proliferation activities anywhere in the world must be reliably detected, accurately characterized, and constantly monitored, regardless of the strategies, tactics, or technologies employed to conceal them. The means to accomplish this task must be developed, refined, consistently updated, and fully implemented. The successful monitoring and controlling of nuclear proliferation will be a vital element of preserving peace in the new multipolar world.

Reducing the nuclear danger associated with the substantial arsenal that remains in states of the former Soviet Union remains a priority. The Russian arsenal must be dismantled to the point stipulated in arms control agreements, and its nuclear materials must be accounted for and secured. In addition, we must help the Russian nuclear weapons centers and scientists redirect their expertise toward much needed civilian activities.

With the exception of environmental restoration and nuclear waste management programs, all these challenges are the direct responsibility of Sandia's defense programs sector. Since the end of the Cold War, the challenges facing the defense programs sector have actually grown. In recognition of the continuing threat posed by the existence and spread of military technologies, the sector must continue to ensure the safety and credibility of the nuclear deterrent. However, the sector is also responding to the much broader challenges to our national interests that result from an increasingly competitive global economy. Thus, we will continue to focus on our critical responsibilities in the areas of nuclear deterrence, arms control, nonproliferation, and associated intelligence while further integrating our capabilities with those of our nation's strategic industrial base.

Sandia's defense programs sector addresses these responsibilities in accordance with five goals outlined in the DOE National Security Strategic Plan.

Goal one is to assure that DOE remains a full participant in preventing the spread of nuclear weapons, materials, and expertise. DOE must remain the preeminent agency for providing the technology to do this. Our efforts to support DOE have two broad and related aspects. One aspect concerns activities specifically associated with monitoring and supporting arms control agreements and treaties with the former Soviet Union. These activities cover a wide range, including preparations for potential agreements concerning the inspection of the stockpiles and facilities within both nations' nuclear weapons complexes. The second aspect involves monitoring and preventing the further spread of nuclear weapon technologies. As the collapse of the bipolar Cold War world gives way to a more dynamic multipolar world, these nonproliferation and counterproliferation responsibilities are increasingly important.

Goal two is to maintain nuclear weapons technology and competence that are responsive to national security needs within expected fiscal constraints. The maintenance of a credible nuclear deterrent remains a fundamental element of US national security policy. This deterrent will be based on an enduring nuclear weapons stockpile and the stewardship of that stockpile, which has been a fundamental Sandia mission for more than forty years. The ability to maintain the surety of the stockpile under all conditions and in all environments is of strategic importance to the nation and a differentiating strength for Sandia. Our work in strategic surety develops and promulgates the underlying science, technologies, methodologies, prototypical components, and system architectures for nuclear weapons. Overall, however, the foundation of stockpile stewardship is the constant monitoring of the stockpile to ensure that the credibility of the deterrent remains high. In this context, reliable stockpile stewardship fundamentally rests on the competence of Sandia staff and our ability to identify and mitigate stockpile concerns effectively. Sandia's defense programs sector has fundamental responsibilities in all phases of the stockpile surveillance and maintenance process. The sector can only address the lack of new weapons in development, increased stockpile weapon lifetimes, and the cessation of nuclear testing by implementing effective strategies for the maintenance of our staff competence. As the nation's nuclear deterrent becomes dependent on a smaller number of systems, increased stockpile surveillance will be essential. As budget concerns and troop strength reductions make many stockpile maintenance responsibilities increasingly burdensome for the military services, the defense programs sector must continue to assist the military services whenever necessary.

Goal three is to reduce the worldwide nuclear stockpile by safely and securely dismantling thousands of nuclear weapons. Sandia will support safe, environmentally sound control and disposition of the nuclear materials and components that could contribute to proliferation.

Sandia's support for the dismantlement process has included direct consultation about the safety of the actual dismantlement process, information and advice concerning characterization of waste materials, and support to ensure the safety and security of materials and components during transport and storage. We have also promoted worldwide nonproliferation and nuclear safety goals by assisting the former Soviet Union in its efforts to control and dispose of nuclear materials and components safely and securely.

Goal four is to achieve continual enhancement of the technology infrastructure and core competencies for executing the national security mission while also assisting industrial competitiveness. Sandia's technology infrastructure and core competencies, which reside in our physical and



Staff members from Sandia, Los Alamos, and Pantex are shown with the last B57 bomb to be dismantled at Pantex.

intellectual capabilities, are essential for the long-term viability of defense sector activities. Elements of Sandia's technology infrastructure underlie and support multiple DOE national security activities, provide the basis for productive interactions with US industry, and generally support activities essential for the successes of other Sandia sectors. Research and development activities include critical supporting sciences and crosscutting exploratory technology assessments and developments. Exceptional science and technology foundations are necessary to respond quickly to problems, technological advances, and potential national security concerns. Important elements of these science and technology foundations include support capabilities (shops, engineering, drafting, and computing), specific developmental testing facilities, aboveground test facilities for radiation-effects assessments, and materials science capabilities.

Goal five is to help transform the DOE national security infrastructure to meet current and future requirements for management of nuclear weapons design, testing, and manufacturing technology; safe, secure disposition of weapons-capable materials; and maintenance of arms control and related technologies. This transformation will make the infrastructure cost effective, responsive, flexible, agile, and environmentally responsible. Changing national security requirements, environmental and budgetary concerns, and the advanced age of many of our nuclear production facilities continue to drive the reconfiguration of the nuclear weapons complex into a smaller, more efficient, more modern, and more environmentally responsible form. The success of these efforts will depend on the development of appropriate production and waste management technologies, improved approaches to the integration of design and manufacturing,

and suitable alternatives for those materials and processes that must be discontinued. Sandia emphasizes commercial procurement of most parts, small-lot manufacturing of essential parts, and standardization of parts, design, and interfaces wherever possible. Sandia has also accepted the transfer of important production responsibilities from other elements of the nuclear weapons complex as part of the overall downsizing.

The defense programs sector has also established some broad and enduring performance criteria against which programmatic plans and strategies can be judged and, if necessary, modified or reinforced. These Strategic Investment Criteria reflect the fundamental principles of the sector and its long-term commitment to remaining a relevant and contributing entity. These criteria are being applied to virtually all projects undertaken by the sector.

Criterion one focuses on customer obligations. Sandia is a customer-focused organization, and the defense programs sector's efforts and activities are routinely scrutinized and monitored for agreement with customer requirements.

Criterion two embraces the concept of dual benefit. The defense programs sector recognizes the need to respond to a broad range of challenges to our national interests. Thus, we are committed to a balanced program heavily focused on the exploration and development of technologies that can benefit both domestic industry and the nuclear weapons program. This approach emphasizes meeting the sector's needs in manufacturing, high-performance computing, electronics, nonproliferation, risk assessment, safety, and security. At the same time, the sector prioritizes cooperation with industry for the further development and maintenance of our national strategic industrial base. Cooperative technology development with industry leverages resources in areas of mutual interest.

Criterion three concerns strategic partnerships. The responsibility of the defense programs sector to the maintenance of a credible nuclear deterrent derives from the original mission of DOE's Defense Programs laboratories. These laboratories have evolved from special-purpose sites dedicated to a single program to multiprogram institutions addressing a wide range of national interests. The impacts and effects of the increasingly competitive international environment are actually strengthening and accelerating this trend. Teamwork within Sandia and cooperation among Sandia and other national laboratories, universities, national research institutions, and the industrial sector are essential for bringing the full potential of our capabilities to bear on complex national issues.

Criterion four focuses on nurturing technical strength. The sector maintains essential elements of national vigilance against the possibility of technological surprise. In this context, the sector is obliged to continuously monitor, explore, and exercise the most modern and advanced elements of technologies likely to have an impact on the interests and security of the nation. The sector has a further responsibility to ensure that Sandia's resources are constantly challenged to grow and that the full potential of their benefit to the nation is realized.

Criterion five is strategic reconfiguration. To remain national assets, the sector and Sandia continuously monitor, reassess, and realign their organizational goals, strategies, and structures and constantly adjust their responses to dynamically changing customer requirements. In this way we ensure that our activities reinforce the strategic directions established for Sandia and the nation.

Assistant Secretary for Defense Programs (GB)

The Assistant Secretary for Defense Programs is the cognizant secretarial officer for Sandia. Weapons activities employ roughly half of Sandia's direct personnel and include research and development, testing, inertial confinement fusion, stockpile support, reconfiguration, emergency response, and a variety of special projects.

Core Research and Development (GB0103)

The technology base developed and preserved by the Assistant Secretary for Defense Programs underlies nearly all Sandia capabilities, including Defense Programs technology partnerships. Although arms control, nonproliferation, and defense waste cleanup activities are no longer a direct responsibility of the Assistant Secretary for Defense Programs, the same technology base is essential to those programs.

In cooperation with Los Alamos and Lawrence Livermore national laboratories, Sandia supports DOE Defense Programs to develop stockpile stewardship documents and program plans that outline strategies for an era of no nuclear testing, no new weapons development, downsized production requirements, and longer stockpile lifetimes. Surety is an important Sandia responsibility, which concerns issues raised by the Drell Panel,[1] problems related to transportation and handling, logistical questions associated with retirement and dismantlement, requirements of a smaller and more flexible stockpile, and increased public sensitivity toward environmental safety and health issues. Sandia's surety strategy is to embed, in all its efforts and products, the principle that the surety of any product or operation is too critical to be allowed to degrade; regardless of its expected service life, it must be constantly updated.

[1] The Drell Panel, formerly the Panel on Nuclear Weapons Safety, evaluated the safety of US nuclear weapons systems for the House Armed Services Committee in 1990.

As Sandia accepts additional responsibilities within the downsized nuclear weapons complex, our science and technology infrastructure must remain adequate to support responsible stockpile stewardship. This is a key priority within the defense programs sector.

In FY 1994 we implemented a process to evaluate every new or ongoing project to determine its potential application to the commercial sector. Faced with a decline in the direct funding that has historically supported the technology base for weapon activities, we expect our technology cooperation efforts and industrial partnerships to help preserve core capabilities necessary to carry out our defense program responsibilities. This policy links the resulting technology transfer activities to specific DOE Defense Programs projects so that substantial spin-back to the weapons program occurs. Also, our defense activities will benefit directly from closer ties with industry, other governmental agencies, and universities.

Special Projects, Education, and Partnerships (GB010304)

Education Initiatives (GB0103044)

The education activities supported in this budget category are described in the section on the Office of Science Education and Technical Information (3.1.3).

Weapons Transportation Safeguards Systems (GB0103045)

DOE's Transportation Safeguards organization is responsible for the safe secure transport of all DOE-owned nuclear weapons and nuclear-weapon-related special nuclear material within the continental United States. As the original design agency for much of the equipment currently in service, Sandia provides Transportation Safeguards with day-to-day operational engineering support for most major elements of the system, including safe secure trailers, armored tractors, the mobile communications system, and the secure communications command/control center. Sandia is also responsible for design, prototyping, fabrication, testing, validation, and subsequent implementation of all upgrades associated with these subsystems. In addition, we provide the Transportation Safeguards organization with support for long-range planning, security analysis, probabilistic risk assessment, fleet maintenance, and small-quantity production runs.

Sandia has played a central role in designing, developing, and prototyping the latest transporter, known as the SafeGuards Transporter. This effort incorporates modern safety and security technologies into a new design that replaces the twenty-year-old safe secure trailer. The SafeGuards Transporter incorporates improvements identified in recent risk assessments in support of a full transportation safety analysis; however, the transporter is only one part of a much-needed comprehensive modernization of all aspects of the system, including operations and procedures.

DOE sites have traditionally used standard or slightly modified trucks or trailers for on-site weapons transportation because more specialized transport vehicles have not been available. Intrasite shipments have been protected by large numbers of security forces. Recently, an intrasite secure transport vehicle prototype was developed with a hardened cab and cargo compartment, access delay system, and vehicle immobilization system. The prototype is being tested and evaluated at several DOE sites.

Site Remediation (GB0103046)

To alleviate concerns over local environmental issues and reduce long-term costs to the nuclear weapons program, we will continue to support the consolidation of tritium-related research and development at other DOE facilities. Toward this end, we have decontaminated and decommissioned the Tritium Research Laboratory at Sandia/California, and this facility has been reclassified from a low-hazard (Category III) nonreactor nuclear facility to a low-risk facility with a radiological hazard. The transition work included reducing the accountable tritium to zero (essentially removing all tritium) and successfully releasing and reapplying roughly $10 million of capital equipment for reuse in other DOE facilities, as opposed to disposing of these valuable assets as low level waste. The excellent operating history and careful restoration of this facility have resulted in a clean laboratory building that is now available for other uses. More than six thousand tons of demolition waste were avoided as a result of the transition, and throughout the transition process environmental releases and human exposure levels remained well below the historic operational levels for the facility. The facility transition was on schedule, below budget, and in full compliance with applicable DOE orders.

Other Special Projects (GB0103049)

The Joint DOE/DoD Munitions Technology Development Program, authorized by a 1985 DOE/DoD memorandum of understanding, is a jointly funded research and development program to develop innovative warhead, explosive, and fuse technologies and improve munitions technology for DoD service missions and the DOE nuclear weapons mission. Technology coordination

groups and a technical advisory committee representing both DOE and DoD develop the program plans for each technical area, evaluate new proposals, and conduct technical reviews. In addition to the direct benefit to the nuclear weapons program, DOE Defense Programs benefits because DoD shares costs associated with maintaining core competencies for the nuclear weapons program. Projects are under way in energetic materials, guidance and control, smart mines, countermines, and systems studies.

Nuclear Emergency Search Team (GB010305)

The Sandia Nuclear Emergency Search Team has historically focused on mitigating radioactive aerosols generated during violent disablement of improvised nuclear devices, predicting the consequences of such dispersals, devising methods of rendering improvised nuclear devices safe, and developing field-portable methods for determining the types of explosives in such devices. Sandia is responsible for developing a training program for all people involved in a Nuclear Emergency Search Team field response and for assuring that these people understand their responsibilities. Sandia was asked to lead the Nuclear Emergency Search Team full-field exercise in the fall of 1994, and we are playing a central role in planning subsequent exercises.

World events have exacerbated nuclear terrorism concerns. Awareness of the role that the Nuclear Emergency Search Team would play in overseas deployments is increasing. The budgetary requirements package for future years identifies a need for additional funding and expansion of the Nuclear Emergency Search Team effort.

Stockpile Technologies (GB010314)

A principal mission of Sandia is stockpile stewardship, which encompasses directing and managing the total life cycle of the nuclear weapons stockpile and maintaining a viable weapons component capability. Duties include maintaining the weapons in the stockpile; monitoring, testing, and assessing stockpile health; developing and retrofitting nuclear weapons as required; developing and maintaining equipment required to support nuclear weapon logistics and operations; developing and maintaining capabilities for safe and secure transportation and storage of nuclear weapons; and supporting the dismantlement of nuclear weapons retired from the stockpile. The development and maintenance of an appropriate stockpile technology base is essential to performing these duties.

Surveillance, Evaluation, Maintenance, and Support (GB0103141)

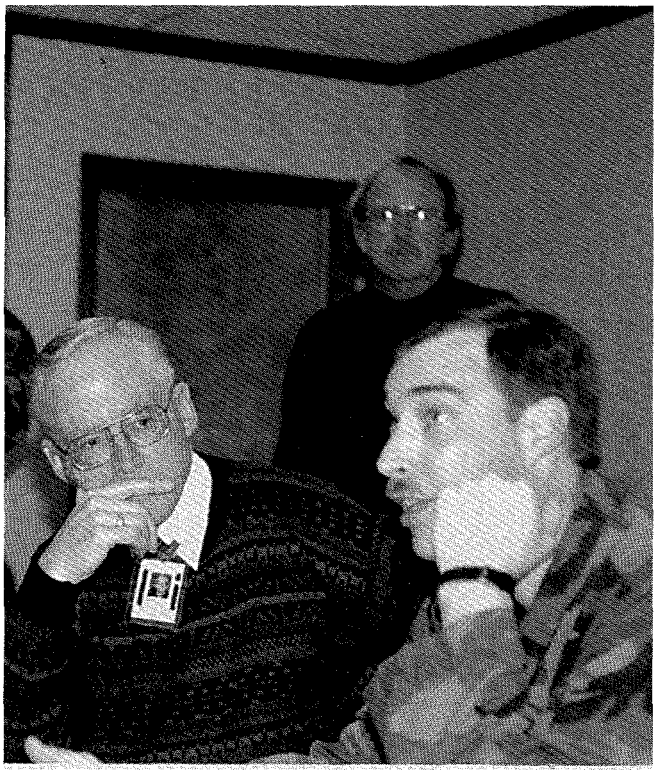
Sandia supports the DOE Stockpile Evaluation Program by analyzing and testing weapons as they enter the stockpile and by evaluating weapons withdrawn from the stockpile. Results from the evaluation program clearly indicate that nuclear weapons do not wear out. However, as the stockpile ages, Sandia and the nuclear design laboratories take corrective action to ensure that the performance and safety of the stockpile do not degrade. Corrective actions can take the form of changes during new weapon construction or retrofits to weapons in the stockpile.

The evaluation program has shown over the last four decades that serious defects in nuclear weapons have been relatively rare. As defects or problems are identified, changes are made to improve operations and maintenance. Sandia's Stockpile Evaluation Program relies heavily on the basic skills required to develop nuclear weapons. Among these skills are materials science, electronic piece-part and subassembly design, electromechanical component design, structural design, applied mechanics analysis, and environmental testing.

During the last four decades, approximately 13,500 weapons in the stockpile have been tested. A total of 2,344 defects has been found, a portion of which could be categorized into 252 actionable defect types. Actionable defects are those that impact reliability or safety and require corrective action. Overall, stockpile reliability has been excellent for the last forty years; however, with the shift to a smaller stockpile, stockpile sampling opportunities will be limited and, with no foreseeable new weapon development, the weapons in the enduring stockpile will be expected to serve through much longer service lives in the future. An important future thrust for this program will be to refine the sampling and testing program to ensure that the reliability and surety of the stockpile are maintained at a high level as the stockpile is reduced in size.

Sandia provides the technical military manuals and training that enable the armed services to maintain stockpile readiness while ensuring safety and control. Training is conducted at Sandia for military logistics specialists who in turn train other military personnel. Sandia also provides on-site field training for the military in response to its needs and requirements.

Most weapons require periodic maintenance, such as replacing limited-life components. Sandia supports this routine maintenance requirement through the Training and Technical Manuals Program and with field engineering staff as appropriate. When problems with nuclear weapons occur in the field, Sandia provides technical support to the military to resolve them. In most cases, problems are resolved in the field without having to return weapons to the DOE production complex.



Sandia provides training to the armed services for stockpile readiness, safety and control, and maintenance.

Retirement, Dismantlement, and Storage Research and Development (GB0103142)

National policy and DoD requirements establish weapons retirement schedules. After the dissolution of the Soviet Union and signing of the Strategic Arms Reduction Treaty agreements, the size of the US nuclear stockpile has been and will continue to be reduced. Many weapons have been retired, and dismantlement continues to be a major effort, with Sandia providing significant support to DOE for this task.

Dismantlement begins when the military designates a weapon for retirement; it ends when DOE has disposed of the weapon components, trainers, handling equipment, and associated hardware. The procedure includes transportation, storage, and disassembly into subsystems and components that are recycled, staged for reuse, or disposed.

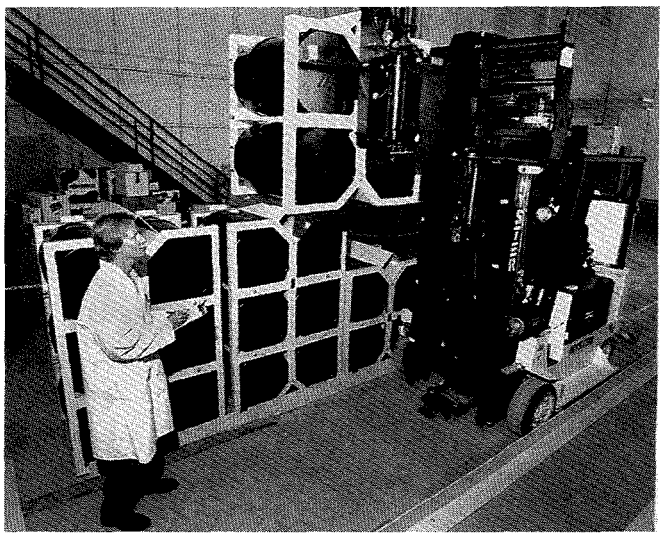
Many issues must be addressed by Sandia to support dismantlement. Where and how will weapons be safely and securely stored while awaiting dismantlement? How will materials be safely and securely transported? What are the best approaches for the safe dismantlement of large quantities of weapons and disposal of weapons materials while ensuring the environmental safety and health of the work force, facilities, and public? Sandia has development programs to address such issues. These programs are coordinated by the DOE Albuquerque Operations Office with DOE's Pantex plant in Amarillo, Texas to ensure that safe and efficient processes are developed.

Sandia is developing automated processes using robotics and computer modeling to support dismantlement. In particular, the Stage Right Project is establishing the feasibility of a robot system for materials movement and inventorying. Stage Right moves, stacks, and retrieves fissile components known as pits from dismantled nuclear weapons. In addition, the system can remotely inventory pits in storage and permit higher pit storage densities in facilities while eliminating the requirement for personnel to enter storage facilities for materials handling and inventory. Thus, personnel can avoid exposure to radiation environments within pit storage facilities.

In addition, we conduct joint projects with DoD to examine methods of disposing explosive and energetic components and materials and to examine methods of using robotics for the disassembly and dissection of electronic components. Studies of automated hazardous materials removal systems, robotic disassembly of explosive components, and arms control are also under way. The payoff could be a modern, safe, and cost-effective dismantlement operation at Pantex with possible dual-use applications for US industry.

Studies, Engineering Development, and Technology Demonstrations (GB0103143)

Sandia is engaged in continuous planning activities associated with stewardship of the enduring US nuclear



The project Stage Right automated guided vehicle lifts and stacks storage containers at DOE's Pantex plant.

weapons stockpile. Current strategic objectives include reducing the nuclear danger; maintaining US abilities in deterrence and nonproliferation strategies through research, design, development, and manufacture of nuclear weapons; keeping the stockpile modern, safe, secure, survivable, and ready; and supporting options for new missions.

Changing missions and unprecedented constraints have been imposed by recent events, including reduced emphasis on mutually assured destruction as a deterrent doctrine. Other issues include cessation of underground nuclear testing, changes in the nuclear weapons production complex, and an emerging threat posed by the proliferation of weapons of mass destruction. These issues demand a new approach to stockpile stewardship, to be realized through new and viable design options, new tools, and a program plan for maintenance and modernization.

The DOE Defense Programs laboratories and production plants remain responsible for the design, development, testing, certification, production, maintenance, stockpile surveillance, and retirement of the warheads and ancillary equipment provided to DoD by DOE. In addition, the laboratories and the production plants are responsible for providing the retrofit kits (components and materials) used by DoD to upgrade weapons in the stockpile. Traditionally, these life cycle activities have occurred in seven phases:

- Phase 1 includes the evaluation of new concepts and advances in technology for possible application to nuclear weapons.
- Phase 2 is a technical feasibility study that examines the military requirements and cost-effectiveness of a new weapon system. Phase 2A is a detailed design and cost study for a selected system.
- Phase 3 begins when DoD or DOE decides to proceed with a weapon system. This phase involves the engineering development work for the life cycle of a nuclear weapon, including overall design definition and component development.
- Phase 4 includes production engineering, during which design and manufacturing development are completed and environmentally conscious manufacturing processes are established.
- Phase 5 begins with first production, in which first units are rigorously checked in the laboratory and the field, and ancillary equipment and manuals are completed.
- Phase 6 includes production of the weapon and maintenance of the weapon in the stockpile. Upgrades or modifications may be performed if required. Stockpile evaluation sampling and surveillance continue throughout stockpile life.
- Phase 7 retires the weapon from the stockpile and reclaims nuclear materials and reusable parts.

Sandia is involved in all phases of the life cycle of nuclear weapons; however, the former paradigm of Phase 1 (concept studies) and Phase 2 (feasibility studies) is largely being replaced by less formal taskings that relate to the critical issues associated with the cessation of underground testing, reduced opportunities for nonnuclear testing and stockpile sampling, and the longer service lives now demanded of weapons in the enduring stockpile. Newer taskings primarily address robustness, long life, command and control, and nonproliferation. Surety measures are now a major focus of newer studies.

A number of engineering development projects are under way in direct support of weapons currently in stockpile. The driving forces behind such projects are surety "soft spots," areas where safety or use control should be improved to be consistent with modern safety requirements and evolving adversary threats to weapons; reliability "soft spots," areas where reliability reductions are either identified or anticipated; stockpile changes that require new approaches for ensuring continued support of DOE's stockpile evaluation program; components to support required future limited-life component change-outs; and replacement of use-control equipment that has either reached the end of its life or has vulnerabilities that should be corrected. In each case radiation survivability is designed into changes or modifications and certified in simulator testing as required.

Development engineering for new weapons or improvements to stockpile weapons traditionally occurs in Phase 3. However, no Phase 3 projects are in progress. For the foreseeable future we are planning to support requirements as needed for systems with greatly enhanced surety features. Safety and use control will be dominant themes in our efforts. We are preserving our essential development engineering competencies through internal programs in technology maturation and systems engineering.

For the foreseeable future, technology demonstration programs will focus on providing near-term options to upgrade the surety of the nuclear weapons stockpile. These programs help preserve vital US nuclear competence by coordinating the essential technical capabilities at the laboratories and production agencies. The use of interagency product realization teams is being emphasized to prioritize workloads and responsibilities within the complex and thereby achieve a more cost-effective weapon development process, along with more intensive use of modern quality methods, integrated design and manufacturing techniques, and environmentally conscious materials and processes. Current emphases are on efficient, flexible options with potential for multiple applications, on providing the necessary program direction to exercise the complex realistically, and on meeting the highest achievable standards of surety, reliability, and maintainability.

Enhanced Surety (GB0103144)

Surety includes safety, use control, and security. Several developmental activities under way will enhance surety for the nuclear weapons stockpile and improve capabilities in new weapon developments that may be required in the future.

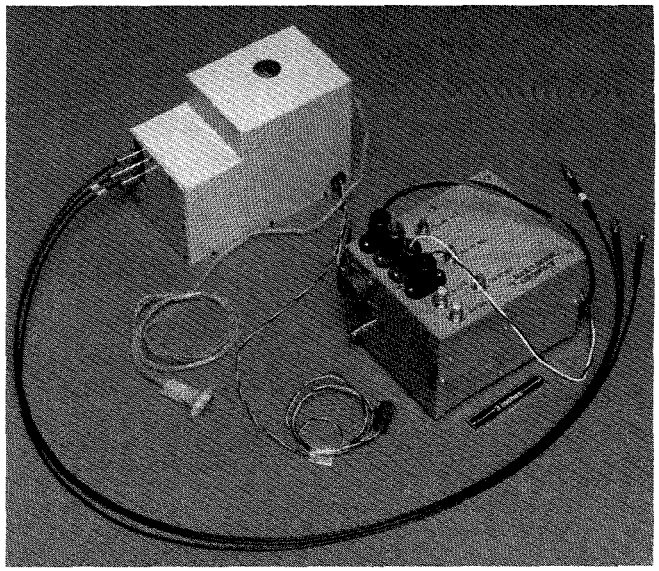
Safety is paramount in warhead development. Safety design provides predictable, safe response at all times, even during and after unpredictable events such as accidents. Safety is achieved through a combination of design features. The nuclear explosive, detonators, and other critical components of a warhead's electrical system are contained in an exclusion region isolated from power sources by physical barriers. The transfer of energy through the barriers for normal operation is controlled by stronglink components to ensure electrical isolation in abnormal environments. Other vital components are designed as weak links that become irreversibly inoperable in accidents at levels well below the projected failure levels for strong links.

Weapon safety is a critical area involving issues raised by the Drell Panel in 1990. These concerns included transportation and handling, the logistics of retirement and dismantlement, and sensitivity to environment, safety, and health. Sandia has begun a major safety technology and engineering program to enhance safety architectures for future nuclear weapons. The long-term goal is to bring new safety technology for warhead designs and components into weapon product lines, provide improved analytical tools for modeling weapon systems response in abnormal environments, and assess probabilistic risk.

Efforts to improve electrical detonation safety are providing the technology to enhance safety in future development programs and stockpile improvement programs. Improvements are focused on safety enhancements and manufacturability. This activity includes the development, demonstration, and evaluation of advanced electrical nuclear detonation safety systems. Improved exclusion-region barriers, weak links, strong links, environmental sensing devices, lightning-arrest connectors, and trajectory-sensing signal generators are being developed.

Significant improvement in nuclear safety will be realized if electrical firing sets can be replaced with optical subsystems in which the high-power signals required to initiate detonators are transmitted as photonic energy carried by optical fibers, rather than as electrical energy. In these systems, the weapon detonators are designed to fire only when proper and sufficient photonic energy is applied. No path to the detonators will exist for electrical energy. The required level of photonic input does not occur in nature and cannot be created by an accident. As part of Sandia's direct optical initiation project, a prototype optical firing system has been developed and used to determine operability in various weapon environments.

In a related area, we have completed exploratory development of laser diode ignition technology, which uses low-power optical signals for controlling and initiating various weapon pyrotechnic functions. By using optical fibers to transmit the ignition stimulus from the laser diode to the energetic material, concerns over electrostatic discharge, electromagnetic susceptibility, and conductance after firing are eliminated.



A Sandia-developed optical firing system that enhances stockpile safety.

An improved detonator safety stronglink under development will reduce potential lightning paths to the detonators, reduce costs, and improve manufacturability. Over the next few years, the design of trajectory-sensing signal generators, advanced solenoid mechanisms, and mechanical weak links will be improved. We anticipate continuous improvement in electrical nuclear detonation safety architectures.

Sandia's probabilistic risk assessment technology development efforts will improve probabilistic risk assessment of nuclear weapons subjected to abnormal environments. The ability to identify vulnerabilities in designs and set priorities in safety technology research and development will be improved by these methods. Over the next few years, an initial methodology suitable for routine use in risk assessment of nuclear weapons subjected to abnormal environments will be completed.

Weapon use-control and physical security are complementary measures contributing to weapon surety. Weapon use-control features and use-control ancillary equipment support the national nuclear command and control system and ensure that nuclear weapons can only be used when authorized by the President of the United States. A number of Sandia projects support DoD and DOE in accordance with the national nuclear command and control system as defined in the 1987 National Security Decision Directive signed by the President. Sandia is the principal laboratory supporting DOE in fulfilling these responsibilities.

Sandia pioneered the development of permissive action links to provide use control. A permissive action link is a coded device within a weapon that protects against terrorists or persons with access authority but without command authority. In the early 1960s, permissive action links were introduced into US nuclear weapons deployed overseas. Sandia continues to advance the design of permissive action link devices and use-control ancillary equipment to provide greater operational capability and flexibility as well as improved use control.

Sandia has developed a permissive-action-link coded switch in support of recode and verification operations with encrypted communications. This device, the code-activated processor, can significantly improve code security for all permissive-action-link operations and significantly enhance operational command and control flexibility for military commanders and national decision authority. A variant of the code-activated processor is intended for weapons with an existing permissive-action-link coded switch. This device, the multiple-code switch encryption translator, can be incorporated into weapons with a field retrofit, resulting in significant savings compared to returning the weapons to the DOE production complex for factory modification. The code-activated processor and multiple-code switch encryption translator cryptographic permissive-action-link devices enable DOE to meet DoD requirements for end-to-end encryption within weapons that contain permissive-action-link use-control.

Modern permissive-action-link coded switches have two components: an electronic component for code storage and processing (such as the code-activated processor and multiple-code switch encryption translator), and an electromechanical output device component. A replacement for the current output device can support surety improvements for existing and new weapons.

Sandia's work on a secure recode system (use-control ancillary equipment) for the Strategic Command supports encrypted recoding of weapons' permissive-action-link devices and meets Air Force requirements for a new secure permissive action link. In addition, an encrypted secure recode system for all nonstrategic weapon recode operations will provide the military with greater permissive-action-link code security and enhanced management flexibility and efficiency for the nuclear weapons stockpile and any future weapons deployments, meeting statements of need from military commanders and high-level studies such as the DoD fail-safe risk reduction study.

The most effective preventive measure against unauthorized use is an active protection system composed of sensors that can detect unauthorized access to weapon components and automatically disable a weapon. The recently completed fail-safe and risk reduction study recommended that weapon use control be improved; therefore, technologies are being developed to support the incorporation of this important capability into a wider range of weapons than was possible in the past.

A plan is being formulated to address nuclear command and control system architectures: first, by characterizing and refining architectural elements to meet present, near-term, and future nuclear command and control requirements; second, by developing and prototyping advanced command and control elements in a nuclear command-and-control test bed; and third, by applying the test bed to develop and demonstrate remote, real-time permissive-action-link recode and remote, real-time inventory and command disablement.

In a broader command and control sense, Sandia provides support directly to DOE headquarters for command and control initiatives. In 1990 DOE published its use-control policy in response to the Nuclear Command and Control System Decision Directive of 1987, which established national policy and government agency requirements. The DOE use-control policy requires a system of integrated positive measures within DOE to prevent unauthorized use of nuclear weapons in DOE custody.

At the request of DOE, Sandia established assessment teams with representation from Los Alamos and Lawrence Livermore national laboratories and DOE management for DOE facilities needing assessments. An assessment was completed in 1992 for operations at the Nevada Test Site. Additional assessments addressed the DOE Albuquerque Operations Office transportation system.

Weapon security protects against unauthorized access to nuclear weapons. Security systems include sensors, alarms, communications, and penalty responses integrated into weapon transportation systems and weapon storage installations. Sandia has the responsibility for developing systems that enhance the security of weapons in DOE custody during transportation, including the replacement for DOE's safe secure trailer, used for transporting weapons and weapon materials. Other areas of emphasis include advanced sensors, alarms, and communications for application to DOE fixed installations or (on a reimbursable basis) to DoD for military installations and deployable site security systems.

Special weapon protection projects at Sandia develop security system concepts and applications to ensure nuclear weapon security and survivability in all phases of the life cycle. In response to near-term changes in the North Atlantic Treaty Organization's nonstrategic forces that may result in the long-term deactivation of some weapon storage and security system installations, a test project was initiated in Germany to determine how weapon storage and security system vaults react to long-term inactivity and to develop technical orders and recommend improved components.

Stockpile Improvement Programs (GB0103145)

Sandia's principal thrusts in stockpile improvement are to support downsizing the nuclear weapon stockpile, ensure the continuing health of weapons remaining in stockpile, identify areas where stockpile surety improvements should

be made, support DOE and DoD in incorporating surety improvements to the stockpile, and, if necessary, support DoD requirements for improved operational capabilities. In support of these thrusts, the objectives of stockpile improvement programs at Sandia are to

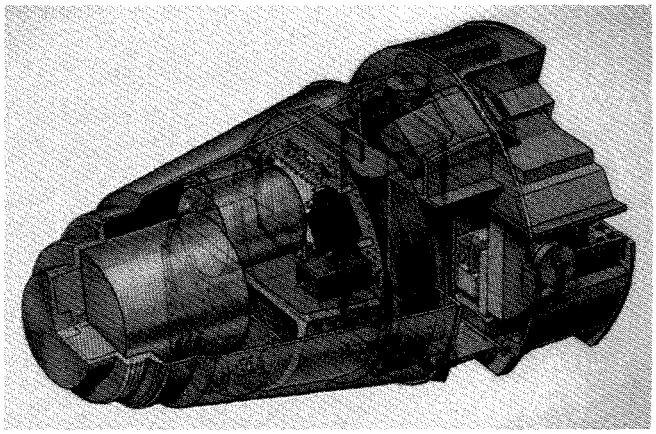
- provide stockpile stewardship leadership in support of DOE and DoD,
- ensure that all programs and projects are customer-oriented,
- ensure that DOE resources are applied to current and anticipated DOE and DoD requirements,
- maintain a credible nuclear weapon stockpile by enhancing surety (safety, security, and control) and operational flexibility,
- support dismantlement of nuclear weapons, and
- maintain within Sandia a viable weapons component development capability (and supporting technologies) to ensure program integrity and to support required improvements of the stockpile.

Nuclear weapons development at Sandia is carried out in close cooperation with Los Alamos and Lawrence Livermore national laboratories, which design the nuclear explosive subsystems. Sandia integrates the nuclear explosive subsystems with many Sandia-designed components to achieve the desired military capabilities and certifies the required radiation hardening of all nonnuclear DOE components in a weapon system.

Sandia works closely with DoD in the critical area of weapon surety. Component manufacture and weapon assembly are performed by other DOE contractors using design definitions furnished by Sandia, Los Alamos, and Lawrence Livermore national laboratories.

Sandia's principal nuclear weapon responsibilities include safing, arming, fuzing, and firing systems; use-control systems; external neutron initiation systems; gas transfer systems; delivery system interfaces; military liaison; stockpile support; and related testing and instrumentation. In addition, Sandia is responsible for ancillary equipment used worldwide by DoD to support nuclear weapon operations in the areas of use control, handling, shipping, storage, and maintenance.

Nuclear weapon development programs may be initiated to correct problems or improve weapons in the stockpile or in the ancillary equipment that supports weapons in the stockpile. New nuclear weapon systems may be developed in response to changing military requirements. Whether for existing weapons or new weapon development, Sandia, Los Alamos, and Lawrence Livermore national laboratories work on behalf of DOE in support of DoD requirements. The laboratories work closely with DoD to understand nuclear weapons requirements and develop solutions. The requirements and needs are the basis for development activities at Sandia.



This MC3810 integrated arming, fuzing, and firing system was developed by Sandia for the Navy's ballistic missiles.

Every year, DOE and DoD review the stockpile surety status. These reviews may result in stockpile improvement programs within DOE and DoD. In addition, needed improvements are identified through the normal exercise of Sandia's stockpile stewardship, which can result in Sandia generating a product change proposal for a weapon in the stockpile. The product change proposal is coordinated with DOE and DoD. If approved, it results in a stockpile improvement program. Stockpile improvements occur as needed to meet military requirements and address surety concerns.

Future Technology (GB0103146)

Nuclear weapons use a large number of electronic, mechanical, and electromechanical products. Each core product has a unique technology or property necessary for its function. These products include explosive components and detonation systems, batteries, electromechanical components, microelectronics and optoelectronic subsystems, neutron generators, switch tubes, reservoirs and valves, radars, and electrical interconnections. Most of these components are unique to weapons applications. Either their function or some significant aspect of their ability to withstand hostile environments or stress is not available in products from commercial sources, and the capability to develop and maintain these unique and essential core products must be retained.

Advanced electronic subsystems provide modern surety features and functional control in nuclear weapons. Use control is provided by miniature electronic locks deep within

weapons and by sophisticated operator-interactive controllers used to manage and enter release codes to unlock weapons after presidential authorization. Trajectory-sensing electromechanical subsystems discriminate between the intended-use environment and abnormal environments and may produce unique signals for driving stronglink switches or otherwise permitting the final arming and firing of a weapon. The firing signals are developed by electronic firing sets. Embedded microcomputers control various weapon components, fuzing, and other functional characteristics. In bombs and some warheads, fuzing may be done by timers or radars developed and manufactured by DOE. Electronic subsystems are used extensively in the evaluation of stockpiled and developmental weapons.

Arming, fuzing, and firing systems use a variety of weapon subsystems such as radars, programmers, firing sets, trajectory sensors, and contact fuses. The requirements for versatility, reliability, and accuracy in a smaller stockpile necessitate continued fuzing advancements. Advanced sensors and hardened guidance and control components will be needed to navigate weapons to mobile targets accurately and to avoid countermeasures. Development will focus on the full spectrum of potential missions in a changing world, with attention to the role of commercial industry and technology transfer opportunities.

Sandia also develops and designs gas boosting systems for many stockpile nuclear weapons. We expect the need for reservoir design and surveillance to persist so long as tritium reservoirs are in the stockpile. Consequently, we will continue to improve our understanding of metallurgy and fabrication for reservoir components, focusing on degradation associated with prolonged tritium exposure.

Recognizing that weapons in the stockpile will experience longer service lives, more work needs to be done on performance criteria for both design and production, particularly in the chemistry and physics associated with the aging of metals and alloys. This work will advance our understanding of the major fabrication processes—metal joining (welding) and forging. This understanding will facilitate the selection of commercial suppliers, reduce reliance on long-term aging tests to certify new vendors, and increase stockpile surety.

The current weapon component development process will be strengthened in two ways. First, applied research and advanced development will focus on technologies critical to meeting weapons program priorities, including surety. Our focus is increasingly on specific critical technologies and system architectures that address multiple nuclear weapon needs. Second, we will strive for greater continuity in the products developed. Product lines will increasingly consist of standardized, modular components, with the goal of more rapid and flexible response to new weapons system needs and reduced weapons development and production costs and risks.

Nonproliferation, Arms Control, and Threat Assessment (GB010316)

Sandia supports DOE Defense Programs with research, development, and analysis for intelligence, proliferation detection, arms control, verification technology, and policy development. Sandia has one of the oldest and largest programs of such work in support of the US national security policy. This work supports our core nuclear weapons research and development responsibility and complements work performed for the Office of Nonproliferation and National Security.

Policy Support (GB0103161)

Sandia's DOE Defense Programs policy support activities are targeted at both sides of the policy-technology interface. We support technical analysis of policy options for the DOE, and we provide national security policy insight to Sandia organizations. In addition, we provide direct support to various negotiations, either in the form of temporary duty personnel or in the form of direct negotiation backstopping at Sandia.

Assessments and Technological Surprise (GB0103162)

Sandia's support for assessments to avoid technological surprise has focused on foreign technology assessment and technology development. In particular, we have devoted resources to the evaluation of weaponization components of foreign nuclear weapon systems as well as studies of various "pathways" that potential proliferants might use to move from nuclear explosive devices to fully weaponized and deliverable nuclear weapon systems.

As the national intelligence boundary has expanded to emphasize information management, Sandia has also responded with programs designed to assist the intelligence community by providing tools and analysis techniques. For example, we provide tools for assimilating and evaluating the wide range of multiple-source information now available, especially information relevant to assessing proliferation of weapons of mass destruction and their associated delivery systems. In addition, evaluations of information surety, a special expertise required by the nuclear weapons program, are increasingly provided to assist the intelligence community.

Although these information management and proliferation-related tasks are of vital importance, this new focus has not supplanted Sandia's traditional intelligence-support mission. We continue to enhance our intelligence collection and exploitation technologies by developing new sensor systems and by evaluating foreign technologies for a variety of customers.

Proliferation Response Technologies (GB0103163)

Sandia is developing technology to assist the proliferation-response community with improved search and searcher training capabilities. This work includes the development of searcher training simulation systems and radiation detection device evaluation algorithms. In addition, advanced concepts for identification, monitoring, and control of high value assets are being developed, prototyped, and demonstrated.

Science and Technology (GB01032)

Activities supported by this category provide the science and technology infrastructure (technical expertise and facilities) needed to support multiple DOE Defense Programs missions, programs, and initiatives. This category emphasizes maintenance and improvement of our understanding of the science of complex nuclear weapon systems. It also advances the technologies necessary for nuclear weapons design, engineering, production, certification, and retirement, including warhead dismantlement and the disposal of hazardous materials. The program sustains core capabilities for all atomic energy defense activities, including those falling outside the direct responsibility of the Assistant Secretary for Defense Programs, such as arms control, nonproliferation, and environmental management.

An important mission element is to facilitate technology transfer to the private sector and otherwise assist US industry with the precompetitive development of commercially promising technologies.

To address broad responsibilities, the Science and Technology Program is subdivided into three general technology categories, each of which is further subdivided into one or more specific focal areas or program elements. The desired levels of capability in these program elements are monitored against the needs and objectives of the research and development activities that use and exercise them. Efforts to augment or enrich program elements directly are made only when programmatic activities within ongoing DOE Defense Programs initiatives are temporarily unable to fully sustain necessary capabilities.

Design and Assessment Science and Technology (GB010322)

This technology category has three focal areas: conceptual design and assessment; physics; and computation and modeling. These areas form the science core of complex nuclear weapons systems and associated subsystems. The work in this program element generates and evaluates new weapons and weapons component concepts. Conceptual design and assessment typically consists of groundbreaking projects in which the new concepts are developed until they are mature enough to be integrated into one of the defense programs initiatives or program elements. Thus, conceptual designs that prove promising for weapons applications (improved capability, reduced life cycle cost, or safety advantages) remain within this program element only through proof-of-concept demonstration. They are then transferred to another program or program element for further work.

The goal of conceptual design and assessment is to explore ideas having the potential to support multiple defense missions, programs, or initiatives. If successful, these ideas will lead to advances in performance, capability, utility, and surety, or to reductions in life cycle costs. Work currently supported by this program includes methods to enhance electrical nuclear detonation safety and innovative concepts that may greatly enhance nuclear safety.

Although hardware development is not typically a major part of this activity, demonstration of concept feasibility is frequently required. The work is often computationally intensive. Current areas of emphasis include enhanced surety, alternatives to hazardous materials, new weapon capabilities, and prevention of technological surprise. Because this focal area looks beyond proven concepts and traditional methods, these capabilities are of critical importance to the Office of Nonproliferation and National Security in the assessment of possible nuclear weapon proliferation in foreign countries.

The physics focal area forms the second part of the core science of complex nuclear weapons systems and associated subsystems. The laws of physics govern virtually every phase of weapon design, engineering, testing, and certification. Physics provides many of the capabilities needed to deal properly with the cessation of underground testing and the curtailment of some types of nonnuclear testing, as well as the capability for predicting the effects of nuclear explosives on military targets and the vulnerability of nuclear weapons to nearby nuclear explosions. Physical principles underlie the design and testing of nuclear weapon systems, many of the unique manufacturing processes for weapon components, and the design of facilities to test these components. These principles also govern the design of complex experiments to test weapons components, validate our understanding of system functions, benchmark the computer codes used to design component subsystems, and assess the safety of weapons components in accident scenarios.

Lastly, the computation and modeling focal area ensures the development and maintenance of computational capabilities that are essential to the design, production, testing, and certification of nuclear weapons. A nuclear weapon is a complex system of many components and subsystems. The actions of these components and subsystems are tightly coupled when the weapon is fired. The structural complexity, function, and interaction

of these components prohibits their efficient design (at any reasonable cost) without the use of extensive computational support. In addition, these systems and components must consistently meet the most demanding requirements for safety and reliability. They must continue to function with high precision throughout a stockpile service life that may last several decades and involve exposure to severe environmental, handling, and transportation stresses.

After a weapon enters the stockpile, opportunities for direct inspection and testing are limited and expensive. Maintaining this extremely high level of product reliability with minimal direct testing and at reasonable cost requires computational modeling at every stage in the design, production, and service life of the weapon.

Computation and modeling are critical to every element of nuclear weapon activities, including

- testing required to assess system performance,
- experimentation to understand the underlying physics,
- correlation of simulations to actual threats,
- design of engineered materials and processes,
- control of intelligent manufacturing equipment and robotics for handling hazardous materials and assembling systems,
- safety assessments, and
- assistance with emergency response.

Computation and modeling are particularly important in several areas. Computational analysis is critical to safety assurance, which ensures that weapons systems in accidents will not fire or release hazardous materials into the environment. In addition, with testing of nuclear weapons suspended, our ability to certify the vulnerability of components to radiation will be even more important than in the past. Computation and modeling are also critical for designing weapon transportation and storage systems and evaluating weapon survivability to nuclear defense measures.

Modeling will be a fundamental tool in agile manufacturing of nonnuclear components in the reconfigured nuclear weapons complex, where production processes will be modeled and integrated through computer-aided design and computer-aided manufacturing to ensure product reliability at low cost and low volume and provide flexible production conditions. Computation and modeling also play a vital role in addressing environmental safety and health concerns. For example, modeling is widely used to determine less hazardous substitute materials and design alternative processes.

Virtually all DOE missions depend heavily on computation and modeling. The Office of Nonproliferation and National Security and the Office of Environmental Management rely on the capabilities maintained by this focal area. In the broadest terms, simulation and modeling of complex systems reduce overall program costs by assisting with risk reduction early in the system life cycle and reducing the need for physical testing.

Systems and Components Science and Technology (GB0103223)

This technology category is subdivided into three focal areas, consisting of systems engineering; electronics, photonics, sensors, and mechanical components; and advanced manufacturing technology development.

Systems engineering assembles and integrates fundamental technologies to create core products and capabilities that anticipate shifting requirements, keep pace with the rapid evolution of technology, and meet the critical systems needs of DOE. It also ensures the maintenance of comprehensive systems engineering and production capabilities that are essential to supporting and integrating multiple research and technology development programs.

Systems engineering emphasizes the integration of multiple technologies, many of which are developed through other programs or through DOE Defense Programs initiatives. While other programs focus on the development of a specific set of technologies to meet a specific set of performance goals, systems engineering has the more comprehensive goal of selecting alternative technologies and integrating them to yield desirable characteristics in broad systemic categories, including manufacturability, affordability, environmental safety and health, dismantlement and disposal, certification, and maintenance of core product capabilities.

An important consideration in selecting activities for systems engineering is the constant need to introduce new or emerging technologies into mainstream design and to regularly update, assure, and modernize the technology of the stockpile. To meet this need, systems engineers examine the work being done in other areas that best support DOE's strategic needs and intent. Promising areas of technological evolution are monitored with particular emphasis on identifying new concepts that have the greatest potential for further development. High priority is then given to developing the enabling technologies to support these promising concepts. Most importantly, systems engineering maintains the design, engineering, and testing infrastructure needed to sustain and enhance the stockpile and to respond to new challenges.

Systems engineering also benefits a number of other defense missions within DOE, including programs for safe and secure transportation of weapons, physical security of weapons and materials, dismantlement, and arms control.

Electronics, photonics, sensors, and mechanical components largely determine the reliability of a system, the

precision of weapon delivery to a target, and the operability of weapons in the potentially severe environments encountered during delivery. Special-purpose electronic components in nuclear weapons include coded switches that prevent unauthorized use, tamper detectors, programmers that control the arming and firing sequence of a weapon, radars, and fuzing and firing sets. These devices must operate reliably over a large temperature range, survive strong mechanical shock, and be fully functional following exposure to the intense ionizing and electromagnetic radiation that can be caused by either the defensive systems at the target or by fratricide. Many of the requirements for devices cannot be met by commercial electronic products. This limitation is also true for many of the mechanical and aerodynamic components that determine the reliability of a weapon after an extended time in stockpile.

Photonics is an emerging technology that uses visible-light energy for functions normally performed by electrical energy. Because of their inherent immunity to electromagnetic interference and their tolerance to the effects of ionizing radiation and intense pulses of electromagnetic radiation, photonic devices offer unique advantages over electronic devices for a wide variety of applications in nuclear weapons. Photonics is the enabling technology in the optical firing set, which is a possible replacement for the traditional electrical system. This firing set offers greatly enhanced safety if a weapon is exposed to severe abnormal environments such as a crash or a direct hit of lightning. It uses a laser and optical fibers to initiate detonators that in turn initiate the nuclear explosion. It also lends itself to unique photonic-based, use-control subsystems that would greatly reduce the threat of unauthorized weapon use.

Sensor research and development in this technology category include radars used to command the firing of a weapon and provide precision terminal guidance, components that detect unauthorized tampering, use-control devices, accelerometers, and chemical sensors to assess the condition of weapons in stockpile.

The technology base in electronics, photonics, sensors, and mechanical components is critical to almost every DOE defense mission, initiative, and program. Satellites that monitor compliance with international arms control agreements require microelectronic devices hardened against the ionizing radiation of space. Application-specific microprocessors and embedded computers are needed by many of the systems to verify treaty compliance and assess activity in foreign countries that may indicate work on weapons of mass destruction. Also, advanced sensors such as chemical microsensors, light detecting and ranging (lidar) systems, and high-performance synthetic aperture radars offer new capabilities for arms control and proliferation assessments. These technologies are also critical for DOE's safeguards and security effort. Chemical sensors and lidar can assess chemical hazards in nuclear waste sites in support of programs of the Office of Environmental Management. Many of these capabilities are of primary importance in the DOE emergency response program. Furthermore, strengths in electronics, microelectronics, and photonics are promoting national technology leadership through technology transfer.

Our efforts in advanced manufacturing technology development will help develop and refine the tools needed to build and implement a more comprehensive, better integrated, "cradle-to-grave" approach to weapons design, production, deployment, dismantlement, and disposal. Much of this work is in direct support of the DOE's Accelerated Strategic Computing initiative and Advanced Design and Production Technology initiative. The ultimate goal of the effort is to either preserve the ability to maintain or rebuild small quantities of weapons very rapidly or to mobilize larger weapons production efforts on command quickly.

Our basic strategy is to integrate minimal specialized internal manufacturing capabilities with selected private-sector industrial partnerships more efficiently to obtain necessary reserve capabilities while minimizing the long-term national burden of sustaining our ability to maintain or build nuclear weapons. Efficient, flexible, and ultimately less expensive design and production capabilities will result from making greater use of evolving computational technologies and capabilities to couple the entire life cycle of the weapon more tightly, with particular emphasis on new approaches to the design, testing, and production phases and processes. Special attention will be paid to those portions of design and process development in which high leverage decisions can be applied to streamline production processes, thereby reducing the costs and risks associated with these processes.

The tactical objectives of these efforts include improving the speed and reducing the cost of the design process, promulgating manufacturability and cost as explicit design criteria, creating comprehensive design and production databases, updating and streamlining DOE manufacturing capabilities, establishing long-term industrial partnerships, enabling rapid small-lot production and environmentally conscious manufacturing, and using life cycle design criteria for cost reduction leverage on eventual dismantlement efforts.

Chemistry and Materials Science and Technology

This technology category focuses on the single broad area of chemistry and materials. Meeting the demanding reliability, safety, and physical security requirements of nuclear weapons requires a diverse range of materials expertise and capabilities, many of which are unique to the nuclear weapons laboratories. Nuclear weapons must operate reliably in the severe environments of strong mechanical shock, intense electromagnetic fields and ionizing radiation, and large temperature excursions. Also, they must not detonate or disperse nuclear materials in accidental exposure to severe abnormal environments such

as fire, mechanical shock, electrical shock and static charge, electromagnetic pulses, or their combinations. In the future, reliability must be certified without underground testing. The activities supported by this technology category are central to meeting these requirements.

We must also maintain the infrastructure needed to assess materials-related deficiencies that are intermittently uncovered in weapons in the stockpile. Such troubleshooting and failure analysis require special expertise and capabilities because of the special nature of many of the components.

Meeting the materials development and analysis requirements for nuclear weapons engineering and stockpile support requires broad strengths in synthesis, processing, materials characterization, theory, modeling, and simulation. This knowledge base must span a wide range of materials, including metals, ceramics, glasses, organics, composites, and semiconductors. Current activities focus on materials and process substitutions to reduce the costs of component production and weapon dismantlement, produce longer-lifetime components that reduce the maintenance requirements for weapons in stockpile, moderate or eliminate sources of harmful effects on the environment, and achieve the highest safety in the workplace. These materials technologies are a cornerstone of the evolving agile product realization process.

The technologies and facilities sustained by this technology category directly benefit many DOE defense projects that fall outside the direct responsibility of the Assistant Secretary for Defense Programs. Projects under the direction of the Office of Environmental Management and projects supporting safeguards and security initiatives are also direct beneficiaries. Both projects have needs for special-purpose materials and processes, and each relies heavily on the materials characterization capabilities sustained by this technology category.

Technology Partnerships (GB0106)

Technology partnerships are a congressionally mandated mission of the DOE national laboratories. These partnerships transfer technologies, skills, and knowledge between the DOE nuclear weapons complex and the private sector. The goal is to make selected nonnuclear technologies available to US private industries in a manner that will help strengthen the core competencies of DOE Defense Programs and enhance the competitiveness of US industry. Partnerships support Sandia's participation in cooperative research and development agreements with individual companies and other cost-shared collaborative projects involving entire industries.

At present, technology partnerships are a separate line item in the DOE budget. Industry participants cooperate with Sandia in six major technology focus areas. Beginning in FY 1997, DOE plans to remove partnership funding as a separate line item. The technology transfer effort will be carried out by specific DOE programs that will need partnerships with private industry. Most of the current DOE Defense Programs Technology Partnerships funding will be focused on the Advanced Design and Production Technology initiative and the Accelerated Strategic Computing initiative.

The Advanced Design and Production Technology initiative will identify, prioritize, and fund development of key advanced product realization technologies, processes, and practices required to maintain an affordable, effective, safe, and reliable nuclear weapons stockpile and to integrate design and process practices for affordable, low-volume delivery of high-reliability products to DOE Defense Programs customers.

The Accelerated Strategic Computing initiative will support stewardship of the enduring stockpile without the benefit of nuclear testing, which will entail shifting from test-based to computational-based methods for stockpile stewardship. An objective is to leverage DOE Defense Programs resources to stimulate the accelerated development of next-generation supercomputers required for defense applications. Applications will focus on nuclear safety, virtual testing and prototyping, materials aging, and production process simulation and control.

Advanced Manufacturing and Precision Engineering

Sandia works closely with DOE production plants during and after weapon development to ensure that designs are manufactured cost-effectively and that products meet design intent.

As a result of this work, Sandia has developed manufacturing capabilities to respond to a variety of national needs. Cooperative research and development agreements in the area of advanced manufacturing and precision engineering focus on manufacturing systems design and development, manufacturing processes, computer-integrated manufacturing, machine tool design, precision measurements, precision engineering, and instrumentation and sensing. Critical industries include aerospace, machine tools and machine tool utilization, and lithography and lithographic equipment for both semiconductor and flat-panel display manufacturing.

Several companies are already working with Sandia on specific projects in these areas. These technology partnerships participants are listed in Table 3-1.

High-Performance Computing and Applications

Sandia's computational science research is aimed at developing massively parallel computing methods and a software infrastructure for parallel computing. Advanced computing technologies will play a critical role in the

future of US national defense and economic security. Cooperative research and development agreements in this area focus on high-performance computing and networking, simulation and modeling, pattern recognition and image analysis, and high-density data storage and transmission. The High-Performance Computing and Applications technology partnerships participants are listed in Table 3-2.

Table 3-1. Technology Partnerships Participants in Advanced Manufacturing and Precision Engineering

Company	Technology
Aluminum Company of America	Precision aluminum forming
Amax Plating, Inc.	Electroplating process control
AMTEX	Demand-activated manufacturing architecture
Beckman Instruments, Inc.	Advanced analytical instrumentation
Corning, Inc.	Flexible manufacturing and molten glass products
General Motors	Simulation and analysis of robotic assembly devices and fixtures
Goodyear Tire & Rubber Company	Advanced mechanics tools for engineering processing analysis
Kaehr Plating & Metal Finishing	Electroplating process control
NCMS	Heat treatment distortion
Precision Fabrics Group, Inc.	Lightweight safety restraint

Table 3-2. Technology Partnerships Participants in High-Performance Computing and Applications

Company	Technology
Amoco Oil Company	Simulation of residual oil hydroprocess units
AT&T	Experimental high-speed network test bed
BIOSYM Technologies	Mathematical libraries for modeling materials
BIOSYM Technologies	Molecular design of polymer alloys
Citibank, N.A.	Advanced information technologies
Cray Research	Massively parallel electron structure research
Fluid Dynamics International	Sandia mesh-generation computer software
Ford Motor Company	Sandia mesh-generation computer software
General Motors	Computer-aided structural system identification
Hewlett-Packard	Properties of visible light-emitting diodes
IBM	Numerical modeling
IBM	Hierarchical high-performance storage system test bed
Intel	Parallel computing C++ mathematical libraries
IRT Corporation	Pattern recognition applied to personnel scanner for contraband
MacNeal-Schwendler	Sandia mesh-generation computer software
nCUBE Corporation	Software tools for scaleable massively parallel databases
Oceania Health Care Systems	Computerized medical patient records
Oracle Corporation	Software tools for scaleable massively parallel databases
PDA Engineering	Sandia mesh-generation computer software
Photonics Imaging	Plasma flat-panel video monitors
Tera/Intel	Next-generation parallel computers
USCAR	Automotive computer technology for design
USCAR	Low-emission research
Weidlinger Corporation	High-performance computing

Energy and Environment

Numerous technologies are mutually beneficial to DOE Defense Programs and the national energy strategy. Cooperative research and development agreements in this area involve environmentally conscious manufacturing technologies that minimize the generation of wastes at the source, systems integration technologies (including life-cycle design, materials recycling, and value-impact assessments), environmental characterizations and monitoring instrumentation, nonintrusive diagnostics and controls, energy conservation, and emission control technologies. The Energy and Environment technology partnerships participants are listed in Table 3-3.

Health Care Technologies

Sandia weapons technologies are being used to address rising US health care costs and their negative effects on US competitiveness. These technologies contribute to reducing health care costs and improving health care delivery. The dual-benefit technologies include biosensors, instrumentation for earlier diagnosis, biomaterials, noninvasive diagnostics, laser therapy, robot-assisted procedures, signal processing of medical images, medical information systems, computational biology, and minimally invasive therapies. The technology partnerships participants in Health Care Technologies are listed in Table 3-4.

Materials and Processes for Manufacturing

The requirement for special materials and fabrication processes for nuclear weapons has produced a need for continuous advancement in this core competency. Cooperative research and development agreements in this area focus on developing new materials and material processing techniques and characterizing and certifying advanced materials. Some projects involve the development of materials and processes used in the manufacture of aircraft engines and the application of DOE Defense Programs joining technology to aerospace and aircraft industry needs. The technology partnerships participants in Materials and Processes for Manufacturing are listed in Table 3-5.

Microelectronics and Photonics

Microelectronics is critical to the development of components for nuclear weapons. Therefore, Sandia researches the fundamental electrical, mechanical, magnetic, and structural properties of electronic materials and explores new techniques for fabricating and selectively altering thin-film layers, surfaces, and surface regions. This research will aid in controlling the properties of microdevices. We also conduct research and development in compound semiconductors such as alloys of gallium arsenide and indium arsenide, materials that will play a greater role in future weapon systems for improved safety and use control.

A competitive domestic microelectronics industry is vital to US national security and to the US economy in the broadest sense. A major concern is the length of time required to translate research developments into manufacturing advantages. Sandia is involved in numerous cooperative research and development agreements with industry to speed up this process. The technology partnerships participants in Microelectronics and Photonics are listed in Table 3-6.

Cost-Shared Collaborations

In addition to cooperative research and development agreements involving individual companies, Sandia's technology partnerships work also supports cost-shared collaborations that involve large segments of specific industries or consortia. Three representative collaborations are discussed below.

Specialty Metals Processing Consortium

The Specialty Metals Processing Consortium conducts research that will improve the technology base for melting processes used in the specialty metals industry. This research will assist the US specialty metals industry and strengthen the nation's industrial base. The program will support Sandia's participation in a joint, five-year program with industry and universities. An interdisciplinary team of Sandia experts, industrial interns, and students will study generic problems of melting processes such as vacuum-arc remelting, electroslag remelting, and electron-beam melting. Developments will be evaluated with industrial experiments at consortium member plants.

FASTCAST™

FASTCAST™ is a Sandia program for rapid production of investment casting prototype hardware. The program is structured to support Sandia organizations that design and fabricate hardware for internal and external customers. The technical goal of the program is to integrate experimental and computational technologies into the investment casting process. The effort should reduce the time required to produce prototypical castings from fourteen to possibly

Table 3-3. Technology Partnerships Participants in Energy and Environment

Company	Technology
Aculight Corporation	Multispectral ultraviolet fluorescence lidar system
Cummins Engine Company	Control of nitrogen oxide emissions
Cummins Engine Company	Pulsed plasma processing of diesel engine exhaust
Electronics Consortium	No-clean soldering processes
General Motors	Reduction of nitrogen oxide emissions
General Motors	Engine fluid condition monitors
General Motors	Automobile combustion systems
Magnetic Separation Systems	Sorting postconsumer waste
Mission Research Corporation	Multispectral ultraviolet fluorescence lidar system
Mobil Research and Development	Large-scale modeling
nCUBE Corporation	Large-scale modeling
RIMtech	Borehole radar imaging technology

Table 3-4. Technology Partnerships Participants in Health Care Technologies

Company	Technology
ARIA Corporation	High-power laser diode systems
Indigo Medical	Biomedical application of high-power lasers
Patient Technology, Inc.	Fluorescent detection of cancer
MicroDexterity Systems, Inc.	Telemicrorobotic applications
Wellman Laboratories	Laser burn diagnostic and debridement system

Table 3-5. Technology Partnerships Participants in Materials and Processes for Manufacturing

Company	Technology
AlliedSignal, Inc.	Joining Si3N4 for advanced turbomachinery applications
Aluminum Company of America	Processing of aluminum alloys
Amoco Chemical Company	Polymeric nonlinear optical materials and devices
Babcock & Wilcox	Advanced materials processing of welded assemblies
Carpenter Technology	Advanced materials for aircraft engine applications
Dow Chemical Company	Processing with chlorinated polyethylene
Dow Corning Corporation	Microengineered materials
Dupont	Diamond reinforced composites
Edison Welding Institute	Arc welding quality control
General Motors	High-temperature electronics
General Motors	Intelligent systems for induction hardening processes
General Motors	Lightweight materials for automotive applications
General Motors	Thermal spray technology for cylinder bore coatings
GeoCenters	Intelligent sensors for composite materials manufacturing
Goodyear Tire & Rubber Company	Materials for improved tire technology
National Center for Manufacturing Sciences	Reduced-lead solders
National Center for Manufacturing Sciences	Wiring board interconnect systems
Norton Company	Large area polycrystalline diamond substrates
Pratt & Whitney	Intelligent processing of thin-section welded assemblies
Pratt & Whitney	Novel laser coating and joining technology
Pratt & Whitney	Welding and processing of an advanced titanium alloy
TN Technologies	Mercuric iodide sensor technology
Xsirius, Inc.	Mercuric iodide sensor technology

Table 3-6. Technology Partnerships Participants in Microelectronics and Photonics

Company	Technology
Advanced Micro Devices, Inc.	New integrated circuit manufacturing
Air Products and Chemicals, Inc.	Advanced diffusion barrier
Alpha Industries	Manufacturing of monolithic microwave memories
Analog Devices	Microelectronics quality reliability
Applied Materials, Inc.	Polysilicon etcher development
AT&T	Noncontact atomic-level interface force microscope
AT&T	Gold-sulfite electroplating
AT&T	Projection x-ray lithography using a laser plasma source
Bristol Myers Squibb	Massively parallel simulation
Coloray Display Corporation	Field emitter array using SXP lithography
Coloray Display Corporation	Gated field emitter arrays
Conductus	Confocal resonator imaging systems for surface assembly
Cray Research	Massively parallel simulation
Digital Instruments	Noncontact atomic-level interface force microscope
Dupont	Massively parallel simulation
Dupont	Tl-based, high-temperature superconductor
EMCORE Corporation	High-throughput rotating-disk reactors
General Motors	Antimonide semiconductors
GCA Tropel	Soft x-ray projection imaging optics
Hewlett-Packard	Advanced manufacturing techniques for optoelectronics
Hewlett-Packard	Field emission source with phosphor screen
Hewlett-Packard	Wafer-level accelerated reliability testing software
Intel	Advanced diffusion barrier technology
J. W. Harley	Fiber-optic hydrogen sensing
LAM Research Corporation	Advanced intermetal dielectric technology
Micrion	Integrated circuit failure analysis
Micro & Computer Technology	Field-emission flat-panel display
Motorola	Compound semiconductor heterostructures and materials
Motorola	Advanced precursors and chemistries
Motorola	Thin-film diamond growth
Motorola	Organic luminescence
Motorola	Advanced SiGeC materials
Olin-Hunt Specialty Products, Inc.	Evaluation of electromigration tolerance in CCVD aluminum
Philips Semiconductor Company	Investigation assessment and benchmarking
Photonics Imaging	Plasma panel materials
Radiant Technologies	Ferroelectric read/write optical disc
Radiant Technologies	Nondestructive readout nonvolatile memories
Schumacher, Inc.	Chemical vapor deposition of copper
Schumacher, Inc.	Advanced diffusion barrier technology
SEMATECH	Semiconductor Equipment Technology Center, for contamination-free manufacturing research, equipment, and process development
Thunder Scientific	Fabrication of porous silicon humidity sensors
Triquint	SQWFET/MODFET process development
University of New Mexico	Noncontact atomic level interface force microscope
University of New Mexico	Fabrication of microreactors in silicon

three weeks. The work will develop the experimental rules to design gating systems, integrate those rules into a database, verify computer models to predict casting processes, and develop a database of materials properties related to investment casting.

Sandia capabilities in investment casting include an airfoil-quality ceramics laboratory for mold preparation, a rapid prototyping laboratory for wax pattern production, a vacuum foundry, extensive diagnostic and computational capabilities, and state-of-the-art materials research facilities. Over the past three years, Sandia has integrated these technologies into a comprehensive base to support investment casting process research.

Semiconductor Equipment Technology Center

Sandia's semiconductor equipment technology center applies research in reliability modeling and process technology to the development of new integrated circuit production equipment by US manufacturers. This microelectronics technology and benchmarking project will strengthen the infrastructure of the semiconductor manufacturing industry. The work is conducted in collaboration with SEMATECH, a consortium involving the federal government and major US semiconductor manufacturers.

Industrial Partnering with the Newly Independent States (GB0107)

Cooperation with Russia and other newly independent states of the former Soviet Union has been encouraged by US policy. Sandia is supporting the safe and secure dismantlement of Russian nuclear weapons and other projects for nonproliferation of weapons of mass destruction.

Collaboration with Russian weapons institutes and other entities in the former Soviet Union is allowing us to gather and develop unique technologies for our programs and technology partnerships. This is consistent with the national goal of providing weapon scientists and engineers of the former Soviet Union with opportunities to redirect their talents toward peaceful activities. Collaborations have been initiated in environmental, computational, and materials sciences; pulsed power; space power systems testing and development; specialty metals research and development; shock-wave physics research and testing; materials protection, control, and accountability; and surety technology. We also continue to explore collaborations in the research, development, and testing of reactor-driven lasers, nuclear propulsion, and nuclear power safety techniques and technologies.

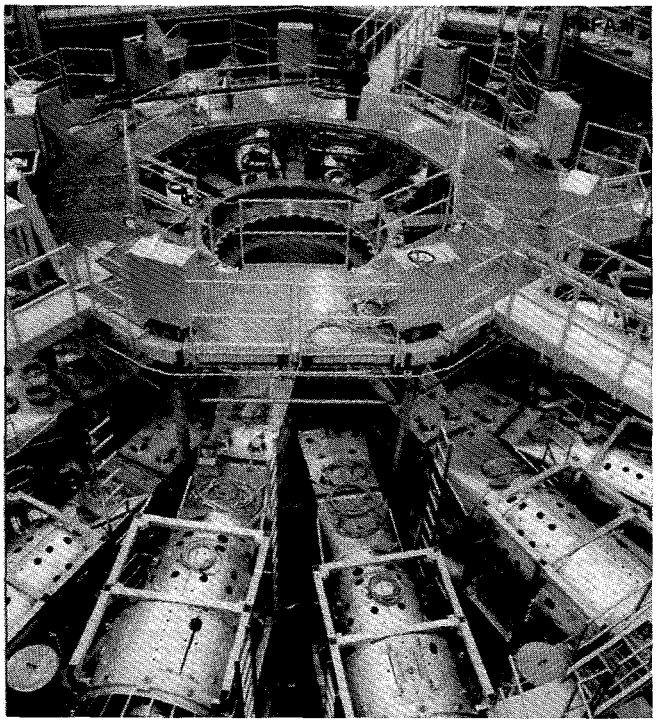
Most collaborations have been initiated since the breakup of the former Soviet Union, when new US policies encouraged cooperation with the newly independent states to support democracy and shift the governmental focus from the military to the civilian economy. As we continue our interactions with entities in the former Soviet Union, we will identify new areas of joint interest in science and technology and our collaborative efforts to exploit these new areas for mutual benefit will grow.

Stockpile Stewardship (GB0108)

Sandia is the lead DOE laboratory for aboveground test simulation of radiation effects and certification of nuclear weapons to operate reliably in hostile radiation environments. We integrate experimentation and computational simulation efforts in support of radiation effects testing, radiation transport, diagnostics, analysis, and computation development to certify that electronic components will operate in hostile radiation environments. As a consequence of recent test program budget cuts, support of the core capabilities at the Nevada Test Site has necessarily been reduced. These reduced capabilities maintain nuclear testing safeguards consistent with DOE directives and the continuation of the testing moratorium. Sandia will support Los Alamos and Lawrence Livermore national laboratories hydrodynamic experiments and will maintain the capability to resume underground nuclear testing as required by presidential directive. Looking to the future, Sandia is consciously shifting resources from underground nuclear testing to aboveground simulation. If a comprehensive test-ban treaty is signed, Sandia's aboveground capability will be the strong link in ensuring that the enduring stockpile remains survivable. As such, every effort is being made to enhance the aboveground testing program, maintain our radiation effects science expertise, and collaborate with the key DoD agency (the Defense Nuclear Agency) that has similar mission requirements.

Sandia's radiation effects testing program certifies that weapon components and subsystems will function reliably in the hostile nuclear burst environments that may be encountered in any specified stockpile-to-target sequence. These threats include the nuclear radiation outputs of x-rays, gamma-rays, and neutrons. Formerly, we employed a combination of aboveground testing, analysis, and underground testing for this development and certification process. Although a recent presidential directive extends the moratorium on underground nuclear testing, any stockpile improvement program hardware, including upgrades in safety and reliability, will need to be certified to operate in hostile radiation environments. Moreover, single-mode failures must be avoided in the much smaller stockpile of the future.

Sandia's radiation facilities and effects science expertise are recognized national resources for high-fidelity simulation and understanding of nuclear weapon effects. Our aboveground experimental facilities, the



Sandia's Saturn pulsed-power accelerator.

Saturn and High-Energy Radiation Megavolt Electron Source (HERMES) III accelerators and the Sandia Pulse Reactor-III (SPR-III) and Annular Core Research reactors, are primarily used to simulate x-ray, gamma-ray, and neutron environments. The Saturn and HERMES III accelerators are pulsed power machines that generate low- or high-voltage bremsstrahlung radiation, electron beams, or radiation from plasma sources and are used to simulate the x-ray and gamma-ray portion of typical nuclear weapon threats. We typically test strategic reentry vehicles, missile and satellite components, and subsystems or tactical subsystems and systems in these simulated x-ray and gamma-ray environments.

The Annular Core Research Reactor is a pool-type reactor with an annular-shaped core formed around the dry, central irradiation cavity. The neutron spectrum and pulse time profile of the reactor are representative of most endoatmospheric engagements. The reactor is also used to simulate high-level gamma environments. It is the only facility in the United States capable of properly simulating the total dose received in a fireball fly-through. It is now being converted to produce medical isotopes; however, the capability to support defense programs will be retained if we are directed to do so. The SPR-III fast pulse reactor is an unmoderated cylindrical assembly of fully enriched uranium alloyed with 10 percent molybdenum. These are major, unique aboveground experimental facilities used to certify the hardness of the stockpile to radiation effects.

We are not yet positioned to certify future or reconfigured strategic systems without underground tests. In 1991 we began a program in cooperation with the Defense Nuclear Agency to assess our ability to correlate aboveground and underground test results for electronic systems and extrapolate them to realistic hostile environments. The goal of this work is to develop a test protocol for certifying nuclear survivability without underground testing. To reach this goal, we will need to improve our aboveground testing capabilities, including rise time, pulse width, and fluence improvements in Saturn and HERMES III, and build a new x-ray simulation facility to cover testing that now can only be conducted underground. This new Jupiter Pulsed Power Facility will be a cold and warm x-ray source that permits testing the radiation response of materials and structures currently possible only with underground testing.

The Jupiter x-ray simulation facility will generate 20 megajoules of x-rays using a plasma radiation source. This radiation source will be controlled to provide excellent testing capability with photons of 8 kiloelectronvolts and below, and good capability at 14 kiloelectronvolts. It will also have weapons physics research applications, provide x-ray physics testing with 5 to 20 megajoules of thermal x-rays, and provide the next reasonable, developmental step for providing an x-ray source capable of testing a large system in an x-ray environment. Materials survivability testing in hostile x-ray environments is an area that has only been approached in an underground test. Jupiter is a key to future testing of materials in x-ray environments under a test moratorium.

Even with the improvements in our aboveground testing capabilities, testing for thermonuclear weapons effects in full reentry vehicle or reentry body structures could not be accomplished without underground testing. However, by enhancing our aboveground testing capabilities and constructing the Jupiter Pulsed Power Facility, we think we can certify weapon subsystems without underground testing.

Sandia maintains core underground testing capabilities to support both vertical weapons safety and reliability tests and the DoD-sponsored horizontal-line-of-sight weapon effects tests to ensure reliability. Because the testing moratorium may continue indefinitely, these core capabilities are being maintained to support the nuclear testing safeguards sanctioned by Congress. These safeguards require that DOE maintain the scientific resources and technical capabilities to resume underground tests if directed. To enhance this effort, Sandia has joined with Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and the Defense Nuclear Agency to form the Joint Test Organization at the Nevada Test Site. The members of the Joint Test Organization share resources and focus on planning, managing, and executing a cooperative program at the Nevada Test Site. The intent is to maintain a state of readiness consistent with nuclear testing safeguard

requirements to support hydrodynamic experiments and resume underground nuclear testing as required by presidential directive.

The principal Sandia core capabilities supporting the Nevada Test Site are in the arming and firing systems used in every test. These systems for DOE safety or reliability tests, including complex multiples, are provided and fielded by Sandia. Additionally, the arming and firing systems for DoD-sponsored reliability tests, including integration with the closure systems and experimenter firing and timing requirements, are also provided and fielded by Sandia. In each case, a detailed inventory of the required electronics, power supplies, supporting hardware, and limited-life components is maintained to ensure that all planned tests are fully supported and may be executed without delay.

The core capability to design, fabricate, and field closures for DoD-sponsored tests is now being jointly supported by the Defense Nuclear Agency and Sandia. This capability is critical both to protect the effects experiments on a test and to ensure that containment is successful.

The core capability for ground motion measurements and seismic measurements on all DOE and Joint Test Organization tests is maintained by Sandia. Additionally, the Defense Nuclear Agency and Sandia jointly support containment diagnostics, developed and fielded by Sandia, for Defense Nuclear Agency weapon effects tests involving horizontal-line-of-sight pipe-flow measurements, stemming response, fast closure performance, ground shock, air blast, cratering, and free-field ground shock measurements.

The instrumentation group rounds out the core capabilities at the Nevada Test Site that are critical to underground testing. The Sandia Data Acquisition System and supporting personnel are key to ensuring the execution of Joint Test Organization activities or the success of Defense Nuclear Agency-sponsored effects tests. We are implementing a nuclear effects safeguards program to make repairs and improvements that can enhance quality, maximize efficiencies, and improve system performance while minimizing the impact on cost, personnel, or schedule.

The aboveground and underground testing capabilities at Sandia are utilized extensively to design hardness and survivability into every nuclear weapons system in the stockpile. Once the systems are in the stockpile, they are subject to a detailed surveillance program that has historically identified a number of new problems to be corrected each year. When the corrective action requires replacement of a component within a system, then that component is certified to the integrated hardness level required for the system, primarily using Sandia's aboveground capabilities.

In the future, with a significantly smaller stockpile, the survivability of each system will be even more critical. Therefore, maintenance actions will be dependent on the aboveground testing capabilities at Sandia to ensure that the stockpile remains hard and survivable.

Additionally, a stockpile confidence program being considered includes periodic verification of the certified radiation hardness of stockpiled systems. Such a program was sponsored for earlier systems (the Mark 3 and Mark 4) and ensured that they would operate as required. Knowing that the stockpile lifespan of many existing weapon systems will be much greater than the current average lifespan places additional responsibility on surveillance to ensure that no "surprises" exist that are undetectable with current nonradiation testing.

Sandia initiated the Sandia Test Information Preservation Program in FY 1994 to address the proper archival of underground nuclear effects test data and information. The project goal is to create a nuclear weapons effects library system containing Sandia information (documents, data, images, and materials samples) that can be of great importance for above- and underground testing data correlation and the future understanding of stockpile problems. This effort is intensive because Sandia has participated in more than seventy radiation effects tests; if seismic/ground motion data are considered, data from hundreds of tests must be preserved.

Inertial Confinement Fusion (GB02)

DOE funding has provided the principal pulsed-power technology and facilities for our exploration of inertial fusion as a future x-ray source for nuclear weapon effects testing, weapon physics studies (in collaboration with Los Alamos and Lawrence Livermore national laboratories), and fusion power production.

The low cost and high efficiency of the pulsed-power approach to inertial fusion have permitted unique megajoule-class facilities to be constructed and used for inertial confinement fusion research. The Particle Beam Fusion Accelerator I and Proto II facilities have fulfilled their original research purposes and have been converted into major national facilities for nuclear weapon effects simulation, x-ray atomic physics research, radiation flow research, and survivability testing.

Pulsed power is an integrated capability of Sandia. Applications contribute to national security today as we develop the pulsed-power-driven light ion approach to inertial confinement fusion for even greater utility. The lower cost per unit of energy of light ion beams (compared to lasers) offers potential savings for the Sandia microfusion facility, a future aboveground testing facility that will provide a thermonuclear yield exceeding 500 million joules. The fundamentally different x-ray production mechanism with light ions provides prudent risk management of potentially severe laser/plasma interactions in the hohlraum for the laser approach to inertial confinement fusion.

Our responsibilities include technical direction of all DOE-funded activities for light ion inertial confinement fusion. Sandia directs light ion efforts in accelerator develop-

ment, intense ion beam generation and transport, beam focusing, beam-target interaction, radiation production and symmetrization, and target hydrodynamics.

Sandia's Particle Beam Fusion Accelerator II, the world's most powerful particle accelerator, is being used for ion-beam-driven target experiments. Both the Particle Beam Fusion Accelerator II and the Sandia accelerator and beam research experiment enable us to develop beam generation and transport techniques in the geometry needed for high yield. This work is determining the feasibility and cost-effectiveness of the light ion approach for the laboratory microfusion facility.

Recent experiments give us confidence that a 500-megajoule laboratory source of thermonuclear radiation may be obtainable through inertial confinement fusion if progress in three major areas can be developed and integrated further.

Intense proton-beam generation and focusing in the Particle Beam Fusion Accelerator II were advanced in FY 1989 with the achievement of a power density of 5 trillion watts per square centimeter. In FY 1993 the lithium beam power intensity was improved from 0.1 to 1.4 trillion watts per square centimeter.

Ultimately, high-yield experiments will require that the pulsed power components, the beam generation apparatus, and the target chamber wall be separated from the target by several meters. Propagating ion beams over these distances will require improvement in beam divergence from 20 milliradians to as low as 6 milliradians and demonstration of stable transport in low pressure gases.

The near-term goal of the program is to establish the feasibility of inertial confinement fusion using ion beams produced directly from a pulsed-power generator. This goal will be approached through target and beam experiments in Sandia's Particle Beam Fusion Accelerator II and the Sandia accelerator and beam research experiment with supporting experiments at Cornell University and the Naval Research Laboratory. In addition, we will use the best available facilities to develop the target database required to design a credible high-yield target. These facilities include the Particle Beam Fusion Accelerator II and the Sandia accelerator and beam research experiment for ion/materials interaction studies, Saturn for radiation flow and "foot physics" studies, and the Nova laser at Lawrence Livermore National Laboratory for internal pulse shaping experiments at high hohlraum temperatures.

In the interim, we will continue to collaborate with other DOE laboratories to develop the core science and technology required for the national ignition facility and equip the laboratory with a glass-laser driver. Sandia's contributions to the conceptual design included pulsed-power conditioning, design of the target chamber, development and integration of radiation-hardened target diagnostics, and work on internally pulse-shaped targets for ignition and gain.

The long-term goal of the program is to provide the driver for a laboratory microfusion facility for the weapon physics and weapon effects aspects of stockpile stewardship. Ultimately, the low cost and high efficiency of the pulsed-power approach may provide fusion power generation for electricity.

Stockpile Management and Support (GB03)

As it has for the past four decades, the US nuclear weapons stockpile continues to respond to changes in global security. For the foreseeable future, new weapons are not expected to be introduced into the stockpile. The stockpile is being reduced, and some types of stockpiled weapons are being eliminated. These modifications will result in a significantly smaller stockpile with greater surety, reliability, and longevity requirements. In this context, stockpile support involves three broad activities. First, the weapons remaining in the enduring stockpile must be properly maintained to ensure the continuing credibility of the deterrent. Second, weapons in excess of national nuclear deterrent requirements must be dismantled and disposed. Third, the enduring stockpile must be constantly monitored and evaluated to ensure that all aspects of safety, security, and use-control are addressed responsibly.

Stockpile support at Sandia focuses on understanding, maintaining, updating, and improving the safety, security, performance, and reliability of the nuclear weapon stockpile. Our efforts entail stockpile maintenance, dismantlement and disposal, and stockpile evaluation. Success across all fronts requires a sound investment strategy that preserves the foundation of nuclear design and manufacturing capability.

Stockpile Maintenance (GB031002)

The public's expectations for safety, security, survivability, reliability, and environmental protection in all phases of nuclear weapon stockpile management continue to evolve. Supporting this evolving stockpile in an era of declining budgets demands that Sandia be both innovative and efficient.

Weapons will probably remain in the stockpile well beyond their original design lives. Weapon delivery systems will evolve in response to technology advancement, budgetary constraints, obsolescence, or treaty actions. These changes will necessitate continuous assessment of the surety, military effectiveness, delivery system compatibility, and longevity of the stockpile, all of which will be accompanied by programs that evaluate and implement value-adding improvements.

Recent reductions and changes in our strategic nuclear forces have dictated changes to the intercontinental ballistic missile force structure that may extend to 2003. By then the force will be configured entirely with Minuteman III missiles loaded with single warheads. During the interim, several warheads need to be qualified for the new environments

associated with single reentry vehicle loads on the Minuteman III missile. Similar restructuring is scheduled for submarine-launched ballistic missiles, air-delivered strategic weapons, forward-deployed weapons, and naval fleet weapons. This redeployment requires alterations to reduce maintenance and special initiatives to provide an adequate quantity of interim storage containers.

Concurrently, some limited-life components will be replaced to extend the interval between changes. Product improvements to maintain surety, reliability, and longevity will be the principal activity for the foreseeable future, as exemplified by the recent efforts to replace radars and trajectory-sensing signal devices in several nuclear bombs.

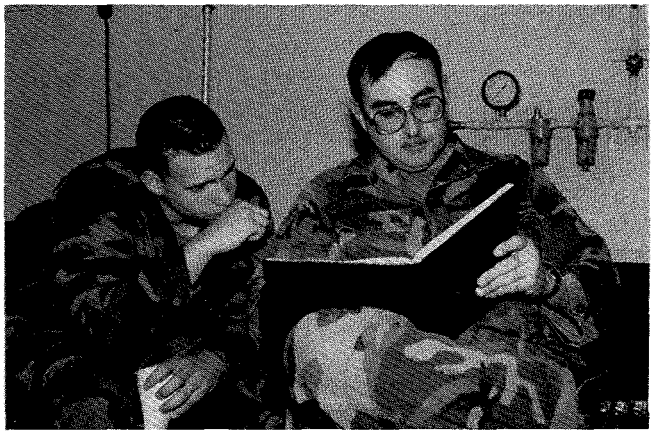
In the area of military liaison, the surety and effectiveness of the nuclear stockpile remain crucial to US national security. Support of the stockpile must also be compatible with the changing infrastructure of the military services. Base closures and consolidations and the overall reduction of service personnel will have significant impact on the military services' capability to maintain the stockpile and implement improvements. Our maintenance and improvement programs must remain compatible with the services' capabilities.

Part of Sandia's mission is to serve as the DOE focal point for integrating military operational needs and surety requirements. In maintaining stockpile integrity, we provide a broad range of support services to ensure that the stockpile remains safe, secure, and reliable. Sandia is the recognized leader of operations, maintenance, and logistics for nuclear weapons from concept through dismantlement. We provide stockpile support through classroom and field training in weapons handling for DOE, DoD, and Sandia personnel. Training classes are provided for DoD weapons instructors, operational staff, and maintenance technicians. Weapons refresher training is also provided to DOE and other DoD personnel. We maintain a staff of trained instructors and modern training facilities for this purpose.

Sandia writes and distributes more than two hundred technical manuals for DoD on how to use, maintain, inspect, and transport nuclear weapons. By using a new publications system that complies with the requirements of the DoD computer-aided acquisition and logistics support system, we reduce costs while improving the timeliness and quality of our technical publications. We also produce video presentations to aid instructors in weapons maintenance, special repair procedures, and permissive-action-link operations. Sandia's military liaison group also represents DOE on the joint nuclear weapons publications system council.

New deployment postures require more attention to the stockpile. Limited-life components are now being exchanged in the field using new equipment and procedures that improve reliability and safety.

Stockpile maintenance also requires the capability to build or rebuild replacement components for the enduring stockpile. Our manufacturing development engineering concept focuses on working directly with commercial vendors



Sandia writes technical manuals and provides classroom and field training for military personnel.

to develop and manufacture nonnuclear weapon components in the private sector. This concept requires high-level interaction between our weapons engineering personnel and private industry and includes the tasks of identifying and developing private sector suppliers, transferring technology, and maintaining an involvement with process design and manufacturing engineering. Manufacturing development engineering will provide a number of advantages to DOE in the anticipated very low volume production environment of the future nuclear weapons complex.

By relying on private industry for the production of weapon components, the nuclear weapons complex will require less overall production capability. Thus, the maintenance cost of manufacturing development engineering technologies will be reduced. Components manufactured using high-volume, standard industrial processes will also be more cost-effective and better characterized than components manufactured using low-volume, custom processes. Thus, the strategic objectives of the manufacturing development engineering program are to

- develop an infrastructure that will demonstrate Sandia's ability to directly produce certain specialized nuclear weapon components, such as neutron generators;
- increase our design engineers' general understanding of manufacturing issues and industry standards, products, and processing;
- move Sandia toward concurrent engineering and agile manufacturing; and
- facilitate the reconfiguration of the nuclear weapons complex by transferring appropriate activities formerly performed at the Mound and Pinellas facilities to private industry.

Sandia's stewardship also reflects increased concern for the environment. Procedures have been revised to eliminate hazardous materials, and better containers are being designed for transporting components that contain radioactive materials. Our goal is to make the maintenance of the stockpile as safe as possible for both personnel and the environment.

Our environmentally conscious manufacturing program is reducing the environmental impacts of manufacturing activities without reducing the quality or performance of the product. We will continuously develop the materials and processes used in the fabrication of weapon components to minimize their impact on the environment.

Environmentally conscious manufacturing focuses directly on manufacturing activities, as opposed to cleanup and restoration. Even though remediation technologies are essential for correcting past mistakes, reliance on end-of-pipe solutions will not be the basis for future manufacturing decisions. Any attempt to remove an environmental threat after its creation is almost certain to be less effective than avoiding that threat from the beginning.

For the foreseeable future, Sandia's environmentally conscious manufacturing efforts relative to weapon component production will be directed toward the specific needs of the enduring stockpile; however, a major benefit of Sandia's environmentally conscious manufacturing will be materials and processes that can be applied to domestic commercial enterprises. Maintaining a robust domestic economy with substantially less waste and resource consumption will be one of the greatest challenges of the next century. Sandia's unique blend of manufacturing and environmental experience is well suited to addressing this challenge.

The need for accurate, complete, and up-to-date engineering information is also fundamental to all our efforts in stockpile maintenance. Our objective in collecting, assembling, and maintaining engineering information merges existing and anticipated stockpile support requirements with practical and cost-effective information technology in a systems approach to meeting the need for such information. This mission is challenged by a reduced stockpile and very limited new build opportunities. We will modernize information systems; downsize to more cost-effective platforms; and align with industrial, national, and international standards. The goal of our information management efforts is thus to establish a state-of-the-technology stockpile analysis and maintenance capability built on standard hardware and software products and with reduced access times and operational costs. Conformance to industry standards will ensure that solutions adopted today will match the options of tomorrow.

Our engineering information support strategies are based on multifunctional teams that link information specialists and computer scientists with the weapon engineers who actually use the product. Agility and economies of scope will allow the teams to apply their expertise to a heterogeneous computing environment in which data are managed, stored, and distributed on a network immediately accessible from engineers' desktops. An evaluation of the processes of creating and sharing data will result in solutions consistent with established operating plans. Our commitment to concept-to-product systems will eliminate the need to input information repeatedly and will permit data sharing among multidisciplinary design and manufacturing teams.

Numerous initiatives are under way for the engineering information systems. Tools for mechanical design were identified by the ACCORD project selection, which rests on a tightly integrated solid-modeling foundation. This approach uses the concepts of rapid prototyping and early product visualization to contain costs in the development stage. The NIRVANA project tools for electrical design and fabrication provide the necessary flexibility and infrastructure. Record-of-assembly and product test databases will migrate from mainframe systems to smaller, less expensive, and more easily maintained workstations. Engineering information created at both Sandia sites will be stored electronically at a single location that allows managed access from both sites.

An electronic configuration management system is being developed to monitor and control design changes. Native electronic files and scanned images will be placed in an optical disc storage system for off-line storage and recall of electronic drawings, documents, and models to engineering workstations. The trend is from a secure computing network to restricted and open environments that will facilitate concurrent engineering with outside agencies throughout the product development cycle.

An accurate and complete understanding of the materials and components used in weapons must be developed and maintained about the stockpile. The continuous analysis and modeling of materials, semiconductors, printed circuit boards, and all other components and their production processes are essential for the enduring stockpile. We work closely with the nuclear weapon production agencies and, as a result, the resources and expertise we maintain are being fully utilized in the reconfiguration of the production complex.

Sandia has traditionally provided a rapid response to material and process issues detected within the production cycle or discovered during stockpile surveillance. There will be more demanding needs in the future to develop and maintain a capability to produce prototypes and limited quantities of war-reserve semiconductors, neutron generators, batteries, and switch tubes. Associated with this maintenance of capability will be strong efforts to develop advanced, agile investment casting processes that will be used within the streamlined production complex and shared with US industry.

Semiconductor efforts maintain a very strong analytical modeling capability (for radiation behavior, tolerance, design, and fabrication), preserve and improve an experimental failure analysis capability, and maintain and improve a technology base that can be applied to reliability and semiconductor life expectancy predictions. In the future, we expect that weapon systems will have

much longer service lives. In addition, there will be strong interaction with semiconductor manufacturers to assist in the privatization effort. The ability to evaluate radiation hardness experimentally is another capability that needs to be preserved. In addition, a significant effort continues to qualify new materials and processes for printed circuits, hybrids, and encapsulants for future applications.

Further development of the rapid production of investment casting prototype hardware will provide a concurrent design and manufacturing platform for the production of electronics housings. Sandia's accomplishments in developing the system architecture, the thermal code, and a complete integration into an agile manufacturing platform are well recognized by industry.

Sandia provides technical support to DOE to develop and maintain readiness to respond to accidents involving nuclear weapons, and participates in the readiness mission of the DOE Accident Response Group. In the event of an accident, Sandia supplies experts in nuclear weapons, nuclear weapons safety, and health physics, all specially trained to support field efforts for the safe recovery of damaged nuclear weapons. In support of the Accident Response Group, Sandia develops training materials, provides training, develops field equipment for use in weapons recovery, provides systems program planning, plans and implements field exercises, and assists in nuclear safety evaluation of specialized equipment and procedures. With guidance from the DOE Albuquerque Operations Office, the Accident Response Capability Coordinating Committee, and subgroups, Sandia also provides necessary specialty equipment.

In association with our support to the Accident Response Group, we are developing systems using proven modern methodologies and technologies to provide greater operational flexibility, safety, training, and exercises that are comprehensive and cost-efficient. One near-term example is the portable integrated video system, which provides two-way video camera viewing and recording from a command post up to four kilometers away. Longer-term activity will incorporate this technology into an interactive multimedia training system. This will allow visual simulation of weapon accident scenarios that incorporate multiple recovery activities and allow simulation training for all personnel. A new system will improve DOE's packaging containers used to ship a damaged nuclear weapon to a final disposal site. In addition, remotely controlled robotics technology is being adapted to reduce recovery operations hazards to personnel.

Because of our stewardship of the nuclear weapons stockpile, it is important that we also maintain test facilities critical to the evaluation of nuclear weapon power sources and neutron generators. As required by new safety mandates or because of obsolescence, tester hardware and software modifications will continue as long as a nuclear weapons stockpile exists.



Sandia supports the DOE Accident Response Group with field exercises like this simulated accident scenario involving a safe secure trailer. Sandia provides specially trained experts, develops field equipment, and plans and implements field exercises.

Dismantlement and Disposal (GB031003)

Under the terms of the Strategic Arms Reduction Treaty I (START I) and eventually under START II, the United States will dismantle more than ten thousand nuclear weapons. Because of the backlog of weapons and the full pipeline of returns, the DOE's Pantex plant in Amarillo, Texas will continue to dismantle well over a thousand weapons per year until the 1997-1998 time frame, when the requirement will drop to a few hundred per year to meet ongoing DoD retirements. Our limited national capacity to dismantle nuclear weapons means that some weapons with older, limited surety features will remain assembled for many years. These weapons require full oversight to maximize safety and surety from the time they are designated for retirement until their constituent components are disposed.

In the past, the volume of weapon retirements was generally low enough that disassembly operations were performed as a work filler between assembly operations. The accelerated stockpile reduction and the nation's increased concern for the environment require that Sandia's broad technological base and systems integration expertise be used to assist DOE in downsizing the stockpile. For many operations, the development of new dismantlement processes is essential to meet the immediate work load schedule and to provide a way of supporting future operations.

Dismantlement begins when the military designates a weapon for retirement and ends when DOE has disposed of the weapon components, handling equipment, and associated hardware. This procedure includes transportation, storage, and disassembly into subsystems and components that are recycled, staged for reuse, evaluated for information about the enduring stockpile, or prepared for disposal.

Sandia works closely with the DOE's Pantex plant to design safe and efficient processes for all phases of the effort. Automated processes using robotics and computer modeling are being developed to handle the increased dismantlement volume safely and cost effectively. Sandia system analysts are helping to automate dismantlement by scheduling the return and staging of retiring weapons, analyzing the processes for security and safeguards, prioritizing retirement and disassembly, and providing risk assessment management. Engineers are developing computer models to improve the transportation and staging of weapons.

Robotics is being used to mitigate personnel hazards, particularly those associated with radioactive materials. Sandia and Pantex are developing a system called Stage Right that uses remotely controlled forklifts to load, unload, and inventory pits in storage containers for magazines at Pantex. The Secretary of Energy has approved the use of a new storage configuration (multiple horizontal layers versus a single vertical layer) and thirteen additional magazines to increase the pit storage capacity from about six thousand to twelve thousand. Plans are in place to use robots for cleaning, leak checking, and weighing nuclear weapon parts. The feasibility of using robotics systems for disassembly of explosives and radioactive parts and for the separation of materials for disposal is being studied.

Concern for the environment introduces new challenges in the disposal of materials. Limited understanding of the materials in some older weapons will limit our capability to dispose of the components that make up those weapons. For example, new federal and local regulations require that certain materials scheduled for disposal (lead in solder, copper in electrical wiring, cadmium in plated metal parts, etc.) be identified; however, original assembly drawings do not always describe these materials in sufficient detail. It is our responsibility to provide engineering expertise for DOE to use in overcoming these limitations; statistical sampling techniques continue to be developed. Sandia has also developed a common materials database to be used by all design and production agencies.

Disposal of subsystems and components often requires declassifying, demilitarizing, and sanitizing. Sandia engineers are exploring new processes to perform these functions simultaneously. Because of the immediate need, two commercially available technologies (forge hammer fracture and water-jet cutting) are now available at Sandia and Pantex. Improved automated technologies are being investigated for future operations.

The role of Lawrence Livermore, Los Alamos, and Sandia national laboratories in operations at Pantex has been expanded at the request of the DOE Albuquerque Operations Office. Formal reviews and quality evaluation for dismantlement have been instituted to require laboratory teams to review all dismantlement procedures and operations for safety assurance. Formal dismantlement program reviews have been instituted similar to those done in development. The most recent initiative requested by DOE is for the laboratories' team to develop weapon disassembly procedures and processes for cells at Pantex using modern technology to achieve safety through design rather than by reviews.

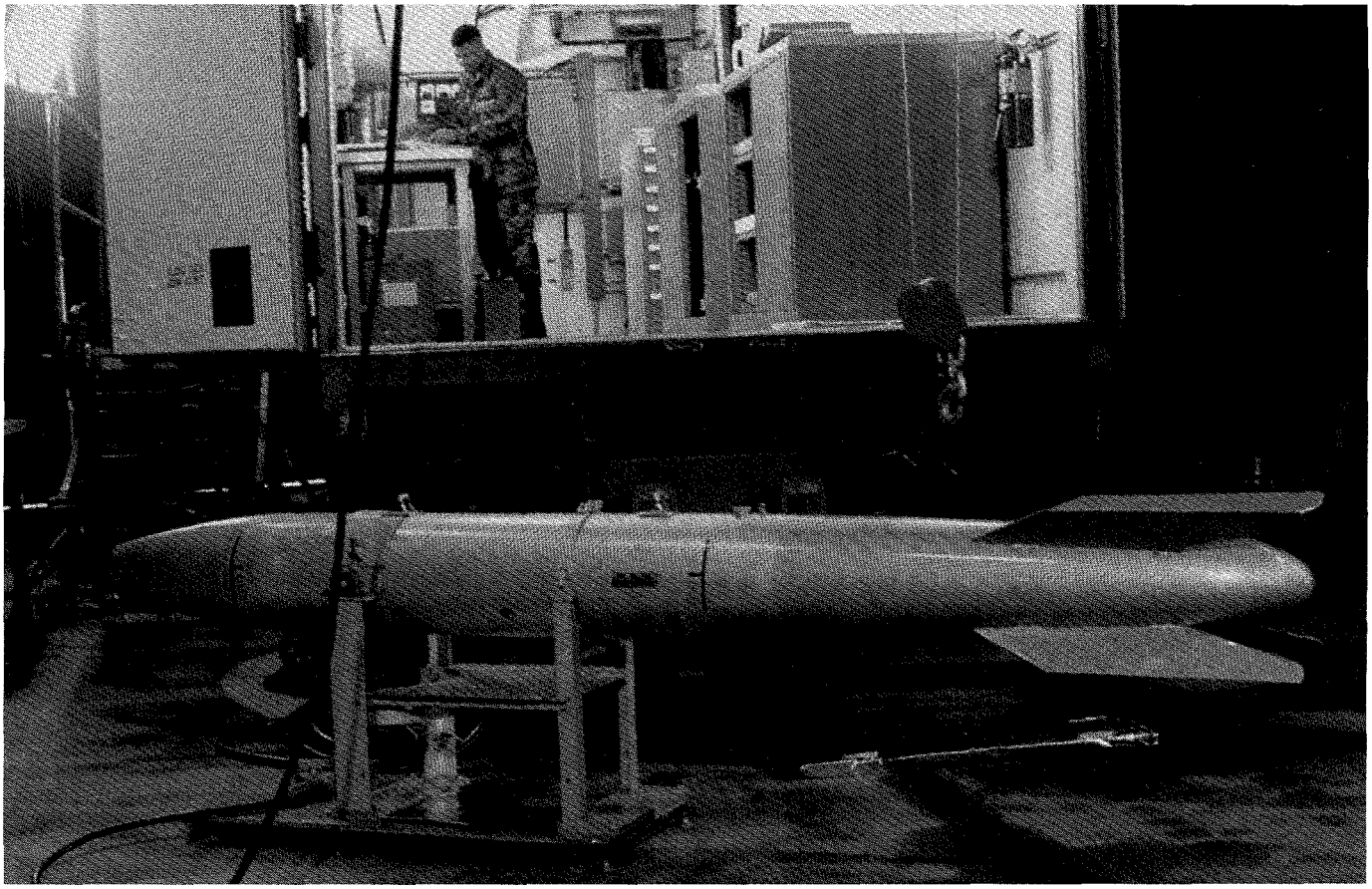
High weapon disassembly rates combined with the stringent certification requirements for transportation containers to withstand accidents mean that special containers for the safe storage and/or transportation of nuclear weapons and nuclear weapon components are increasingly in demand. Several types of containers are needed to satisfy significantly different requirements and Sandia has unique experience in designing and certifying low-cost, regulatory-compliant containers that satisfy international quality standards. Sandia has designed and produced containers for safely shipping and storing nuclear weapons since the advent of nuclear weapons. These containers relied on auxiliary equipment and facilities to meet many safety requirements; however, federal regulations for shipping components now require that the containers themselves provide this ability, so we are focused on meeting these additional requirements for containers for tritium reservoirs and their associated leak test equipment. We are also supporting the need for nuclear component containers in association with the dismantlement programs of both the United States and the former Soviet Union. These activities assist DOE in meeting international agreements and national nuclear shipping and storage requirements.

Our development of technologies for the nuclear waste complex derives from the needs of both dismantlement and reconfiguration of the production complex. Consolidating the current nuclear weapons complex will require an investment in the development and demonstration of advanced manufacturing technologies. Sandia is developing these advanced manufacturing technologies in conjunction with the private sector to enhance the relevance of the technologies and to demonstrate the agility of advanced manufacturing technologies in meeting the requirements of nuclear weapons production and US industrial needs. We are investing in technologies such as computer-aided design and manufacturing, concurrent engineering, information-driven architectures, environmentally conscious manufacturing, and rapid prototyping. These are the same technologies needed by US industry. We are also exploring the integration of manufacturing sites into a virtual factory to meet the requirements of the future complex.

The work associated with the nuclear waste complex will reach beyond the needs of the nuclear weapons community. Sandia's program is directed toward becoming a test bed for research, development, and manufacturing integration and for developing new industrial processes. The program can be a working model of fully integrated manufacturing technologies and a centerpiece for DOE contributions to advanced manufacturing.

Stockpile Evaluation (GB031004)

The first priority of the weapons program at Sandia is to ensure safety in the design, development, production, and



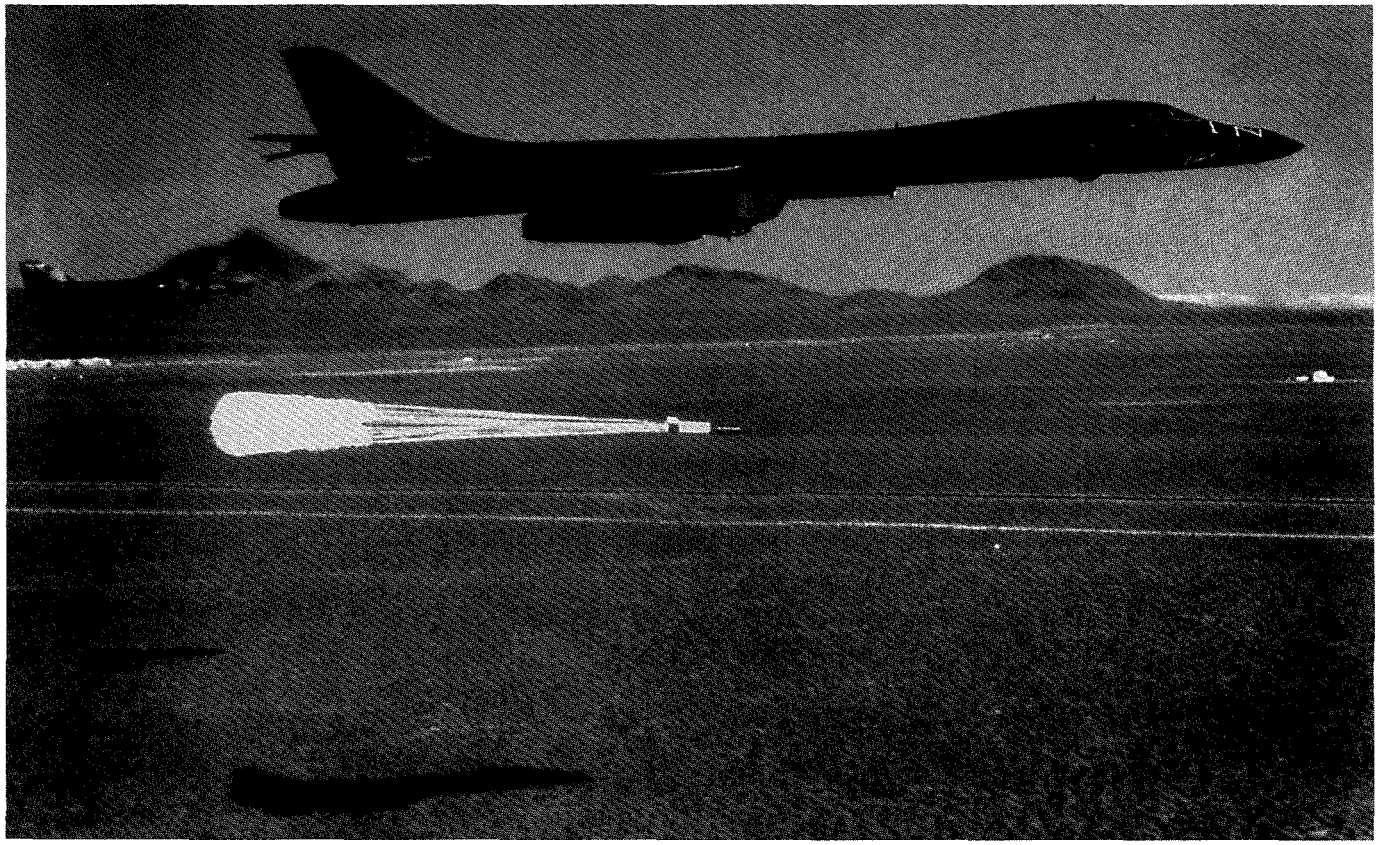
A B61 bomb awaits work after removal from a weapon storage vault and before loading into a weapons maintenance truck.

deployment of nuclear weapons. The highest levels of nuclear safety assurance are achieved by independent safety assessments conducted by experts in the nuclear weapon design and safety disciplines. The independent assessment of weapon safety evaluates and implements design safety and determines the quality of critical weapon components. This assessment supports the development of new weapon design concepts and safety upgrades in the weapon stockpile, a process that requires unique test and evaluation programs to determine the response of components and systems to both normal and abnormal environments. The goal is to provide increasingly comprehensive assessments of nuclear safety from system concept through warhead retirement.

We are committed to the concept that nuclear safety starts with features designed into the nuclear weapon at the most fundamental levels to prevent unintended detonations. The wide variety of nuclear weapon systems and the various environments for their deployment and operations complicate nuclear safety assessment. Possible conditions include multiple weapon configurations and launch platforms, numerous locations, many procedures involving a wide variety of personnel and special equipment, and exposure to a myriad of energy sources. Given our responsibility for comprehensive safety assessment of nuclear weapons, we continue to take the initiative in joint DOE/DoD assessments, in further development of methodologies for the assessment of safety in complex systems, and in gathering system-related data to support these assessments.

Sandia possesses unique experience in safety evaluations and in testing and analysis of weapon and system response in complex and abnormal environments. This experience will be augmented by an extensive nuclear safety test and evaluation program, the development of evaluation methodologies, and an expanding information base on nuclear safety technology. This information will continue to be integrated into a state-of-the-art, multimedia database that will form the basis for training personnel responsible for nuclear explosive safety, support for nuclear accident response activities, and cooperative efforts with Russia and the other countries of the former Soviet Union.

Sandia conducts quality evaluation and qualification of weapon designs, weapon hardware, associated software, controllers, field handling and test equipment, and joint test



A B1B bomber drops an inert B83 bomb in a systems design evaluation test at the Tonopah test range.

systems hardware and software during design and throughout the production and application periods. We also provide product acceptance and maintain records for Sandia-procured products; our qualification evaluation information center maintains a database of the qualification history and lessons learned. We help develop quality plans, furnish support to suppliers, provide service to development groups, and conduct supplier surveys and audits. We also conduct process evaluation by characterizing the manufacturing processes and equipment, especially for process transfers and new suppliers. We qualify acceptance equipment, testers, gauges, and associated software. We conduct internal quality assessments based on our sponsor's quality criteria for production activities and research and development. We ensure that the product meets the requirements of its intended use and that acceptance equipment supports this goal.

Sandia also conducts weapon quality process activities and software quality development and evaluation. Quality is incorporated in weapon design and development via early involvement and team concepts. We continue to develop a software management program to ensure a consistent approach to the management of all software being acquired, developed, supported, and used. We encourage organization-specific, results-oriented management plans that promote software improvement and incorporate quality assurance and quality control. We help guide project designers through software engineering processes. In-house software engineering courses are offered and software guidelines are promulgated. We plan to establish software metrics for war-reserve embedded computer systems. Results will be integrated into the system and ultimately used to improve the software reliability of the stockpile.

Sandia's independent assessment program verifies that the reliability and safety of nuclear weapons in the stockpile are at the levels required by DOE and DoD. The entire testing and evaluation program is formulated by a Sandia/DOE/DoD team.

Nuclear weapons are selected from the stockpile, returned to DOE's Pantex plant, denuclearized, instrumented, and tested. Some are subjected to environmental extremes in the Weapons Evaluation Test Facility at Pantex. Others are shipped to DoD sites, mated to their delivery systems, and used in test flights. If problems are detected or failures occur, a team is formed to find the cause of the anomaly, assess its impact, and recommend resolution. A

databank of all system tests and problems is maintained to provide proof-of-system reliability, safety data, and a record for use in future designs.

Major changes to the stockpile evaluation program are being made to accommodate a smaller number of weapons and a declining budget. Handling, shipping, and disassembly costs will be reduced by coordinating the selection of weapons to be tested with weapons operations such as scheduled maintenance. Tests are being replanned to place more emphasis on aging effects caused by longer-than-expected lifetimes. Critical safety components are being examined due to higher standards of environmental safety and health.

More realistic test configurations are being generated to improve our ability to detect subtle problems in ultrahigh-reliability systems. We are redesigning denuclearized test units for laboratory testing of more than one type of weapon system. This will provide more flexibility during routine maintenance or breakdowns and a more interchangeable, economical tester mix.

We are responding to increased personnel safety requirements by performing test operations safety reviews with independent assessors and by replacing test equipment that was built to less stringent safety standards. The hydraulic-driven centrifuges at the weapons evaluation test facility are being converted to electrical systems. Our objective is to support a highly reliable and extremely safe stockpile with a timely, cost-effective, well coordinated, and mutually beneficial stockpile evaluation program.

Sandia also provides primary physical, electrical, and radiation standards for equipment calibration for the entire nuclear weapons complex. Sandia's Primary Standards Laboratory Metrology Program ensures accurate measurements for the nuclear weapons program by developing and maintaining primary standards traceable to national standards and by calibrating and certifying customer reference standards. In addition, the program supports other DOE programs, government agencies, industry, and universities. The program also provides technical guidance, support, and consultation; precision measurement techniques; and oversight activities, including technical surveys and measurement audits. Development programs ensure the timely introduction of standards for new technologies. A recent development is the portable Josephson volt, which will permit this intrinsic standard to be used in many field applications, ensuring quantum-level accuracy on voltage standards, digital dividers, and other ultraprecise test equipment.

Sandia's Primary Standards Laboratory performs more than two thousand calibrations of top-level standards each year in more than eighty different areas of technology for various sites and facilities across the entire nuclear weapons complex. The standards laboratories at various contractor sites use these standards for as many as 300,000 annual calibrations of their own instrumentation. The future focus of the Primary Standards Laboratory will include support for the reconfigured nuclear weapons complex and advanced manufacturing initiatives. This will require the development of new metrology disciplines such as chemical standards.

Weapons Complex Reconfiguration (GB06)

The aging nuclear weapons production complex remains a widely distributed, environmentally outdated, expensive collection of sites built to meet peak Cold War demands. As production requirements decrease, the weapons complex must become smaller and less costly while maintaining its technical competence. DOE is consolidating the complex and increasing its efficiency by integrating the essential competencies that exist in the weapons laboratories, the private sector, and the remaining weapons production sites (Kansas City, Y-12, Savannah River, and Pantex). This consolidation plan assigns Sandia the responsibility for prototyping and small-lot fabrication of neutron generators and thermal batteries. During the past two years, DOE's plans to reconfigure and consolidate the nuclear weapons complex have included tighter integration of the weapons laboratories with the production complex.

Sandia supports DOE with research, development, and analysis for intelligence, proliferation detection and analysis, arms control, verification technology, and policy development. Sandia has one of the oldest and largest programs of such work in support of US national security policy. This work continues to complement our nuclear weapon research and development responsibility, which provides expertise for nonproliferation and arms control research and development.

Verification and Control Technology

The Verification and Control Technologies Program includes research and development for a variety of systems, technologies, and processes for detecting proliferation of weapons of mass destruction and for verifying agreements for transparency and arms limitations. An increasingly important aspect of all these program areas is Sandia's activity in information management, fusion, and analysis. Because the political framework within which these technologies are implemented reflects national and international momentum toward openness, Sandia's advanced monitoring technology strikes a balance between supporting national goals of openness and transparency and ensuring that sensitive national security information continues to be safeguarded.

Technology Development Programs

Sandia is developing new sensors to detect low-yield nuclear explosions in the atmosphere. Instrumentation being

deployed on the global positioning system satellites will soon provide continuous worldwide coverage. Data from these instruments are also used by DoD, which shares system costs.

We are developing satellite-based systems and technology for detecting and characterizing nuclear proliferation activities. These systems and technologies have potential applications to detection of chemical weapons, biological weapons, and missile development. In conjunction with Los Alamos National Laboratory, we are developing an advanced multispectral thermal imager. Working with Los Alamos, Lawrence Livermore, Pacific Northwest, and Brookhaven national laboratories, we are developing laser-based techniques for remote detection and identification of chemical species in effluent plumes emanating from suspect sites. Both concepts could be developed into operational integrated systems and demonstrated in space aboard small satellites.

Sandia is developing chemical sensors related to nuclear and chemical weapons, ultraviolet light detection, light detecting and ranging technology, radiation detection sensors, remote video surveillance systems, and the nondestructive determination of particulate compositions. In some instances, component technology will be incorporated into unattended and possibly remote ground-based sensor systems.

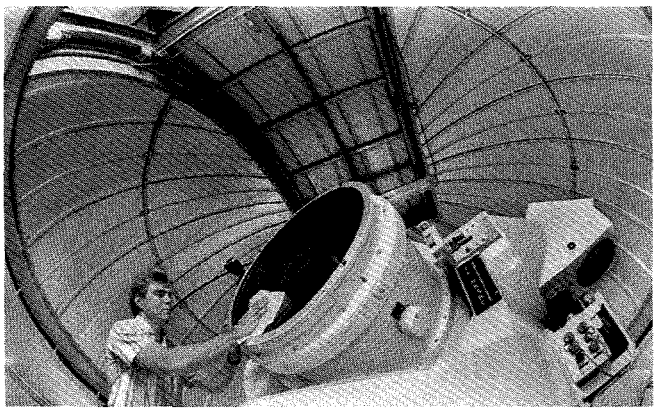
We develop synthetic aperture radar systems for a wide variety of treaty verification and nonproliferation applications. We are also exploring the integration of synthetic aperture radar with other imaging data and automated data analysis to handle the large volume of data from such systems. Synthetic aperture radar can also be used for all-weather and day-and-night aerial inspection.

Tags and seals are being considered for use in securing key elements associated with the Chemical Weapon Convention, weapon dismantlement, and the containers designated to transport and store US and Russian special nuclear materials. Sandia has broadened the tag and seal effort to include information integrity, which covers the general application of tags and seals to a wide range of monitoring applications. Data authentication techniques are being developed to provide security for remotely monitored, sensor-based sealing systems.

Sandia continues to develop technology for fiber-optic tags and seals and advanced tamper-indicating packaging. The technology base developed for these applications uses input from private industry, the university community, other national laboratories, and centers of expertise within Sandia.

Studies are under way to investigate the impact on DOE facilities of nuclear weapon dismantlement and special nuclear material controls in the context of various treaties, agreements, and transparency arrangements. One of our tasks is to design and develop a secure container for the safe transportation and storage of special nuclear materials. This work provides some of the background necessary to support discussions with Russia on nuclear weapon dismantlement.

Seismic technology is being developed to detect, locate, and characterize nuclear explosions under ground and under water. In line with the emerging geopolitical climate, the emphasis of this program has shifted from monitoring bilateral agreements to global monitoring for a comprehensive test ban and monitoring for covert, proliferation-related nuclear testing. Our research and development is part of a multilaboratory effort focused on verification-quality seismic and hydro-acoustic data acquisition and data processing that is affordable, easily deployable, and flexible. Our technology development activities are being coordinated and in many cases co-funded by DoD, which has the operational nuclear test monitoring responsibility within the US government.



Dave Denning cleans the lens of the Cassegrain beam telescope, which is used to calibrate satellite-based sensors that monitor nuclear test ban treaties.

Export Control and International Atomic Energy Agency Support

Sandia supports the evaluation of export licenses in weaponization technology, drawing on our considerable experience in the engineering of nuclear weapons. Sandia also provides analytical support for the Office of Export Control's International Atomic Energy Agency activities. Analysis includes evaluation of various proposed inspection regimes, evaluation of International Atomic Energy Agency information management technology and procedures, and technology development support for ongoing International Atomic Energy Agency inspections.

Nonproliferation Policy

Sandia supports the Office of Nonproliferation Policy in regional arms control. Sandia's cooperative monitoring center is used by a wide variety of countries and agencies to evaluate the applicability of various arms control technolo-

gies and procedures to regional security issues. Prototype monitoring facilities can be developed so that representatives of regional parties (from South Asia, the Middle East, the Korean peninsula, etc.) can perform hands-on evaluation of various technologies and use models to simulate the appropriateness of technological solutions to their particular regional problems.

Policy Analysis

Sandia's policy support activities target both sides of the policy/technology interface. We support technical analysis of policy options for DOE and provide national security policy insight to Sandia organizations. Our direct support includes furnishing technical advisors to DOE Headquarters and to the International Science and Technology Center in Moscow.

Analytical support for DOE includes treaty implementation analysis, staff support, nuclear testing analysis, and dismantlement analysis. Sandia has been a mainstay of DOE's on-site evaluation program since 1986 and continues to support evaluations of the impact of on-site inspections on sensitive industrial facilities and other issues related to implementation of various treaties.

Sandia has participated in various evaluations of the impact of further testing restrictions on our ability to act as stewards of the remaining nuclear stockpile. In addition, Sandia is providing guidance to policy-makers about the verifiability of various proposed test-related treaties.

As the superpower stockpiles are reduced and their respective infrastructures consolidated, numerous issues will arise concerning verification and monitoring of the reduction, the residual weapons, and the components and materials resulting from dismantlement. Sandia has long evaluated the processes, procedures, and technologies associated with these dismantlement activities; this support is expected to continue.

Intelligence Support Activities

Sandia has a long history of support for the intelligence community via DOE's Office of Foreign Intelligence and other agencies. Our support has focused on foreign technology assessment and technology development.

As the national intelligence horizon has expanded to emphasize information management, Sandia has responded with programs to assist the intelligence community with tools and analytical techniques. For example, we provide tools for evaluating the wide range of multisource information now available, especially information relevant to assessing the proliferation of weapons of mass destruction and their delivery systems. In addition, evaluations of information surety, a special expertise required by the nuclear weapons program, are increasingly provided to the intelligence community.

Although information management and proliferation-related tasks are of vital importance, this new focus has not supplanted Sandia's traditional intelligence support mission. We continue to enhance our intelligence collection and exploitation role by developing new sensor systems and evaluating foreign technologies for a variety of customers.

Office of Environmental Management

Defense Waste and Environmental Restoration (EW)

Work for the Office of Environmental Management includes environmentally conscious manufacturing technology, waste management technology, environmental restoration for Sandia, hazardous material transportation, and waste repository technology. Work performed for this office includes site-specific corrective actions for the Environmental Restoration Program.

Environmentally Conscious Manufacturing

Sandia plays a key role in developing and demonstrating environmentally conscious manufacturing technologies and using them to manufacture nonnuclear weapons components. These efforts focus on electronic assemblies and electromechanical components, reducing the use of hazardous or environmentally injurious materials during weapon production. A concurrent goal is to interface with US industry regarding environmentally conscious manufacturing technologies and processes and promote their transfer to our mutual benefit. In cases where it is appropriate to transfer technologies from the DOE complex to US industry (i.e., where the result is increased competitiveness or decreased environmental cost during manufacture), Sandia plays an important role in their evaluation and demonstration prior to transfer.

Sandia's efforts in environmentally conscious manufacturing have focused on developing decision tools and methods to identify environmentally conscious manufacturing opportunities, evaluating environmentally benign technologies, demonstrating these technologies, and documenting the benefits of their use in manufacturing. In conducting environmentally conscious manufacturing demonstrations, a total systems approach has been used to identify environmental improvement opportunities during manufacture (e.g., of electronic components). The systems approach is used to identify areas where hazardous waste is generated or where workers could be exposed to hazardous materials. In this approach, opportunities for replacing these materials and processes with environmentally benign manufacturing technologies are also identified: replacement

of hazardous organic compounds such as chlorofluorocarbons and chlorinated hydrocarbons with semiaqueous and aqueous cleaners; applications of urethane foams and elastomers that do not contain carinogenic precursors; use of no-clean fluxes and fluxless soldering; material replacements, including methylenedianiline-free printed wiring boards; chromium-free metal coatings; and safe marking inks. Life-cycle analyses, environmental impact compliance assessment tools, and cost-benefit assessments of the new technologies are key to such demonstrations. These activities involve research and development of technologies, methods, and decision tools for life-cycle analysis/environmental impact at Sandia; coordination of complementary development and demonstration of the technology and methodologies at supplier and production sites (e.g., small business suppliers and AlliedSignal in Kansas City); coordination of research at US universities and private industry; identification, evaluation, and development of environmentally friendly alternative technologies; and technology transfer through ongoing partnerships with US industry.

Another environmentally conscious manufacturing program activity is benchmarking for waste minimization. Its mission is to improve waste minimization techniques and technologies within the DOE complex using the quality tool of benchmarking to identify appropriate best-in-class practices from industry partners. This effort seeks to develop a benchmarking process for DOE, apply the process to identify significant complex-wide waste minimization opportunities, and find innovative ways to reduce this waste. Environmentally conscious manufacturing program activities also develop various methods and software tools for improving process and equipment reliability, product/process performance, designer assessment of environmental impacts of alternative products and processes, and small business self-assessment of compliance with Occupational Safety and Health Act and Environmental Protection Agency requirements.

Waste Management

Sandia performs a wide variety of waste management activities, including research on chemical reactions. Crystalline silicotitanate ion-exchange material, invented by Sandia and Texas A&M University, solves the problem of cesium and strontium removal from radioactive liquid wastes. Sandia has signed a cooperative research and development agreement and license with UOP, Inc. to commercialize production of the materials for radioactive waste treatment in 1995. To date, UOP has produced one thousand pounds of crystalline silicotitanate powder. *Environment Today* (January 1994) included crystalline silicotitanate materials in its list of the "ten most promising R&D efforts that could change the face of pollution control."

Other waste management technologies are being developed for Sandia waste operations and for many other parts of the DOE complex. We helped the DOE Albuquerque Operations Office develop a mixed waste treatment plan to satisfy DOE's obligations under the Federal Facilities Compliance Act and have served as the technical integrator for the Compliance Act Disposal Work Group since 1994. This role has allowed us to develop insights into the workings of the governors' offices and regulatory agencies of the affected states (as facilitated by the National Governors Association) concerning disposal issues related to treated mixed wastes. These insights have been applied to our own waste disposal operations and to those of other DOE facilities. We continue to conduct waste management operations required to support a diversity of activities at Sandia and have an active waste minimization program consistent with the philosophy that the best way to manage waste is not to generate it in the first place.

In support of DOE's mission of nuclear weapons stewardship, we have developed an array of recycle, treatment, and disposal technologies for weapon components by focusing on electronic components from dismantled nuclear weapons. This work has used a systems approach to identify areas where advanced recycling can be applied to a process. This includes quick separation of dissimilar materials (using an abrasive water-jet cutter, x-ray system, and recirculation system) to maximize recycling potential, rapid rubblization to facilitate recycling, multistep mechanical-separation processes, and thermal treatment systems that simultaneously produce usable fuel gases and allow metal recycling.

At the DOE Hanford Site in Washington State, approximately 20 million gallons of liquid radioactive waste are contained in 177 storage tanks. Sandia has offered a unique new technology to help address problems resulting from lack of tank space, leaking tanks (sixty-six tanks are presumed to be leaking), tank age, and tank integrity. Sandia's technology includes steam reforming for destroying organics and nitrates in a variety of waste streams, monitoring and control systems for incineration processes, waste dislodging and conveyance technologies for underground storage tanks, supercritical water oxidation destruction of explosives and propellants, and solar detoxification of waste.

Finally, on a much broader scale, Sandia has chaired the Laboratory Directors' Environmental and Occupational/Public Health Standards Steering Group. This group, chartered by the directors of thirteen laboratories, has pursued a wide range of issues focused on improving the scientific and public understanding of the risks associated with hazardous agents in the environment and workplace. Throughout its history, the steering group has often been progressive. It was the first to establish a formal dialogue with public interest groups, and it developed the first joint interlaboratory synopsis of risk-related work. It also sponsored and conducted several symposiums on risk-based standards and other topics, including the first symposium on DOE land-use planning, emphasizing issues associated with waste disposal. Both the vice chairman of the Military Impacts on the Environment Committee and the Assistant

Secretary for Environmental Management have commended the work of the steering group.

Environmental Restoration

The DOE Environmental Restoration Program was initiated in 1987 to consolidate and coordinate regulatory compliance activities that identify and remediate inactive sites at DOE installations contaminated with hazardous, radioactive, or mixed waste. This program includes both operational activities and technology development to improve our future restoration processes.

The Environmental Restoration Program addresses environmental problems resulting from past practices, assesses the extent and nature of these problems, and remediates sites as necessary using effective, cost-efficient methods. Activities include identifying inactive hazardous-waste release sites, developing an environmental restoration investigation and remediation program, coordinating National Environmental Policy Act documentation, obtaining necessary permits, evaluating surface and groundwater contamination potential, reviewing practices affecting sites with underground storage tanks, evaluating other waste management practices, and ensuring compliance with federal, state, and local environmental regulations. Projects involve the investigation and remediation of inactive waste-handling, disposal, and spill sites in accordance with the provisions of the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, and relevant DOE orders.

Most environmental restoration sites fall under the Resource Conservation and Recovery Act, but some will be addressed consistent with the National Contingency Plan. Sandia's environmental restoration efforts are grouped into three categories:

- Resource Conservation and Recovery Act corrective actions required to address releases of hazardous waste or constituents from solid waste management units;
- Resource Conservation and Recovery Act closure actions pertaining to inactive treatment, storage, and disposal units that will not be permitted for continuing operation; and
- other actions to assess or remediate sites where a release has occurred or where a substantial threat of a hazardous substance release exists.

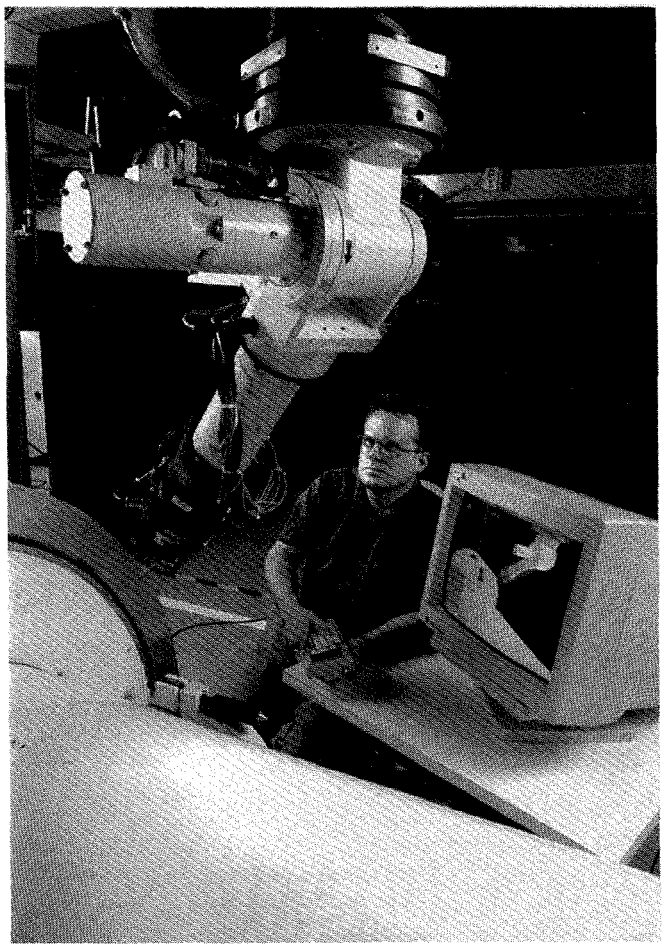
In 1992 Region VI of the Environmental Protection Agency issued Sandia a permit that established a schedule for the assessment and remediation of sites under Resource Conservation and Recovery Act corrective action authority at Sandia/New Mexico.

In site restoration technologies, Sandia is a leader in new ways to both characterize and remediate previously contaminated areas. We have been conducting a technology applications program that has developed new decision-support and characterization techniques for our own sites. Nationally, Sandia directed the Mixed Waste Landfill/Integrated Demonstration for DOE/EM-50. This demonstrated improved technologies for cleaning a contaminated site in an arid location. Because of our experience and background, Sandia is becoming a key participant in the plume and landfill stabilization focus areas under DOE's new approach to environmental technology development.

Hazardous Material Transportation and Crosscut Technologies

A principal program for the Office of Environmental Management is the group of technical tasks that make up the Transportation Technology Development Program. This program directly addresses ongoing DOE programmatic packaging and transportation needs. It includes projects in the following areas:

- engineering-based comprehensive risk assessment of the seaborne transportation of radioactive material;
- development of alternative packaging concepts to facilitate the cost-effective decontamination and decommissioning of closed DOE weapons manufacturing facilities;
- determination of the cost-benefit of applying burnup credit factors to the design requirements for packagings for DOE spent fuel;
- advanced technology development to characterize materials (especially casting metals and brittle materials) that address identified needs in transportation and waste management;
- work with DOE program offices to identify and evaluate unresolved technical requirements to address packaging systems, design features, and materials compatibility issues;
- engineering analysis to improve and apply thermal and structural analysis codes, develop code modules, and create databases specific to transportation problems;
- certification and regulatory support that provides technical expertise to DOE elements involved in packaging certification efforts and supports DOE efforts in clarification, analysis, and change to regulations at the international and national level;
- environmental and systems planning to develop and



Michael McDonald monitors a gantry robot using a graphical programming system developed at Sandia. The robot will be used for remote handling of hazardous materials.

apply systems analysis techniques, risk assessment codes, and data relating to transportation systems operations (including material flows, modal options, accident data, and phenomenology);

- testing to support package certification, confirm new design concepts, and provide results for code confirmation and risk assessments;
- transportation automation and technical assistance, including providing the TRANSNET technology transfer facility to furnish results of DOE work to a variety of users;
- transportation intelligent monitoring, which develops technologies to improve emergency response systems for DOE activities;
- geographic information systems development and integration to provide links for transportation risk assessment, preferred route determination algorithms, environmental justice analysis, and accident rate prediction codes; and
- source-term containment evaluation, which develops information and analysis techniques to set requirements for allowable package leakage.

In addition, Sandia has technologies that provide support to several problem areas. This includes major efforts in our robotics and intelligent systems area. Robotics technology offers a safe and reliable way to protect workers and the public from hazardous and radioactive materials during handling, storage, treatment, or transport. As a member of a multiorganizational team of DOE laboratories, industry, and universities, Sandia has developed and demonstrated a robotics control software system called the Generic Intelligent System Control system. The system dramatically decreases the time and training requirements for state-of-the-art commercial systems. With this system, DOE recently was able to satisfy several key Environmental Protection Agency and Washington State Department of Ecology milestones for waste removal from the Hanford tanks. Sandia has signed a cooperative research and development agreement with Deneb Robotics to transfer and commercialize the Generic Intelligent System Control software technology.

Nuclear Waste Repositories

The Waste Isolation Pilot Plant

Sandia is responsible for experiments and performance modeling to demonstrate the long-term behavior and containment properties of the Waste Isolation Pilot Plant repository and its suitability for long-term disposal of DOE's transuranic waste. Sandia is providing a detailed geotechnical understanding of the Waste Isolation Pilot Plant Site (twenty-six miles southeast of Carlsbad, New Mexico) and scientific research on issues related to disposal of transuranic waste. Sandia is providing scientific assistance for the predisposal phase (expected to last through at least 1998) and other assistance to meet the requirements of the 1992 Waste Isolation Pilot Plant Land Withdrawal Act (Public Law 102-579). Sandia's activities are focused in the following seven areas:

- disposal room and drift system studies to understand how wastes will interact with the repository bedded salt,
- laboratory gas-generation studies to determine how the waste forms may degrade and chemically interact,
- sealing systems and rock mechanics studies to design short- and long-term barriers to prevent wastes from escaping through mined entrances,

- Salado hydrology and transport studies to determine how liquids and gases flow into and out of the repository rock salt,
- non-Salado flow and transport studies to determine the properties of formations overlying the repository,
- performance assessment modeling of long-term repository behavior with the wastes emplaced, and
- other activities for compliance demonstration and management.

Disposal room and drift system activities consider backfills, brine, simulated waste, waste containers, disposal rooms, and test designs for laboratory and field experiments. These experiments will provide an understanding of important waste interactions to support development of source-term and gas-generation models.

The laboratory gas-generation experiments use simulated and real waste to study the effects of various waste degradation processes such as corrosion of metals, microbial decomposition of plastics and cellulosics, and radiolysis. Such processes could have an impact on the short- and long-term waste containment capability of the repository. These experiments will provide confidence that a gas-generation model based on thermodynamic principles and laboratory data can predict gas generation from actual transuranic waste from the DOE complex.

Sealing systems and rock mechanics experiments determine the properties of salt, concretes, clays, and other fillers in laboratory and field settings. These experiments evaluate rock mechanics properties of the repository and overlying rock formations when penetrated by shafts, boreholes, and disposal rooms.

Salado hydrology and transport laboratory and field studies measure hydrologic parameters of the salt such as permeability, threshold pressure, and two-phase flow. Experiment results are input to databases and models of brine- and gas-transport into and away from the repository.

Non-Salado flow and transport experiments use laboratory and field studies to measure hydrologic and chemical transport parameters of formations overlying the repository. Laboratory experiments are developing models of radionuclide transport properties under present and anticipated conditions.

Performance assessment uses input from databases and models of the preceding activity areas to model the predicted performance of the Waste Isolation Pilot Plant as a geologic repository for nuclear waste. The results will be included in the compliance application that DOE will submit to the Environmental Protection Agency as part of the demonstration of compliance with regulatory requirements. This will be a significant part of the basis for the disposal decision by the Secretary of Energy.

Other activities are concerned with integration and management. These activities include responses to inquiries from oversight groups, definition of the waste inventory parameters needed for performance assessment, and quality assurance for all facets of the above efforts.

FY 1996 activities will focus on completing the experiments most essential for compliance with Environmental Protection Agency repository standards, documenting the results, and incorporating the information in a comprehensive performance assessment of the Waste Isolation Pilot Plant. A quality assurance program will provide the Environmental Protection Agency with documentation that addresses both historic data and current experiments, analyses, and software. The performance assessment will be the basis of DOE's compliance application to the Environmental Protection Agency. After the Waste Isolation Pilot Plant is certified as complying with Environmental Protection Agency standards, Sandia will retain key scientific investigators in critical areas so that expanded categories of transuranic waste may be emplaced and five-year updates of performance can be provided to the Environmental Protection Agency.

Greater Confinement Disposal Project

Sandia has been selected by the DOE Nevada Operations Office to lead and conduct technical compliance assessment analyses for the Greater Confinement Disposal Project. The Greater Confinement Disposal Project site, located within the Radioactive Waste Management Site at Area 5 of the Nevada Test Site, has been proposed for the permanent disposal of a small amount of transuranic waste that does not meet the waste acceptance criteria for other waste repository programs. These wastes have been included in a category termed special-case wastes, requiring an alternative disposal method. In order for the waste to remain emplaced, the Greater Confinement Disposal Project facility must demonstrate compliance with the Environmental Protection Agency's standard for disposal of high-level waste, transuranic waste, and spent fuel.

Sandia's role in the Greater Confinement Disposal Project includes development and implementation of a compliance assessment strategy for all applicable rules and regulations, model development and application for all Greater Confinement Disposal Project performance assessment activities, design and conduct of site characterization activities supporting Greater Confinement Disposal Project performance assessment, analyses to identify the suite of potential special-case wastes and to evaluate alternative disposal system configurations for possible future use of the Greater Confinement Disposal Project concept for special-case waste disposal, technical program integration, and development and implementation of an overall project strategy.

Performance of DOE Nuclear Waste in Future Repositories

Drawing on work from other geologic disposal projects, Sandia is examining possible options for the treatment of highly enriched spent fuel from DOE military and experimental reactors and for high-level waste generated from past processing of some of this defense spent fuel. The waste is currently stored at the Idaho National Engineering Laboratory and throughout the DOE complex. Sandia is helping the Westinghouse Idaho Nuclear Company by providing expertise in performance assessment methodology. Sandia's performance assessment evaluates possible treatment options by assessing the long-term behavior of the resulting waste forms in hypothetical, deep-geologic repositories in salt, granite, and volcanic tuff and then calculating performance measures for comparison with applicable environmental regulations. This assessment is part of the waste management technology development program designed to help DOE develop and demonstrate the capability to dispose of its spent fuel and high-level radioactive waste permanently, as mandated by the Nuclear Waste Policy Act of 1982.

National Transuranic Program

DOE established the National Transuranic Program to coordinate the generation, characterization, handling, treatment, processing, packaging, transport, and storage of transuranic waste. Sandia assists DOE in all of these areas. Sandia's role includes studying waste processing technologies, developing recommendations for disposal of transuranic waste, developing a strategy to manage sites with small quantities of waste, advising DOE on regulatory issues, initiating and developing an integrated plan for managing remote-handled waste, and revising the criteria used to characterize waste destined for disposal at the Waste Isolation Pilot Plant.

3.1.2 Energy Programs

Sandia supports DOE's goals of providing secure and environmentally acceptable energy supplies by improving energy production, conversion, and use. Drawing on more than twenty years' experience in energy research and technology development, Sandia now specializes in areas that leverage its research, design, and manufacturing capabilities.

Our current programs include high-temperature superconductor research for electric power systems, stationary battery storage systems for utilities, geothermal energy systems, solar electric technologies (photovoltaic and solar thermal), wind energy, industrial and transportation applications, fossil energy programs, and projects that address the complete life cycle of nuclear energy needs. These programs mesh with industry, allowing Sandia to develop a strong record in technology partnerships.

Assistant Secretary for Energy Efficiency and Renewable Energy

Sandia's energy programs are integrated to assist DOE in developing creative solutions to global energy problems and reduce the impact of energy use on the environment. To this end, we use Sandia's capabilities to bring in appropriate expertise, and we collaborate with US industry, government agencies, and universities to determine economical, practical, environmentally friendly solutions to worldwide energy issues. We are helping to make US energy technologies cost-competitive in a global market.

Sandia's multiprogram structure provides a resource for the nation in systems analysis, technology development, and engineering design. We use these crosscutting strengths to assist in ensuring the nation's energy security. Furthermore, we undertake research and development for DOE to solve anticipated energy needs.

Staff members in our program areas of renewable energy, fossil energy, and energy efficiency initiate and maintain technical collaborations with industry and users to solve problems and curb pollution.

The economic viability of energy technologies in the United States is a major concern. We work in cooperation with DOE and in partnership with industry to strengthen the competitive position of US industry. Sandia's principal contributions are providing engineering studies to identify preferred system applications and configurations; testing, fielding and evaluating prototype systems; and modeling and analyzing current and projected situations. We view our efforts as international, supporting DOE's global policy. We are applying Sandia-wide capabilities in engineered materials and advanced manufacturing technologies to assist industry in improving the manufacturability and cost-competitiveness of renewable energy systems.

Electric Energy Systems (AK)

Sandia is developing practical, high-temperature superconducting wire and magnets to improve the efficiency of electric motors, generators, and transmission lines and to provide fast-discharge energy storage in the form of superconducting magnetic energy.

This work contributes to optimized high-temperature superconducting materials, conductor fabrication technology, and the design and evaluation of prototype devices that

can improve the efficiency of electric power generation and distribution systems. We actively involve industry in all of this work.

Energy Storage Systems (AL)

Sandia is working with industry to develop advanced rechargeable battery systems for utility energy storage applications as part of the DOE utility battery storage systems program. Cost-shared contracts with industry partners develop both components and systems. Sandia's technical expertise is used to manage these contracts, analyze the benefits of battery storage in utility systems, evaluate prototype batteries, and conduct applied research.

Sandia is involved, through partnership with the State of New Mexico and industry, in the design and development of a small superconducting magnetic energy storage system capable of ensuring premium power for high-value manufacturing operations (e.g., microelectronics fabrication) where power fluctuations or interruptions can result in millions of dollars of losses and waste.

Geothermal Systems (AM)

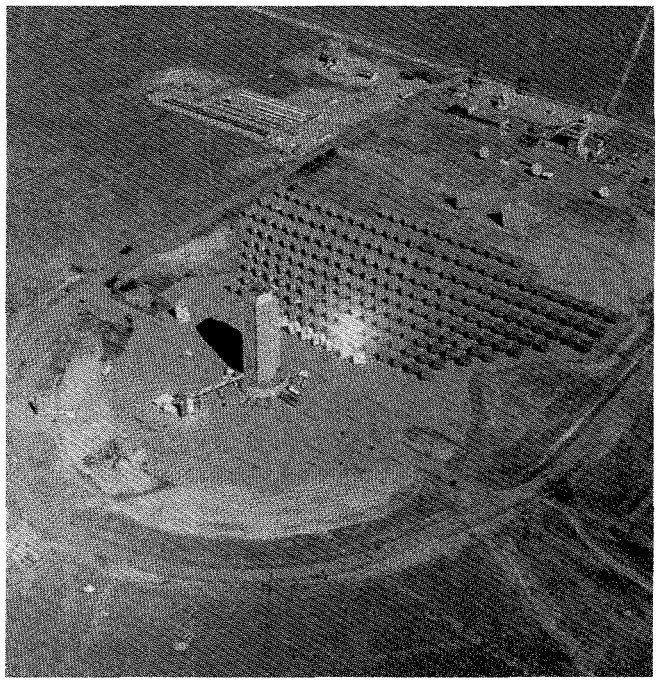
Sandia's geothermal systems work will increase the nation's proven geothermal reserves and assist industry in expanding geothermal power use. We are developing new drilling and completion technologies to help expand the commercial use of US geothermal resources. The technologies we develop in this area can also be used in petroleum and mineral extraction.

Slimhole drilling is a new technique Sandia is perfecting to reduce drilling costs in assessing hydrothermal reservoirs. Our major work in geothermal systems includes developing high-temperature instrumentation for geothermal wells, acoustic telemetry to transmit downhole data through the drill pipe while drilling, and drilling a deep exploratory well in an active volcanic caldera in California.

Solar Energy (EB)

Solar Thermal

Engineers in Sandia's solar thermal programs work with users and manufacturers of solar thermal energy systems to increase acceptance of solar thermal technologies. The programs emphasize cost-competitiveness for power generation and industrial process heat. Sandia operates the National Solar Thermal Test Facility, where we evaluate solar thermal technologies and perform specialized tests requiring high heat flux, a capability used by both government and industry. Sandia provides technical support to Solar Two, a cost-shared project with a consortium of utilities to upgrade the Solar One power tower pilot plant using molten salt heat collection and storage technology.



Sandia evaluates solar thermal technologies at DOE's National Solar Thermal Test Facility in Albuquerque.

Sandia conducts research and development of advanced solar thermal components, dishes, heliostats, and receivers for dish and central receiver systems. We also design, analyze, and test components and systems. In a joint venture with industry, we are developing the first commercial dish/Stirling systems. We operate a design assistance center that promotes the use of solar thermal technologies through services to manufacturers, operators, and decision-makers.

Photovoltaics

Sandia's photovoltaics work is centered on developing cost-effective, reliable photovoltaic energy systems technology produced by US industry and used worldwide. Through its Design Assistance Center, Sandia teams with other agencies to accelerate development and acceptance of the technology at home and abroad.

We use our engineering skills to assist industry in developing high-performance, low-cost concentrator cells, designing cost-effective modular technologies, and perfecting balance-of-systems hardware. We assist industry by providing accurate performance measurements, reliability testing, and evaluation.

Wind Power

Sandia is developing wind turbine technologies to provide economical systems for commercial power generation. Sandia conducts applied research in aerodynamics, structural dynamics, fatigue, materials, controls, and systems integration to increase understanding of phenomena and provide more effective design tools.

Sandia is also developing wind turbine technology and other technologies in partnerships with the US wind industry. We work closely with other national laboratories, wind turbine manufacturers, and wind farm operators to find reliable, cost-effective solutions for domestic and international markets. Sandia engineers are developing user-friendly analytic tools.

Industrial Sector (ED)

Combustion Technology

Combustion work at Sandia's Combustion Research Facility (CRF) includes experimental, theoretical, and computational investigations aimed at reducing energy consumption, preserving the environment, and enhancing science and engineering foundations. This work utilizes the unique laser diagnostic capabilities of the CRF, a major user facility established by the DOE Office of Energy Research.

Sandia collaborates with industry on its combustion projects and concentrates on reducing noxious emissions (without compromising fuel efficiency), on developing improved technologies for internal combustion engines and various industrial processes, and on improving environmental technology systems for the destruction of hazardous wastes.

Materials Processing by Design

The materials processing programs work to improve existing processes and develop new ones that are commercially and environmentally acceptable for the chemical, petroleum, durable goods, and semiconductor industries.

This work explores the underlying physics, chemistry, thermodynamics, and fluid mechanics of new processes for manufacturing commercially important chemicals, powders, composites, coatings, and membranes. We make predictive models of high-temperature chemicals and materials synthesis processes that industry can use in its design, organization, and waste minimization efforts. We also use laser-based sensors to monitor and control manufacturing processes in the steel, chemical, petroleum, and semiconductor industries.

Advanced Industrial Concepts/Materials Research

Sandia's materials research work in the industrial technologies program provides computer-aided design, synthesis, characterization, and testing of new enabling materials with the potential for energy savings and waste reduction in industrial applications.

The present focus is on developing selective inorganic thin films for energy savings through improving performance of light gas membranes and catalysts, synthesizing composites by reactive metal infiltration, optimizing composites manufacturing, and developing induction hardening control technology.

Bioprocessing Research

Sandia develops techniques for catalysis in projects that use computer-aided molecular design of biomimetic carbon dioxide activation catalysts. Research goals include computer-aided molecular design of catalysts that mimic carbon-dioxide-activating enzymes; development of improved molecular modeling techniques; structural studies of carbon-dioxide-activating enzymes; synthesis, characterization, and testing of designed biomimetic catalysts; and integration of successful catalysts into a solar-driven process. The project involves collaborative work with several industry and university groups.

Industrial Waste Reduction Program

Sandia collaborates with industry to develop and commercialize cost-effective waste reduction technologies and practices. The program focuses on reducing wastes generated in manufacturing and improving the energy efficiency of industrial processes. The goal is to stimulate, facilitate, and coordinate development and transfer of waste reduction and energy saving technologies to industry.

The program uses cost-shared projects with industry and involves characterizing waste, assessing promising opportunities for waste reduction, and analyzing barriers to implementation of waste-reduction strategies. We transfer industrial waste reduction technologies to specific companies and to industry as a whole.

Transportation Sector (EE)

Sandia is developing technology to reduce the environmental impacts of automobiles by working on advanced materials; advanced manufacturing processes; and advanced batteries, fuel cells, and hybrid vehicle systems. This work is

primarily in support of the goals of the Partnership for a New Generation of Vehicles. Scientists and engineers at Sandia are developing more efficient engine technology, improved emission catalyst and emission systems, and improved batteries for electric vehicles.

Sandia has a cooperative research and development agreement with the United States Advanced Battery Consortium for research and development of electric vehicle battery technologies. The objective is to advance these technologies to a level that will encourage industry to become a partner in the development program. If successful, industry would then begin development and commercialization of batteries for electric vehicles.

Sandia has initiated several new cooperative research and development projects in materials and materials processing with the domestic automotive industry through the United States Automotive Materials Partnership. Partnerships focus on developing new and improved light metal components and improved manufacturing processes.

Sandia scientists and engineers are also developing new materials, fuel processing catalysts, and improved manufacturing processes for batteries, fuel cells, and supercapacitors. This could lead to future vehicles with electrochemical propulsion systems.

Office of Civilian Radioactive Waste Management

Sandia's major activities for the Office of Civilian Radioactive Waste Management address transportation and geologic disposal of spent fuel and high-level radioactive waste. The work directly supports three strategic program goals: providing transportation of spent fuel, determining the suitability of Yucca Mountain as a disposal site, and providing for timely waste emplacement in a disposal facility. In addition, Sandia participates actively in the efforts to strengthen fiscal and program management practices. During recent years these efforts have included specific improvements in planning, budgeting, scheduling, reporting, record keeping, and quality assurance.

Nuclear Waste Fund (DB)

Yucca Mountain Site Characterization Project

The Yucca Mountain Site Characterization Project is investigating the feasibility of disposing high-level radioactive waste in unsaturated volcanic tuffs. The site is at Yucca Mountain in southern Nevada, adjacent to the Nevada Test Site. As a member of the management and operating team, Sandia collects laboratory and field data, develops detailed models for individual processes, assesses the behavior of the total system, and estimates its long-term performance for comparison with regulatory standards. Sandia's specific responsibilities in this multifaceted project include:

- identifying the features, events, and processes that might affect the repository during the 10,000-year regulatory period and then constructing scenarios to develop numerical models that describe the future states of the repository system;
- performing laboratory experiments to understand fluid flow and radionuclide transport in unsaturated tuff (interactions between flow in fractures and in the rock matrix, nonisothermal effects, geochemical retardation, and scaleup problems);
- developing numerical models that describe the results of fluid-flow and transport experiments in the laboratory;
- conducting laboratory and field experiments to assess the effects of disturbances from the construction and operation of a repository, including thermal and mechanical changes in the host rock from hot waste;
- developing and evaluating conceptual designs for seals in the repository's boreholes, shafts, and drifts;
- using geostatistical data to construct three-dimensional representations of Yucca Mountain lithology to predict the location of rock units and for numerical simulations of the total system;
- using geophysical techniques and direct observation to assess rock-mass quality in exploratory shafts as an aid to construction;
- conducting studies that investigate the effects of climate change on infiltration and on the resulting percolation flux through the repository;
- conducting a performance assessment by abstracting appropriate models from detailed process models, linking coupled processes, performing stochastic calculations of radionuclide releases for the scenarios, and deriving complementary cumulative distribution functions for the releases; and
- developing decision-analysis capabilities to aid in cost-efficient data collection.

The information obtained from the above studies is being combined with information from management and operating teammates in total-system performance assessments to help judge the suitability of Yucca Mountain as a repository. These iterative preliminary assessments (two of which have been completed) are also used to help guide site characterization and design-related activities. Ultimately, the Yucca Mountain Project test and analysis results will be major parts

of the license application that DOE will submit to the Nuclear Regulatory Commission. Completion of these assessments is essential to timely waste emplacement because assessments must be available for the commission to examine as it determines the suitability of the repository.

Transportation Studies for the Office of Civilian Radioactive Waste Management

Sandia's Center for Transportation Technology continues to develop technologies for the design of safe and efficient systems for transporting spent fuel and handling packages. The design and production of actual hardware for transporting commercial wastes to interim storage or repositories are being performed in the private sector. The Center for Transportation Technology will continue to contribute to the development of technologies that facilitate design optimization and certification of the new generation of spent fuel packagings to ensure safety. Sandia will have a special role in pilot- and full-scale testing of designs offered by the private sector for DOE's multipurpose canister, the package that will carry spent civilian reactor fuel from the reactor site to interim storage and to a final disposal site. Sandia's unique capabilities in container testing are being qualified for use in future certification of these waste packages. Sandia also has a central role in the Office of Civilian Radioactive Waste Management's development of a burnup credit methodology to increase efficiency and reduce costs in the development of storage, transportation, and disposal packages.

Sandia's Community Involvement and Issues Management Office supports the Office of Civilian Radioactive Waste Management via a credible discussion of the potential impacts of alternative high-level nuclear waste management strategies.

Office of Nuclear Energy

Sandia's current efforts for the Office of Nuclear Energy focus on existing and advanced light water reactor technology. Nuclear power is an essential component of this nation's energy supply, and its environmental advantages are becoming known because of worldwide concern over the emission of greenhouse gases from fossil-fuel power plants. The United States has invested more than $200 billion in nuclear power facilities that generate 20 percent of the nation's electricity. Nuclear power plants are licensed for forty years, but studies indicate that plant life could be extended an additional twenty to thirty years. If an average of ten years of additional operation could be gained, $170 billion would be saved.

Our activities include studies of the following: systems concepts; technology evaluation; safety and reliability; electronic devices operating in severe environments; management techniques to ensure functionality of aging equipment; component testing; engineering of high-reliability components; and materials behavior and degradation.

These efforts are expected to increase with corresponding increases in funding levels for Sandia, given new administration goals to support only light water reactor concepts and increased emphasis on maintenance of the light-water-reactor option for domestic electricity generation.

Nuclear Energy Research and Development (AF)

This work will improve the safety, reliability, and cost-effectiveness of commercial light water reactors and allow license renewal of existing light water reactors.

Sandia operates the Light Water Reactor Technology Center for DOE. Activities include development and implementation of reactor safety features and concepts that offer significant safety improvements and longer operating lives, and development of approaches for improving the reactor licensing process. Projects include studying the technical, institutional, and economic aspects of extending the licensed lifetimes of commercial nuclear power plants, conducting technical studies in support of DOE's nuclear regulatory reform activities, evaluating Nuclear Regulatory Commission regulations being developed, and applying new techniques to the reactor licensing process.

The Light Water Technology Center works with the nuclear power industry to resolve technical issues associated with extending the useful lives of light water reactors. We will also investigate improved approaches to licensing nuclear power generation plants and explore technological developments in support of future nuclear plant designs. This work is closely coordinated with industry, universities, and other national laboratories.

These programs form a basis for closer cooperation with industry. We have formed technology alliances with industry that couple Sandia's strengths with the nuclear power industry's experience and knowledge to address issues of importance to current and future nuclear power plants.

Assistant Secretary for Fossil Energy

Sandia's fossil energy programs support DOE's goals by developing technologies that promote the clean and efficient use of the nation's coal, oil, and natural gas resources and by maintaining a secure economic supply of natural gas and crude oil. To this end, we evaluate the impact of fossil fuel use on the environment and work to mitigate adverse effects of energy use.

Sandia develops new technology in designing and

optimizing clean current and next-generation coal combustion systems; developing advanced catalysts and process concepts to convert natural gas and coal to environmentally compatible liquid fuels and for high efficiency natural-gas-driven fuel cells; providing scientific support to assure reliable design and safe performance of underground storage systems; and providing geophysical instrumentation systems for improved fossil energy reservoir diagnostics.

We maintain collaborative research and development partnerships with the coal, petroleum, natural gas, and fuel cell industries and with universities and other national laboratories. Our coal combustion programs interact strongly with US industry through a number of Sandia/California Combustion Research Facility programs. Our commitment to national security and DOE policy continues to guide Sandia's program efforts, including our support of the DOE Office of the Strategic Petroleum Reserve.

Coal (AA)

Coal Conversion

Sandia supports the research program implemented by the DOE/Pittsburgh Energy Technology Center by leading efforts in catalyst development for direct and indirect liquefaction processes. This work involves studying coal reactivity, understanding the relationship of reactivity to the molecular and macroscopic structure of coal, and developing advanced catalysts and catalytic processes for coal conversion.

Research is focused on the catalytic conversion of coal to liquid fuels at more moderate temperatures and pressures with optimum hydrogen use and with effective removal of sulfur and nitrogen. We are also using computer-aided molecular design techniques to study coal structure and design catalysts for the direct conversion of light hydrocarbons to alcohol and other liquid fuels. Sandia is establishing a center for the evaluation of catalysts for DOE's Fine Particle Catalyst Program.

Coal Combustion

Sandia uses its Combustion Research Facility in conjunction with DOE's Office of Fossil Energy and with industrial partners in the United States to develop predictive models of the behavior of the organic and inorganic constituents in commercially important coals from the United States to use in the present and next generation of coal combustion systems.

The work includes determining the chemical kinetics and mechanisms of coal pyrolysis and char oxidation and determining the significance of the quality of coal on unburned carbon in the exhaust. Sandia conducts pilot-scale research to establish the mechanisms of transformation, release, and deposition of inorganic species during coal combustion, develops user-oriented models to predict the combustion and behavior of the ash of coals from the United States in current and next-generation coal combustors, and develops and validates optical diagnostic sensors for in situ measurement of state properties, gas species composition, and particulate loads in coal combustors.

Gas (AB): Natural Gas Research

The natural gas program seeks to improve the production, quality, and utilization of natural gas from conventional and low-permeability gas reservoirs by combining comprehensive geologic characterization with the development of new reservoir stimulation technology and by the upgrading, conversion, and delivery of natural gas products.

Sandia performs geotechnical studies in sedimentology and natural fractures; geomechanics and in situ stress; and reservoir stimulation. Sandia is developing a methodology to aid industry in understanding and exploiting natural fracture systems in US western basins. Sandia is also performing basic research in biomimetic catalysts for direct conversion of natural gas into fuel liquids.

Petroleum (AC)

The petroleum program focuses on advanced reservoir evaluation technology and improved oil recovery. Sandia is developing superior geophysical techniques for improved reservoir characterization and in situ process monitoring. Key efforts are the development of advanced computational capabilities for design and assessment of the many different source receiver variations that are possible and the interpretation of field data by both forward and inverse analyses. Selected methods are evaluated in field experiments at various sites in conjunction with other national laboratories, industry, and universities.

Sandia is also developing technologies to improve production and recovery of domestic oil. A reservoir simulation has been developed that describes and predicts resistivity changes. Sandia has measured in situ stresses and other long-term phenomena in several producing fields, including the Ekofisk Field in the North Sea (in conjunction with Phillips Petroleum). This has led to a concept of geomechanics that views reservoirs as dynamic systems to be studied with full awareness of changing conditions over reservoirs' lifetimes. Sandia participates in DOE's Natural Gas and Oil Recovery Technology Partnership Program with the other multiprogram laboratories to match technology with the needs of the natural gas and petroleum industry. In FY 1995 the partnership was expanded by the Advanced Computational Technology initiative, an effort to work on a

cost-shared basis with the natural gas and oil industries to utilize, expand, and enhance Sandia's capability to find and evaluate oil and gas resources.

Strategic Petroleum Reserve (SA): Storage Facilities Development

Sandia is developing technology for safe underground crude oil storage in the US Strategic Petroleum Reserve and to support commercial underground storage of petroleum liquids and natural gas. The program involves site characterization, engineering design assistance, and evaluation. The program fields instrumentation to provide long-term cavern monitoring, validate cavern creep closure models, assess the integrity of wells and casings penetrating the caverns, and certify the integrity of caverns. In addition, engineers address specific geotechnical problems (e.g., the potential impact of water leaks on withdrawal of oil from storage in mines) and conduct studies to determine optimum cavern drawdown scenarios based on geotechnical considerations.

The technology developed for cavern creation, testing, and operation is being applied to commercial cavern development for natural gas storage.

3.1.3 Science and Technology Programs

Sandia has numerous projects that contribute to DOE's science and technology mission. These projects include established activities in scientific computing, basic energy sciences, and magnetic fusion energy. Research in global climate change for the Office of Health and Environmental Research is a growing responsibility. Advanced computational techniques and information technology are an integral part of these activities, and educational outreach efforts are improving the nation's science and mathematics education infrastructure.

Sandia stresses three important themes in the execution of these research and development activities:

- excellence in scientific research;
- integration of basic research, applied research, and technology development; and
- impact on US industrial competitiveness.

One metric for excellence is winning national and international awards. During the past few years, Sandia researchers have won several such awards, including the Coblentz Award (1995), the International Gordon Bell Prize (1994), the International New Materials Prize (1993), the Dillon Medal (1991), the E.O. Lawrence Award (1985 and 1990), the Karp Prize, and the Silver Medal of the Combustion Institute.

Every phase of Sandia's development cycle integrates science and technology. Examples include geoscience and technology, combustion science and technology, and scientifically tailored materials. In each case, basic research is integrated directly into the objectives of DOE technology programs.

Although this research and development composes only a small portion of Sandia's work, it has a major impact on our interactions with US industry. For example, nearly 60 percent of Sandia's cooperative research and development agreements originate in research for the Office of Basic Energy Sciences and the Office of Scientific Computing. Our projects are also characterized by numerous interactions with US industry.

Office of Energy Research

Sandia's Office of Energy Research provides the foundation for many energy, environment, and manufacturing technologies. The Office of Scientific Computing funds a research program in the development and application of advanced computational techniques. Office of Basic Energy Sciences projects include a national mission in combustion science.

We expect to expand our basic research. Our magnetic fusion energy projects support a long-term, nationally coordinated program and US participation in the international thermonuclear experimental reactor design project. In support of the Office of Health and Environmental Research, we are developing instrumentation and algorithms for measuring water vapor and cloud distributions. Sandia also provides DOE-wide technical direction of the emerging program in unmanned aerospace vehicles and small satellites. These activities support Sandia's integrated capabilities in advanced manufacturing, electronics, advanced information, and pulsed power technologies.

Magnetic Fusion (AT)

Sandia's Magnetic Fusion Program is developing a technology base for the design of components that will perform satisfactorily in fusion plasma environments. To achieve this goal, we study the interactions of plasmas and materials, the behavior of materials exposed to high heat fluxes, and the interfaces of plasmas and fusion reactor walls. Extensive analyses of prototypes are required before components can be qualified for operation in fusion machines. This activity involves selecting, specifying, and developing materials for components exposed to high heat and particle fluxes. Materials samples and prototype

components are tested in Sandia's Plasma Materials Test Facility. This facility uses high-power electron beams to generate high heat fluxes that simulate fusion reactor environments. Materials and components are also exposed to actual tritium plasmas in Sandia's Tritium Plasma Experiment, which has been relocated to Los Alamos National Laboratory. Materials from these tests are characterized using Sandia's accelerator facilities for ion beam analysis.

Sandia directly supports US and international fusion machines. This support includes: diagnostics, tritium inventory assessments, and materials studies for the Princeton Tokamak Fusion Test Reactor; materials analysis and diagnostic development for the General Atomics DIII-D Advanced Diverter Project; and a full toroidal belt advanced limiter test system for the TEXTOR Tokamak in Germany. Sandia designed and installed on the Tora Supra Tokamak in France an actively cooled pumped limiter that was operated at steady-state with a peak heat flux of 30 million watts per square meter.

In all these experiments, Sandia participates in machine operation and provides specialized diagnostics and data analysis for evaluating plasma material interaction processes, boundary layer plasma control, and plasma-facing components. In addition, Sandia continues to collaborate on plasma material interaction and high-heat-flux issues with both the Joint European Torus in Abingdon, United Kingdom, and the JT-60U in Japan. At DOE's direction, Sandia entered into cooperative exchanges on plasma-facing component development with several laboratories in Russia.

In 1992 an international agreement was reached by the United States, Japan, the European Union, and Russia to begin a six-year engineering design for the International Thermonuclear Experimental Reactor. Sandia supports this project by providing personnel to help manage the program in both the United States and Germany. Sandia also has a major role in research, development, and design of plasma-facing components for the US effort. Continued international cooperation is essential to the success of the International Thermonuclear Experimental Reactor Project. Domestically, development of plasma-facing components for the project is a cooperative effort of Sandia, other national laboratories (Argonne, Oak Ridge, Idaho, Lawrence Livermore, Los Alamos, and Princeton), universities (University of California at San Diego, University of Illinois, and the University of New Mexico), and industry (headed by McDonnell Douglas and including Raytheon, General Atomics, Westinghouse, and Rocketdyne). Sandia is coordinating this multisector cooperative effort for the US International Thermonuclear Experimental Reactor Home Team.

Sandia's expertise in materials and components for magnetic fusion systems also supports the Tokamak Physics Experiment (the next major US plasma confinement experiment). We provide design support, high-heat-flux testing, and hydrogen compatibility measurements for the plasma-facing components.

Scientific Computing: Massively Parallel Computation

Sandia's computational sciences research develops methods for solving scientific and engineering problems and a software infrastructure for parallel computing. Research includes the development of algorithms for solving computational problems in physics, chemistry, biology, and engineering. Research in software infrastructure for parallel computing includes work in parallel operating systems, static and dynamic load balancing methods, graphics and visualization methods, and performance evaluation methods. This program uses the performance andcost advantages of massive parallelism to meet critical DOE mission requirements in advanced computing.

Advanced computing technologies are important to national security in both a traditional and economic sense. Sandia has a leading role in the national high-performance computing and communications program. We also have a leading role in computational design of catalysts and biocatalysts, rational drug design, and a variety of scientific problems of national significance. The successful predictions of the impact of the Shoemaker-Levy 9 comet on Jupiter used Sandia's massively parallel computing system. Sandia also maintains a research program that applies this technology to industrial problems. Our work in parallel dense equation solvers applied via the boundary element method to structural mechanics, acoustics, and electromagnetics won the 1994 Gordon Bell Prize for the most significant achievement in parallel computing. Our project in parallel sparse equation solvers applied through the finite-element method to simulation of chemically reacting flows was selected as one of four finalists in the international competition for the Gordon Bell Prize. Sandia is the only institution to have received the Gordon Bell Prize twice. Our work in massively parallel computing has also won the Karp Prize and three Research and Development 100 awards.

The massively parallel computing research laboratory at Sandia/New Mexico creates prototypes of advanced, high-performance computing, such as scaleable massively parallel algorithms, graphics and visualization, and systems software. Sandia's massively parallel computing program has interdisciplinary partnerships with DOE Defense Programs applications to create new simulation capabilities. We also cooperate where appropriate with US industry on mutually beneficial technology development.

The Center for Computational Engineering at Sandia/California helps scientists and engineers in industry use massively parallel processing to solve problems impracticable on conventional machines. The center focuses primarily on software engineering for applications. Applications being investigated include pharmaceutical design (such as drug/organism interactions and designer chemotherapy) and global climate change. The Center for Computational

Engineering creates methodologies for problem specification, code generation, and data management, as well as theorems for generating proofs of software correctness.

Basic Energy Sciences

Sandia supports the Office of Basic Energy Sciences with several research efforts. Larger projects include combustion research and scientifically tailored materials. Smaller projects include engineering and geoscience research.

Chemical Sciences

Sandia's largest project for the Office of Basic Energy Sciences is at the Combustion Research Facility at Sandia/California. In this DOE user facility, Sandia staff and visiting researchers develop advanced research methods and apply them to the study of fundamental combustion processes.

The Combustion Research Facility is available to a wide variety of users. Major users include those supported by the Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy who conduct industry-oriented research in transient and continuous combustion (including coal and biomass processes) and in advanced materials synthesis.

DOE sponsorship and policies facilitate a vigorous visiting scientist program that attracts approximately one-hundred long-term users to the Combustion Research Facility every year. Visiting scientists from industry, universities, and government-sponsored organizations such as the national laboratories conduct basic and applied combustion research and publish their findings. Their participation is an important vehicle for transferring new combustion technology to a large user community. A postdoctoral research program provides advanced training for combustion scientists and engineers and enhances the facility's research productivity.

The continuing programs at the facility help maintain US preeminence in the science and technology of combustion. Facility staff represent the United States in International Energy Agency programs on Energy Conservation in Combustion. International Energy Agency activities involve collaboration with foreign scientists in engine studies and coal research through an informal exchange program.

The long-range objective of the facility is to develop combustion technology to maximize energy efficiency, fuel utilization, environmental protection, industrial productivity, and equipment design. Research conducted for the Office of Basic Energy Sciences' Chemical Sciences Division includes combustion diagnostics, combustion chemistry, reacting flows, and combustion modeling.

A primary thrust of the research program is the development of advanced combustion diagnostic techniques. Because of their nonintrusive nature and great versatility, laser-based optical techniques receive the strongest emphasis. Laser-induced fluorescence, quantitative imaging, and nonlinear optical wave mixing are among the diagnostic methods being developed. These techniques are used to measure temperatures, species concentrations, and other parameters important to understanding combustion phenomena.

Work in combustion chemistry improves our understanding of the complex chemical processes involved when fuels burn. The program determines the rates and mechanisms of elementary chemical processes and stresses the close coupling of experiment, theory, and modeling. Modeling of experiments conducted in low-pressure flames yields insight into the dominant chemical reactions of combustion. Related efforts address fundamental questions of molecular dynamics and support development of models of processes important to energy-producing technologies. The formation and destruction of nitrogen-containing pollutants, the oxidation of hydrocarbons, and chemical paths leading to soot precursors in rich flames are emphasized.

A multidisciplinary program in reacting flows establishes an important link between fundamental studies of combustion chemistry and the world of practical combustion. This program is increasing our understanding of the fundamental interactions between chemistry and fluid dynamics in combustion. Results are being used to improve predictive capabilities for turbulent combustion of hydrocarbon fuels. Experimental studies include investigation of primary turbulent transport in flows involving complex fluid mechanics but simplified chemistry.

Sandia's combustion modeling program is developing numerical methods to predict the mutual influences of chemical reactions and fluid transport on one another. Our current modeling focuses on developing a fundamental understanding of important subprocesses so that future simulations will contain more realistic chemical and physical descriptions of combustion phenomena. We are including fully detailed chemical mechanisms in advanced combustion models.

Materials Sciences

Sandia's Materials Sciences Program has three elements: scientifically tailored materials; defects and impurities in solids; and synthesis and processing. The effort in scientifically tailored materials emphasizes research supporting the development of advanced manufacturing technology relevant to US industry.

Scientifically Tailored Materials

Sandia's effort in scientifically tailored materials combines theory and experimental capabilities in solid-state sciences, atomic-level diagnostics, and materials synthesis

and processing to produce new classes of materials for energy applications, defense needs, and industrial applications.

Scientifically tailored materials research explores how capabilities developed in various projects can be used to enhance the competitiveness of US industry. Therefore, we frequently interact with representatives from industry, universities, and other national laboratories to define critical needs and plan collaborative efforts. Many cooperative research and development agreements with industry have grown out of research in this area.

Research continues in the physics and chemistry of ceramics synthesis and processing, the use of energetic particle beams for the synthesis and study of materials, high-temperature and organic superconductors, tailored surfaces and interfaces for materials applications, chemical vapor deposition sciences, artificially structured semiconductors, advanced growth techniques and science of epitaxy, boron-rich solids, atomic-level science of interfacial adhesion, and synthesis and processing of nanometer-sized clusters for energy applications. Considerable synergy exists among these program elements. Most have common themes based on either the science or the use of common synthesis and processing approaches. These common themes are synthesis and processing, epitaxial materials growth, surfaces and interfaces, energetic particle beams, and high-transition-temperature superconductivity.

The Novel Superconductors Project investigates electronic, structural, and chemical properties of inorganic, high-temperature superconductors and organic superconductors. The goal is to develop a fundamental understanding of the physics of superconductivity in these materials. These studies are integrated with an extensive synthesis and processing program to produce materials with tailored properties and to develop prototype devices.

Research on compound semiconductor strained-layer-superlattice structures and other artificial structures is pioneering, award-winning work. A strained-layer superlattice consists of many thin layers (each a few tens of angstroms thick) of alternating single-crystal semiconductor materials. Superlattices typically are made from the more common periodic table class III–V semiconductors. The multiple thin layers behave macroscopically like new semiconductor materials. Their structures exhibit electronic and optical properties entirely different from those of the constituent materials. The combination of thin layers, lattice strain, and novel patterning allows flexibility in tailoring the properties of these new materials. Sandia is using these new semiconductors to develop high-speed, field-effect transistors, optoelectronic emitters, detectors, novel optoelectronic mirror devices, and broadband light sources.

Chemical vapor deposition science explores the basic physics and chemistry of chemical vapor deposition used in the synthesis of materials, particularly thin films. Our research has concentrated on semiconductors and materials used to make semiconductor devices. However, the understanding gained in this research is applicable to other classes of materials, such as coatings resistant to corrosion and wear, high-temperature superconductors, optical materials, and reduced-friction coatings. Research work will be extended to these materials.

Basic research in energetic particle synthesis and the science of materials focuses on the interactions of ion, electron, laser, and plasma beams with metals, semiconductors, and dielectrics. This research on materials synthesis and modification uses the unique capabilities of energetic particle beams to create new materials, determine their properties, and advance materials processing by elucidating fundamental processes.

We study ceramics to develop a fundamental understanding of the atomic and molecular processes that govern the structure and properties of ceramics. The ultimate goal is to improve ceramics processing by gaining a better understanding of the underlying chemical and physical principles.

Research continues on the atomic-level science of interfacial adhesion. Despite the pervasive nature of adhesion problems in materials science and engineering, solutions are almost always the result of trial and error. Significant technological and economic gains can be made by developing a scientific basis for the phenomena of interfacial adhesion. This will allow the selection of material combinations to provide specific interfacial characteristics. Therefore, this research seeks to understand at the atomic level the nature of the physical and chemical interactions that bind solid surfaces.

The scientifically tailored materials program is investigating atomic-level processes that control the growth and properties of thin-surface layers. This program is also exploring the use of ion, laser, and electron-beam excitation of surfaces during epitaxial growth of semiconductors to control the kinetic energy of surface atoms and extend the range of tailorable epitaxial materials. Additionally, we are examining potential applications of boron-rich solids, which have unique bonding, electronic, and transport properties when used as high-temperature semiconductors. These refractory materials appear promising for use in high-efficiency thermoelectric energy generators and as neutron detectors.

Our newest initiative exploits Sandia's patented technique for producing novel nanometer-sized clusters with potential applications in energy technologies. These clusters are aggregates of a few to a few thousand atoms or molecules whose properties are neither like bulk materials nor like individual atoms or molecules. The clusters represent a totally new class of materials with novel electronic, optical, and chemical properties. Emphasis is on inexpensive metal and semiconductor clusters as alternatives to precious metal catalysts for coal liquefaction, control of emissions, and solar photolysis.

Defects and Impurities in Solids (Computational Materials Science)

Crystalline defects and impurities often determine the properties of solids. Thus, this program seeks to understand

and control such imperfections, which are crucial to technological applications of solid materials.

Unique experimental and theoretical tools developed in this program are combined to study structural defects and impurities in solids and on surfaces. The experimental tools are high-resolution transmission electron microscopy, high- and medium-energy ion scattering facilities, video low-energy electron diffraction, surface analysis, scanning tunneling microscopy, and low-energy electron microscopy. Theoretical tools developed and employed include quantum chemistry codes, local density approximation/pseudopotential methods, the embedded atom method, and cluster functional methods for large-scale atomistic computer simulations.

These experimental and theoretical capabilities are used to study grain boundaries, interfaces, and surfaces in metal alloys and intermetallic compounds; impurity segregation to these boundaries; and interactions with dislocations, gas bubbles, and defect clusters. Growth of metal layers on substrates is investigated using scanning tunneling microscopy, low-energy electron diffraction, and low-energy electron microscopy. Theoretical models are developed for the nucleation and growth kinetics of thin film layers. High-resolution transmission electron microscopy is used in conjunction with large-scale computer simulations to resolve the dislocation core structure in intermetallic compounds and analyze the dislocation network configuration and evolution during plastic deformation.

Many of the results from this research are used in concurrent development and engineering projects at Sandia and other national laboratories. In addition, results are disseminated to materials science programs at universities and industrial research and development laboratories via the Sandia visiting scientist program in computational materials science. Collaborations with industry are also accomplished through cooperative research and development agreements.

Synthesis and Processing Center

Sandia coordinates activities within the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials. This center is a cooperative venture that involves Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Engineering Laboratory, University of Illinois Materials Research Laboratory, Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, Pacific Northwest Laboratory, and Sandia National Laboratories. The center brings together elements of the existing Basic Energy Sciences core programs at these laboratories and also includes appropriate Basic Energy Sciences-funded university grant research. The center enhances the science and engineering of materials synthesis and processing to meet DOE's programmatic needs and facilitate the technological exploitation of materials.

Synthesis and processing are essential elements of materials science and engineering that deal with the assembly of atoms or molecules to form materials, the manipulation and control of structures at all levels from the atomic to the macroscopic scale, and the development of processes to produce materials for specific applications. Synthesis and processing span the range from fundamental research to technology applications.

Basic research in this area ranges from the creation of new materials and the improvement of the properties of known materials to the understanding of such phenomena as diffusion, crystal growth, sintering, and phase transitions. On the applied side, synthesis and processing translate scientific results into useful materials by developing processes capable of producing high-quality, low-cost products. To guide the research and development agenda of the center, an industrial steering group has been formed.

The center has developed a number of coordinated, focused multilaboratory projects. The selection criteria for technical activities in these projects are

- outstanding science with a clear relation to technology,
- strong existing or potential connections to DOE technologies, and
- strong industrial connections through existing or new cooperative research and development agreements.

At present, the center is emphasizing seven multilaboratory projects:

- conventional and superplastic metal forming,
- materials joining,
- nanometer-scale materials for energy applications,
- tailored microstructures in hard magnets,
- microstructural engineering with polymers,
- processing for surface hardness, and
- mechanically reliable surface oxides for high-temperature corrosion resistance.

Two other projects are in the planning stages. These projects will study photovoltaic materials and bulk metallic glasses.

Geosciences

Sandia's basic research in geosciences encompasses geophysics, geochemistry, geomechanics, and geology, concentrating on the study of dynamic processes in the

earth's crust. Sandia's research is focused on geophysical imaging of the subsurface, fluid flow through fractures and porous media, experimental rock mechanics, and the geochemistry of mineral surface interactions with fluids.

A better understanding of fluid flow through complex media (including fractured rock and soils) will aid DOE programs in waste disposal and isolation, fossil fuel exploration and extraction, and environmental restoration. Sandia is using a combination of numerical and experimental techniques to develop improved models for fluid flow through fractured media, including the study of single- and two-phase flow in irregular fracture apertures using two-dimensional laser profilometry, nuclear resonance imaging, and optical techniques. An experimental approach to fluid flow characterization is being applied at Carlsbad Caverns in New Mexico. Water travel times through fractured limestone from the surface into the cave are being documented and modeled in a unique field study of oxygen isotopic data collected from dripwaters. Fluid flow through complex geologic media (focusing on retardation and sorption processes) is being modeled using lattice gas automata computer codes. Fluid paths and rates of flow through the earth's subsurface are also being investigated using three-dimensional electromagnetic imaging techniques.

Sandia's geochemistry research uses a combination of analytical, theoretical, and experimental approaches to study reactions between fluids and mineral surfaces. Projects are focused on mineral surface kinetics for low- and medium-temperature environments, including cation and organic anion reactions with carbonates and other minerals important in diagenesis. We have developed a new experimental technique for measuring very slow ion diffusion into silicate minerals. Sandia has also pioneered the use of several spectroscopic techniques to study mineral surfaces and is using molecular modeling techniques to augment the experimental and analytical studies. State-of-the-art experimental facilities in geomechanics provide the opportunity for advances in understanding shear strain localization as a precursor to fracturing in various types of rocks. The micromechanics of brittle failure processes in porous and nonporous geomaterials are also being studied using laser confocal microscopy and triaxial compression experiments.

Basic research activities in the geosciences develop a fundamental understanding of geologic processes. Projects change every two to four years as they evolve to support DOE interests. Sandia's focus areas support many different DOE technology programs, including nuclear waste facility design, fossil energy exploration and storage, environmental restoration, and geothermal energy exploration.

Engineering Sciences

Sandia's research in engineering sciences includes several projects that seek to improve our understanding of the physics of fluids. As part of a study of multiphase flow, we have teamed with the Massachusetts Institute of Technology and Los Alamos National Laboratory to investigate suspensions of particles in Newtonian and non-Newtonian liquids by developing new theories, conducting numerical simulation, and performing experiments. This work has determined the effects of microstructures on the macroscopic properties of suspensions.

We are also developing and validating a statistical model of molecular mixing in turbulent flow. This model will be used to predict and interpret experimentally observed phenomena. In another effort, we are using optical techniques to investigate the supercritical water oxidation process. This process may be able to destroy toxic and hazardous wastes.

Biological and Environmental Research (KP)

During the past several years, global climate change has come to the forefront of the world's and the nation's science and policy agendas. Although most scientists agree that human-made, energy-related emissions will cause a greenhouse warming effect, there is uncertainty about the magnitude, timing, and distribution of this phenomenon.

To understand such issues better, the US government has embarked on a global change research program, with DOE as a major participant. To support DOE in this role, we have drawn on Sandia expertise in remote sensing (from ground, air, and space), field testing, systems engineering, and massively parallel computing to conduct three program elements: measurement of water vapor and cloud distribution, measurement of atmospheric radiation, and climate studies (described below).

Novel Instruments and Algorithms for Measuring Water Vapor and Cloud Distribution—Key Uncertainties in Current Climate Models

Water vapor is the greenhouse gas that plays a key role in cloud formation and in driving atmospheric circulation through the release of latent energy. However, available instruments lack the vertical and temporal resolution required to study water vapor profiles adequately.

Working with the National Aeronautics and Space Administration, we have developed the next generation of a laser remote-sensing technique (Raman light detecting and ranging [lidar]) for providing high-vertical-resolution water vapor profiles during the night and day. We plan to use this technique at one of the DOE cloud and radiation test bed sites to study the distribution of upper tropospheric moisture, an important but poorly understood issue.

Although Raman lidar is a particularly robust way of

measuring water vapor profiles from the ground, different laser techniques are required for the longer ranges characteristic of air and space measurements. To this end, we are developing a miniature-package, water-vapor, differential-absorption lidar for small aircraft or unmanned aerospace vehicles.

Clouds are the other key feedback parameter. Uncertainty in radiative cloud feedback accounts for most of the uncertainty in predicted temperature rises if atmospheric carbon dioxide doubles. However, it is difficult to measure even the most basic cloud parameter (its shape), let alone the microscopic properties that affect the interaction of the cloud with the earth's radiation field. Therefore, we have developed a novel set of algorithms that uses the motion of clouds for extracting geometric information about cloud fields (e.g., cloud base heights) from sets of whole-sky imaging cameras.

We are now using Sandia's experience in massively parallel computing to develop novel ways of fusing these data with complementary data from sources such as satellites and radars to produce true three-dimensional maps. We are also developing a miniature cloud radiometer to provide key radiative properties such as cloud albedo, droplet size, and phase (ice or water). This miniature cloud radiometer will be compatible with both small unmanned aerospace vehicles and small satellites.

Atmospheric Radiation Measurement Sites

DOE's atmospheric radiation measurement program seeks to improve the understanding of earth radiation field/cloud interactions by studying these processes at intensively instrumented cloud and radiation test-bed sites. A new site scheduled to begin operation in FY 1996 will be located on Alaska's North Slope. This locale was chosen because the polar region is the heat sink in the overall climate and because the pole has extremes of insolation (six months of day and six months of night), humidity (wet summers and dry winters), and surface albedo (highly reflective snow that melts) that provide a stringent test of the understanding of earth radiation/cloud interactions. As the manager for this site, Sandia will be responsible for planning, implementation, and operation. Also, we will work closely with scientists at the University of Alaska to formulate the science plans and coordinate the atmospheric radiation measurement program with other research activities in the Arctic.

Unmanned Aerospace Vehicles and Small Satellites for Climate Studies

Although the initial phases of atmospheric radiation measurement emphasized ground-based measurements, it was recognized from the start that air- and space-based measurements are needed to provide information about radiative fluxes, water vapor profiles, and cloud top properties in the atmosphere and to extend the range of these measurements to regional and global scales.

Conventional aircraft and satellites can meet part of these needs but not all of them. For example, aircraft currently cannot operate for multiple days at the tropopause. DOE has proposed major initiatives that use a new generation of small unmanned aerospace vehicles, small satellites, and associated miniature instruments to fill these key measurement gaps. DOE has selected a Sandian as technical director and coordinator of this multilaboratory/multiagency program. Our role includes program formulation and direction, payload integration, and instrument development.

Sandia scientists developed and integrated a baseline radiometric payload for an unmanned aerospace vehicle. This payload worked flawlessly on one engineering test flight and eight scientific data flights at the DOE climate site in Oklahoma. These were the first climate measurements from an unmanned aerospace vehicle and constitute an unprecedented high-accuracy data set for testing our understanding of radiation transport in clear skies. The next step will use three specially developed instruments for measuring cloud heating and cloud properties. These instruments are playing a key role in our FY 1996 mission to address the critical issue of enhanced solar absorption in cloudy skies and to calibrate satellite measurements to leverage these valuable space assets for climate studies.

Office of Science Education and Technical Information

Sandia's Education Outreach initiative consists of an extensive and interrelated set of programs supporting scientific and technical education for students, teachers, and faculty. Each program is designed to improve scientific and technical literacy and increase the number of scientists and engineers from historically underrepresented groups in support of DOE's goal of a technically literate and culturally diverse work force. The programs are designed to encourage students interested in a career in science or engineering, beginning in grade school and continuing through college. Summer research programs are part of the postsecondary through graduate student activity and are designed to support Sandia's Affirmative Action Program by promoting the hiring of qualified individuals from these programs. Outreach programs also exist for teachers at all educational levels from grade school through university faculty.

These efforts are funded by DOE through Defense Programs and the Office of Science Education and Technical Information, which administers DOE initiatives.

Science and Mathematics Education Outreach Programs

Sandia's outreach efforts are described below under the general headings of pre-college programs, programs for college and university undergraduate students, programs for university graduate students, and programs for college and university faculty.

Pre-College Programs

Science and Mathematics Education Enhancement for Students in Grades 1 through 12

The Science/Math Carnival for elementary school students encourages educators to teach science and mathematics by offering up to fourteen hands-on activities. The carnival is staffed by 180 Sandia/California volunteers and in a twelve-month period typically visits about eighty schools and contacts 35,000 students.

The Summer Science Enrichment Program was developed by a Sandia/California engineer serving as a science advisor in the Oakland schools and was implemented in four Oakland elementary schools. This program is aimed at students who lack motivation in the classroom and who belong to traditionally underrepresented groups in science. An introductory evening of hands-on science activities for the families of the students encourages parents and children to enjoy science exploration at home. Parents are also invited to participate in as many of the daytime sessions as they can. This program emphasizes hands-on cooperative experiences with attention to integrating the arts, math, and literature in a science base. The program is structured around a hands-on science curriculum developed at the Lawrence Hall of Science.

The After-School Science Club was initiated for Oakland middle school students who were significantly below grade level in reading and critical thinking skills. Sandia/California Education Outreach developed the basic concept and format for the club, secured funding, and developed ideas for student summer projects. During the weekly sessions, students engage in a variety of experiments and activities. Evaluation demonstrated that the student participants improve their skills, show increased interest in science, and make progress in developing self-esteem.

The New Mexico State Science Olympiad is an academic interscholastic competition that increases student interest in and enthusiasm for science education. Middle and high school students participate in hands-on activities in almost every aspect of science. Students from across the state compete to participate in the state finals. Winners of both the middle school and high school divisions represent New Mexico at the national finals. The Science Olympiad is an opportunity for competitors to excel in scientific thinking and applied science, individually or on a team. Under the guidance of approximately 250 volunteer coaches throughout the state, these students balance knowledge of facts, concepts, processes, skills, and applications while competing in all areas of science. Sandia sponsors the New Mexico State Science Olympiad, providing support and advice. The state competition involves more than 750 students, 125 coaches, one hundred event supervisors, an eight-member advisory board, one state coordinator, and one state director.

The Expanding Your Horizons Program, sponsored by the Women's Math/Science Network, encourages junior high and high school girls to explore many scientific disciplines and numerous science and technology career options. The program is a day-long career conference that regularly attracts large crowds of students. Expanding Your Horizons encourages girls to study math and science in school and consider careers in mathematics, science, and technology. Sandia/California co-produces two Expanding Your Horizons conferences each year.

In the College Bound Program at the Southwestern Indian Polytechnic Institute, New Mexico and California Sandians work closely with the institute to provide ninth- through twelfth-grade students with the skills and motivation to remain in school and enter college in a math, science, or technological field. Students from fifteen tribal groups participate in the six-week intensive residential summer program at the institute in Albuquerque, New Mexico. Students attend classes, workshops, and field trips to increase their science, math, and communication abilities and to improve their problem-solving skills. The College Bound Program at the Southwestern Indian Polytechnic Institute also collaborates with the Rural American Indian Science Enrichment Project, a teacher-enhancement program funded by the Bureau of Indian Affairs.

The DOE High School Science Student Honors Program is offered for two weeks during the summer to introduce high school honor students in science to a diverse range of engineering research topics. Student are selected by their state, providing approximately fifty student participants. Goals of this program are to cultivate relationships with these outstanding students and to enhance Sandia and other DOE national laboratories' future technical work force.

The High School Speaker's Bureau provides high school teachers with speakers from Sandia to discuss specialized math and science topics and offer career information. Speakers from this program contact approximately 550 students per year.

The New Mexico Supercomputing Challenge provides an opportunity for hundreds of high school students to design and run computer programs. Sponsored by a number of state organizations, the program involves students in mathematics and computation science projects, then offers scholarships to promising students to attend New Mexico universities. The program fosters student creativity in applying computational solutions to scientific problems. Open to all secondary schools, this statewide competition

brings students together in problem-solving teams. Experts from national laboratories and research universities coach students in supercomputer use. Sandia provides training, supercomputer time, and coaches for the teams.

As part of the DOE National Science Bowl, Sandia hosts regional competitions for high school students in New Mexico and California. Teams from both states participate annually in this science, mathematics, and technology question-and-answer tournament. Sandia is represented by each winning team at the national finals held in Washington, DC. Nationwide, the program involves more than twelve thousand students from two thousand high schools.

The School Partnership Project recruits, trains, and equips scientists and engineers to conduct motivational hands-on science activities with students to make science more understandable, make science principles interesting and relevant, and foster positive impressions of science and scientists. Members of the Sandia technical staff develop and conduct monthly science enrichment activities at Albuquerque schools in direct support of current science curriculum topics. These activities are designed to offer resources to which teachers would not normally have access (such as liquid nitrogen, x-y plotters, and oscilloscopes). In addition, Sandia provides program ideas and technical assistance to local organizations involved in informal science education. Sandia also actively shares the principles and activities that have proven successful in the local program with other groups and organizations to promote national support of science education.

Sandia offers three supplementary student projects: Hands-on/Minds-on Technology for African-American students, the Dream Catcher Science Program for American Indian students, and the Hands-on Science and Engineering Program for Hispanic students. These classes are offered after school for several weeks during the fall and spring semesters and are taught principally by Sandia employees from the Black Leadership and Outreach Committee, the American Indian Outreach Committee, and the Hispanic Leadership and Outreach Committee.

Teacher Training and Curriculum Development for Teachers of Grades 1 through 12

Adventures in Supercomputing is a DOE-funded effort to bolster computer literacy and scientific understanding among teachers. At no cost to schools, Sandia and two other national laboratories offer participating schools the use of high-performance computers, software, networks, and expertise. A two-week summer institute at Sandia for New Mexico teachers introduces instructional materials for teaching computational science. It also demonstrates software applications and examples of high-level tools for modeling scientific problems.

The Bay Area Science and Technology Education Collaboration is a partnership that includes Sandia/California, three other bay area DOE laboratories, the Oakland Unified School District, local businesses, industries, and civic groups working together to improve mathematics, science, and technology education in the Oakland schools. Sandia/California is a full partner on the collaboration board, participates on collaboration subcommittees, and assists with curriculum development. Sandia's one-week Summer Teachers Institute helps Oakland teachers gain a better understanding of the basic science concepts taught through the Science/Math Carnival. Several one-day, Sandia-sponsored workshops each year prepare Oakland teachers to utilize selected science modules and provide teachers with kits for classroom use.

The Bureau of Indian Affairs and Rural Schools Science Advisors Program works with schools in five educational agencies, ten public school districts, and one private school system to provide teacher enhancement in science and mathematics instruction. Approximately 450 teachers have direct contact with their science advisor on a regular basis throughout the academic year. In addition, more than seven hundred teachers annually attend in-service workshops conducted by the program. More than nine thousand students are affected as a result of teacher involvement in the program. In the Rural American Indian Science Education Project, Sandia scientists, engineers, and technicians serve as long-distance consultants to science and mathematics teachers in rural and American Indian schools. Sandia personnel provide guidance on classroom experiments and examples of state-of-the-art, practical, scientific applications. A Sandia employee is assigned to visit a school once each semester and interact with faculty from the school weekly by phone or teleconference. Schools currently in the project are located in Arizona, Maine, New Mexico, North Carolina, North Dakota, South Dakota, Oregon, and Oklahoma.

The DOE-sponsored Teacher Research Associates Program provides summer opportunities in scientific and engineering research for outstanding high school science and mathematics teachers. These teachers receive a stipend of $550 per week, $1,000 for housing and travel expenses, tuition up to $200 for academic credit, and a follow-on activity award of $250 times the number of first-year teacher research associates at a given facility.

The Science Advisors Program enhances the mathematics, science, and engineering education of large numbers of students by helping teachers become more knowledgeable about and comfortable in teaching those subjects. The project assigns an engineer, technician, or scientist to support the faculty at an elementary or middle school one day a week for an entire school year. One unique benefit of the Science Advisors Program is that it does not target a particular group of students but benefits all children.

With Sandia's support, the Portable Science Advisors Program has expanded to Las Cruces and Carlsbad, New Mexico and El Paso, Texas. This program is modeled after

the Albuquerque and New Mexico Bureau of Indian Affairs Science Advisors Program but is implemented through a partnership of area businesses. Sandia provides guidance for the design of each individual program, assistance for establishing resource centers, technical assistance, and workshops for science advisors and teachers.

The Science Education for Public Understanding Program is a collaboration between Sandia and the Lawrence Hall of Science. This program develops middle school strategies for teaching science with a focus on environmental issues. The program provides teachers with a model for hands-on instruction and all materials needed for performing the experiments in a class of thirty-two students. Students working with the program modules collect and process scientific evidence and use it to make decisions. As a result they begin to appreciate both the power and limitations of science.

Science Seminars are offered through a partnership between Sandia/California and the Livermore Valley Unified School District. The seminars are open to all first- through twelfth-grade teachers in the area.

The Summer Teacher-Enrichment Program provides an opportunity for middle- and high-school teachers to upgrade their knowledge and skills through practical work experience in areas related to their educational specialties and exposure to programs and projects at Sandia.

The Teacher Opportunities to Promote Science Program was developed and implemented by Sandia and Los Alamos national laboratories as a teacher enhancement program for middle school teachers in rural areas of New Mexico. Through participation in this program, teachers improve their teaching skills and ultimately serve as role models and mentors to their colleagues. Sixth-, seventh-, and eighth-grade teachers participate in an intensive three-year training program in science. The teachers attend a three-week summer institute, participate in three follow-up workshops during the academic year, and receive visits to the classroom by program staff. Additionally, participants have the opportunity to establish a student/parent component at their schools. One hundred participants (fifty at each laboratory) have shared their expertise with approximately six thousand students. Participants also facilitated workshops for teachers in their districts and at state and national conferences. Hundreds of families have been affected through the student/parent component.

The Science Understanding Promotes Environmental Responsibility Summer Institute for middle- and high-school teachers presents the science behind such environmental issues as risk assessment and management, groundwater cleanup, plastics, and hazardous waste cleanup. The institute offers presentations by Sandians and outside speakers, field trips, and laboratory work. Teachers are trained using the Science Education for Public Understanding Program environmental science modules developed by the Lawrence Hall of Science. Another important thrust of the institute is training leadership teams who spearhead reform in their schools through teacher in-service workshops, by encouraging cross-curricular teaching, and by deploying alternative teaching and assessment strategies.

The Leadership Academy for Science Education Reform is a multiyear workshop for elementary school teachers conducted by the California Science Implementation Network, the National Science Foundation-funded State Reform Program for elementary schools, and the Lawrence Hall of Science. The National Science Foundation's National Teacher Enhancement Project is partially funding this three-year program at $100,000 a year. The academy supports California's educational reform movement by creating a group of lead teachers who are mentors for their colleagues and credible role models of good science instruction. The program brings together the strengths and long-term commitments of schools, scientific communities, and the California Department of Education. Each year, the same group of teacher/leaders spends three weeks in July and six days of the school year strengthening their science knowledge, pedagogy, assessment skills, and leadership abilities. The academy's program is based on a teaching/learning model that parallels the way scientists acquire knowledge and solve problems. The academy uses the unique resources available at Sandia by immersing the participants in research conducted at the laboratory, where the teachers explore, investigate, and participate in hands-on science. By inviting teachers to join Sandia scientists and engineers in solving problems, DOE provides an opportunity for them to explore what it means to use the scientific method. The partnership with the Lawrence Hall of Science allows teachers to work with educators in applying their hands-on science experience in their classrooms. The involvement of the California Science Implementation Network brings the strength of the State Department of Education to these reforms in science instruction.

Programs for College and University Undergraduate Students

The American Indian Community College initiative develops accredited, two-year technology programs at the Southwestern Indian Polytechnic Institute in Albuquerque, New Mexico. This initiative provides a two-year curriculum that meshes with both the Southwestern Indian Polytechnic Institute and Haskell Indian Nations University in Lawrence, Kansas. The program uses retired Sandia and university personnel to formulate and teach new courses, and provides release time for existing faculty to obtain the advanced degrees required for accreditation.

The Cooperative Education Program provides opportunities for undergraduate students to acquire laboratory experience along with college studies. Work

assignments are carefully matched to individual interests, and the technical challenge increases as a student's education advances.

The Historically Black Colleges and Universities Program is sponsored by DOE. Sandia is an active participant, offering summer employment to exceptional junior, senior, and graduate engineering and science students. Students earn academic credit for participating in research activities and documenting those activities in a technical report.

The Outstanding Student Summer Program offers engineering and science majors from the junior year through graduate studies an opportunity for summer work in a laboratory environment.

The Science and Technology Alliance was created in November 1987 to increase the number of African-Americans, American Indians, and Hispanics in the scientific and engineering programs of DOE, other government agencies, and private industry. The DOE-sponsored alliance assists participating universities in upgrading their infrastructures and increasing collaboration with the national laboratories. Sandia is the lead laboratory in a consortium that includes Los Alamos National Laboratory, Oak Ridge National Laboratory, the Fundación Educativa Ana G. Mendez in Puerto Rico, New Mexico Highlands University, North Carolina A&T State University, and the Montana consortium. The Montana consortium is composed of three tribal colleges (Salish Kootenai College, Fort Peck Community College, and Little Bighorn College) and a four-year private college (Rocky Mountain College) in Billings. The Georgia Institute of Technology is an affiliate member, providing programmatic counsel and graduate opportunities. AT&T and Lockheed Martin are the first industry participants.

The Summer Employment for Minority Youth Program provides summer employment for underrepresented youth who are high school juniors and seniors or university freshmen and sophomores. The program provides real-world work experience in technology fields. The program targets only students with mathematics and science interests and imposes no financial criteria.

The Summer Employment Program for Native Americans recruits undergraduate and graduate students nationwide who are enrolled in math, science, engineering, technology, or computer science programs. Opportunities also exist for students to participate in a cooperative program for a maximum of twenty hours a week during the academic year.

The first Lunar Shelter Student Contest was conducted as part of Space 94: The Fourth International Conference and Exposition on Engineering, Construction, and Operations in Space, which was co-located with the Conference and Exposition on Robotics for Challenging Environments at the Albuquerque Convention Center from February 26 through 28, 1994. This competition was sponsored by Sandia's Education Outreach Department and the National Aeronautics and Space Administration. The objective was to construct a model lunar base telerobotically. Specific tasks included unloading, transporting, positioning, and covering a model lunar habitat. This competition exposed students to real-world problems associated with project planning, budget constraints, system integration, and teamwork.

Programs for University Graduate Students

The Graduate Engineering Internship Program provides opportunities for University of New Mexico graduate students in engineering and science to acquire meaningful laboratory experience by alternating work and academic experience. It is available during the academic year.

The National Consortium for Graduate Degrees for Minorities in Engineering is composed of university and industry members. The consortium provides opportunities for students from underrepresented groups to obtain master's degrees in engineering through a program of paid summer internships and financial aid.

The One-Year-on-Campus Program helps Sandia increase the number of underrepresented engineers and scientists. Holders of bachelor's degrees who have a high grade-point average are recruited and allowed to attend graduate school full-time for a year. In specific disciplines where Sandia has difficulty recruiting persons with master's degrees, persons with bachelor's degrees are hired and allowed to attend school full-time for two years to complete their master's degree.

Sandia's Postdoctoral Internship Program hosts postdoctoral students in areas of research where Sandia expertise or facilities provide a good match for students' interests. The program encourages a continuous flow of top scientists and engineers into Sandia.

Programs for College and University Faculty

The Sandia University Research Program provides research funds for faculty members at the three PhD-granting institutions in New Mexico. The program is limited to new faculty members and is usually the first funding they receive. This seed money is sufficient only to fund one graduate student, pay the summer salary of the faculty member, and reduce the teaching load during the academic year. Funding is limited to research of interest to the sponsoring Sandia organization for a maximum of two years.

The Sandia University of New Mexico Distinguished Professor Program provides Sandia technical staff to teach courses at the University of New Mexico and assist in the development of collaborative research projects. The position

is fully funded by the University of New Mexico, and Sandia staff members are provided with office space and the responsibilities of a visiting professor.

The Sandia/University of New Mexico Joint Appointments Program seeks new faculty members for positions in fields important to both the University of New Mexico and Sandia. Appointees devote half their time to teaching at the university and half their time to research at Sandia for two years.

The University Faculty Summer Employment and Academic Year Sabbatical programs attract outstanding professors from universities nationwide. Participating individuals make meaningful contributions to Sandia's technical expertise. At the same time, they have the opportunity to perform mission-oriented work. These professors are considered temporary employees who work on research and development projects specified by Sandia organizations.

3.1.4 Work for Other Department of Energy Locations, Contractors, and Offices

Sandia performs work for other DOE elements as requested to support programmatic and institutional requirements. These elements may include field operations and facilities of the nuclear weapons complex, as well as special programs administered by DOE Headquarters.

Sandia assists other DOE locations with facility safeguards and security. We have a broad base of experience in this field as it relates to nuclear materials and operations.

Sandia developed and delivered the device transport vehicle to DOE's Nevada Operations Office for use at the Nevada Test Site. This vehicle substantially upgraded the safety and security of transporting nuclear explosive test devices.

Sandia also developed the analytic system and software for evaluating safeguards security. This tool has been used at many DOE sites to help identify security needs and the adequacy of upgrades.

Sandia is assisting the Portsmouth Gaseous Diffusion Plant in the design and implementation of its alarm communications and display system. We are collaborating with Los Alamos National Laboratory on an integrated safeguards system for Argonne National Laboratory-West that will provide physical security and materials accounting features. We are also consulting with a number of other sites, including Savannah River, Y-12, Pantex, AlliedSignal, Mound Laboratories, Lawrence Livermore, and Bettis Naval Reactors.

We are playing a major role in the waste energy conservation program sponsored by DOE's Office of Waste Reduction. This program is an alliance of DOE, Sandia, Los Alamos National Laboratory, and industry.

3.2 Work for Non-DOE Entities (Work for Others)

Approximately 20 percent of Sandia's programmatic effort is work for agencies other than DOE and about 80 percent of that effort is for DoD. These DoD programs exercise and strengthen the capitalized resources we maintain for the nuclear weapons programs. They also make cost-effective use of existing federal investments for technological needs in areas such as conventional defense, strategic defense, treaty verification, law enforcement, microelectronics, manufacturing, transportation, biomedical engineering, and space. The technology base developed through our work for DOE has established expertise and capabilities not usually found in industry or in other government agencies. Therefore, opportunities to contribute technological solutions to agencies other than DOE help solve national needs, benefit the supported agencies through leverage of multiagency funds, and help maintain our abilities to perform DOE missions.

Before undertaking a work-for-others project, we ascertain that the work is consistent with other Sandia and DOE missions, will not adversely affect assigned DOE programs, will not be in direct competition with the domestic private sector, and will not burden DOE resources in the future. Acceptable projects involve problems of national importance that are feasible in terms of program goals and availability of required assets. Many work-for-others sponsors utilize Sandia's strong systems integration capabilities for rapid prototypes to identify and resolve critical technical issues quickly. Often this work is completed jointly with private industry, requiring our involvement as needed to meet the sponsor's objectives.

3.2.1 Department of Defense

Air Force

Sandia has long collaborated with the Air Force on developing satellite instrumentation, weapon subsystems, and physical security systems.

We are continuing to support Air Force satellite programs with special flight instrumentation systems, sensors, and ground processing capabilities to meet unique requirements. These activities provide sensors and data processors for satellite tactical and treaty monitoring missions and provide ground-based calibration and data processing systems to support these missions. A nuclear burst electromagnetic pulse detection sensor is being developed for the Air Force Space and Missile Systems Center. This sensor will work in conjunction with the DOE-funded optical detector deployed on the Global Positioning System satellite constellation.

Sandia has developed and fielded an integrated correlation and display system for processing data from nuclear detonation sensors carried aboard Global Positioning System and Defense Support Program satellites. We are also developing a transportable version of that system called the Ground Nuclear Detonation Detection System Terminal. In addition to the satellite-based sensing capability, we are developing a distributed network of computer systems to monitor underground and underwater nuclear explosions. These are ongoing efforts to take advantage of new technology in sensor development and data processing.

In programs for the protection of space assets, we are developing a laser sensor system and a ground station capable of detecting, characterizing, and reporting laser irradiation directed toward a satellite from ground-based or airborne sources. Sandia has a state-of-the-art capability in the design of high-data-rate, survivable, radiation-hardened, integrated communication systems and is in the process of codifying the design rules for such devices for the benefit of defense electronics manufacturers.

Sandia has unique technical capability in the area of mobile command and control centers that can survive in a nuclear environment. We have delivered transportable, survivable, multishelter command centers for the Strategic Command, the Strategic Target Planning Staff, and the United States Space Command. We continue to support these activities.

Sandia and the Air Force Central Inertial Guidance Test Facility are developing a small, high-accuracy, ring laser gyroscope inertial navigation system. This system is being developed for maneuvering reentry vehicles and will also be used by the Air Force in a scoring system to evaluate other missile guidance systems.

We are working with Phillips Laboratory to support its Ballistic Missile Technology Program with maneuvering, guidance and control, kinetic energy penetrators, and earth penetration warhead technologies based on our earlier work in reentry vehicles.

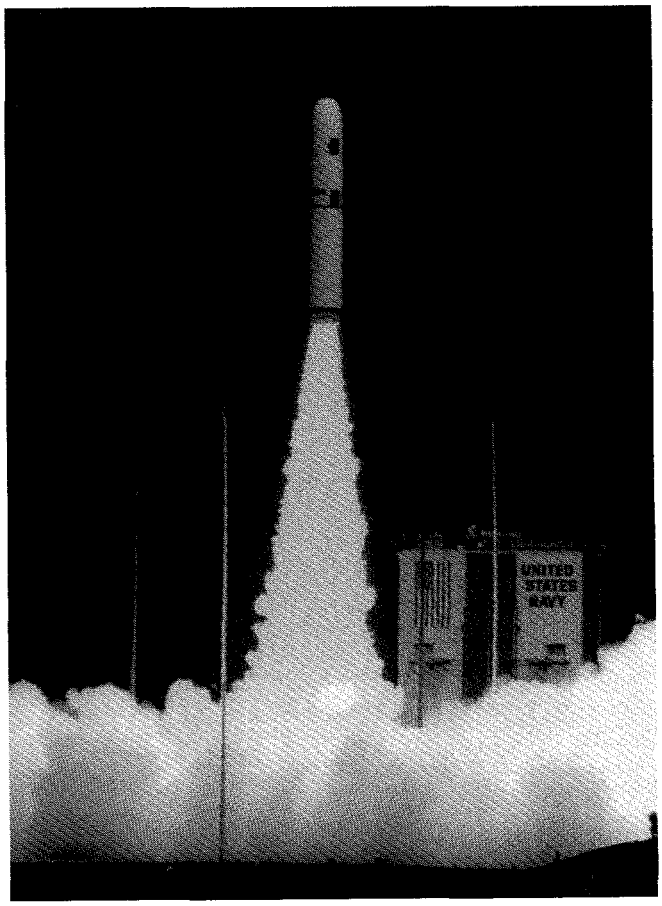
Sandia is a major contributor to the Phillips Laboratory high-power microwave research, development, and testing program. We are developing compact, narrow-bandwidth sources and high-power broad-bandwidth sources. These sources are used in tests for collecting susceptibility data and evaluating system hardening techniques. We contribute to system studies and mission analysis.

Activities in support of US Air Force physical security programs include the development, evaluation, and application of advanced security concepts, technologies, and systems for the protection of Air Force nuclear and other high value assets. Sandia has been a partner in this program with the US Air Force Electronic Systems Center since the early 1970s. Accomplishments include the design of the US Weapon Storage Vault and the development, evaluation, and application of advanced security technologies and systems at most Air Force sites around the world. Other activities have been in direct support of the US European Command, Space Command, Air Combat Command, US Air Forces in Europe, Pacific Air Force, and other Air Force organizations.

These efforts draw directly on and supplement our experience in providing security technologies for the DOE nuclear weapons complex. We have successfully transferred some of these technologies to private industry and continue to work with industrial partners to improve their security equipment.

Navy

Building on the successful relationship with the Navy that produced integrated arming, fuzing, and firing systems for the Poseidon/Mark 3 and Trident/Mark 4 reentry bodies, Sandia developed a highly integrated arming, fuzing, and firing system for the Trident/Mark 5 weapon program, which provides fuzing options to enhance effectiveness against hardened targets. The first production unit was



Sandia developed a highly integrated arming, fuzing, and firing system for the Navy's Trident II missile.

completed in 1988 in time to support the Navy's initial operating capability in 1989. In September 1994 production of the arming, fuzing, and firing assembly was completed.

Sandia supports the submarine-launched ballistic missile strategic capabilities enhancement program (sponsored by the Navy Strategic Systems Programs, Reentry Branch) by developing and characterizing general purpose/precise trajectory reconstruction flight instrumentation. Sandia's experience in navigational guidance and control with radiation-hardened microelectronics will be used to develop a broad mission telemetry package.

We also provide engineering services for and technical evaluation of the aging characteristics of a limited number of arming, fuzing, and firing assemblies for the Trident II/ Mark 5 reentry body and of flight performance of stockpiled Mark 4 and Mark 5 reentry body assemblies. This work involves periodic testing and inspection of war reserve materials and emphasizes the detection and evaluation of any degradation that might change the functionality, reliability, and safety of a component or system.

We are also working with the Navy Special Projects Office to develop and test unique reentry body instrumentation options that will provide the Navy with low-cost trajectory measurement systems consisting of an inertial measurement system updated by a Global Positioning System receiver.

Materials modeling and structural analysis by Sandia in earlier weapon development work for DOE and DoD are being applied to Navy problems of assessing the lethality of conventional warheads against various targets. This work for the Naval Underwater Systems Center uses analytical and experimental techniques to determine the onset of material failure and the propagation of damage under short-time, high-energy deposition.

Sandia's considerable experience with reentry system design, instrumentation, research and development, testing, and analysis/evaluation through reimbursable programs with other federal agencies led to new reimbursable projects with the Navy Strategic Systems Project Office in the areas of reentry body design, instrumentation, and guidance and control. In the recently completed Reentry Body Instrumentation Project, several Global Positioning Satellite-related experiments were successfully tested on two reentry bodies launched on a Trident missile. This test produced the first satellite navigation data on a high-speed reenty body. A follow-on experiment known as the Reentry Body Impact Fuze Flight will assess the performance of the Mark 5 fuse system in a contact initiation mode at high impact velocity (more than 9,000 feet per second). This experiment will feature two highly-instrumented reentry bodies separately launched by guided, two-stage rocket systems. The reentry bodies will each have Global Positioning Satellite-aided inertial measurement systems for navigation and guidance as well as a unique moving mass control system. The moving mass control is being designed and fabricated by Lockheed Martin under Navy Strategic Project Office guidance. Sandia will assist with the integration and checkout of the moving mass control in each reentry body prior to flight.

Sandia has also performed reimbursable work in support of Marine Corps expeditionary force capabilities. Drawing on our expertise in sensor technology and rugged microelectronics, we developed a family of remote, unattended ground sensors for perimeter security, battlefield route surveillance, and support of amphibious assaults.

Our experience with deployable sensor systems led to the development of a mini-intrusion detection system for the armed services and other federal agencies. This system provides advanced, cost-effective patrol security for small installations. Sandia's competency and experience in sensor-based security systems may have application to a variety of unique government requirements.

Our capabilities in providing robotics technology for the physical security of DOE sites led to the development and demonstration of teleoperated battlefield vehicles. We are also providing consultation as these concepts are developed by the Marine Corps and private industry.

We work closely with David Taylor Laboratories on system studies for electrothermal guns. We develop pulsed power system components for providing energy to electrothermal guns, and we work with Naval Sea Systems Command and their industrial contractors to advance electrothermal gun technology.

Army

Sandia has unique experience in the design of safe secure transportation containers for hazardous and radioactive materials. The Army asked Sandia to apply this expertise to the design, development, and testing of a container for transporting chemical munitions on military installations. Sandia will support private sector fabrication of a fleet of such containers.

We are also developing and qualifying a container for safe air transport of the Army's tactical nuclear weapons, which must be returned to the continental United States for destruction.

We have developed an improved, all-electronic safing and arming system for the Patriot missile. The safing and arming technology in the Patriot system was developed in the DOE nuclear weapons program. The design is being transferred to industry for production.

Sandia also has unique experience in the design, integration, and testing of terrain-referenced navigation algorithms. Using this experience base, we are applying the Defense Mapping Agency's digital land mass system level-1 digital elevation data to the terrain-referenced navigation and terrain capabilities of the Army's JOH58C helicopter.

Sandia's parachute and control system technologies are being used to develop high-speed, low-level, airdrop resupply systems. We are exploring guidance concepts to destroy high-value battlefield targets and are studying the

effects of low-observable materials on survivability in the battlefield of the future.

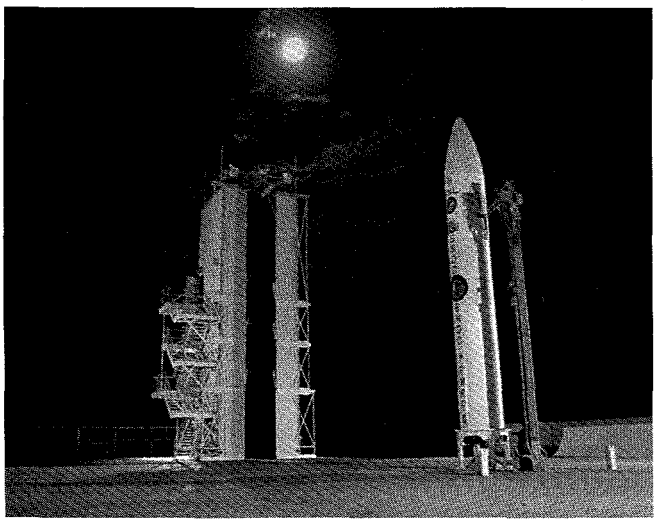
We are working with the Belvoir Research, Development, and Engineering Center to evaluate the use of backscattered x-rays for imaging land mines. Toward this end, we are integrating an x-ray source, detectors, and imaging technologies into a system and using that system to measure the effectiveness of backscattered x-rays for mine detection in the field.

We are adding models and options to the computer codes developed at Sandia for earlier DOE programs to enhance their capabilities for addressing conventional weapon effects issues, including terminal ballistics problems and other armor-related studies.

We support the Maintainability and Hardness Assurance Program radiation survivability testing at Sandia's High-Energy Radiation Megavolt Electron Source (HERMES) III with system-level tests of critical major systems.

Ballistic Missile Defense Organization

The Ballistic Missile Defense Organization sponsors a broad range of research on technologies relevant to Sandia's prime mission and to its own programmatic goals. We provide support in a number of areas where we either have special capabilities or unique facilities and the work complements our DOE mission. We plan to continue working in the areas of discrimination, countermeasures, space power, pulsed power, threat definition, space survivability, space experiments, smart targets, rocket launch services, and theater ballistic missile defense.



A Ballistic Missile Defense Organization mission is prepared for launch at Sandia's Kauai Test Facility.

The countermeasures evaluation activity stems from our experience in nuclear weapon design, our previous activities in reentry vehicle technology, and the application and evaluation of concepts that could make strategic and theater nuclear weapons more robust against a strategic defense. This work will help provide a baseline from which the cost-effectiveness and cost to the adversary of deploying countermeasures may be evaluated. Our activities in threat definition help provide a better understanding of both near- and long-term strategic and theater ballistic missile threats.

The Ballistic Missile Defense Organization push for deployment of a National Missile Defense System as early as practical has placed a premium on the timely execution of rocket missions needed in the development of ballistic missile defense technology. Sandia's rocket launching test facilities allow flight testing of instrumented vehicles. The Kauai, Hawaii facility has been upgraded and is capable of launching strategic target systems boosters. We anticipate continuing to use this upgraded facility to support flight tests for the Ballistic Missile Defense Organization.

Sandia builds unique, instrumented targets for experiments conducted for the Ballistic Missile Defense Organization and the US Army Strategic Defense Command. In order to provide more uniform assessment of proposed defense system elements, a baseline target set has been defined consisting of target vehicles and potential penetration-aiding articles developed by Sandia. The experiments are launched from Vandenburg Air Force Base and the Kauai test facility. The Operational Deployment Experiment Simulator is a target deployment platform built for experiments that have and will be flown on strategic target systems missiles.

Sandia's expertise in weapon system analysis will be used to evaluate the utility of smart mines for theater missile defense. We hope to evaluate this innovative concept fully for intercepting missiles during the boost phase of flight. If fully funded, the work will require detailed concept definition of all subsystems; rigorous analysis of the concept with regard to sensors, command and control, and launch detection; and test planning and execution for several demonstrations against simulated targets.

We continue to develop our capabilities to model space nuclear power systems for potential strategic defense applications, and we have produced comparative evaluations of the various systems for the Ballistic Missile Defense Organization, DOE, Air Force, and Army. Our work also involves developing instrumentation and control technology and independent analyses of safety features.

Sandia's capabilities in radiation hardening are a foundation for evaluating methods and penalties to enhance the survivability of objects in space by hardening the electronics and structure and for evaluating methods of maneuverability, shootback, and other features.

Capabilities developed primarily for DOE's Inertial Confinement Fusion Program and for aboveground effects

simulation and new split-cavity oscillator microwave sources for high-power microwaves are being developed and can be utilized in more compact jammers, radars, and weapons.

We also provide direct support to the Ballistic Missile Defense Organization's Phase One Engineering Team. In the past, we have chaired the threat specification group for this team. We provide advanced computing capabilities and have developed massively parallel tracking and correlating programs that can handle large, complex threat scenarios. The potential for real-time tracking and correlation in realistic defense scenarios will be demonstrated soon. We expect to continue to participate in threat specification evaluation, lethality test and evaluation activities, risk assessment, modeling and simulation, and command and communications issues.

Defense Nuclear Agency

The end of the Cold War offered the opportunity for the United States to assist Russia in the safe drawdown of its nuclear arsenal. As part of the United States' Safe Secure Dismantlement Program and under sponsorship of the Defense Nuclear Agency, Sandia is developing an enhanced communications system to aid the Russian accident response team and a transportation and storage container for dismantled weapon pits.

Sandia has supported the Defense Nuclear Agency by providing security hardware to assist Russia in protecting its nuclear weapons from theft or sabotage. Armored blanket technology has been developed and transferred to US industry for manufacture and sale to Russia to protect nuclear weapons from ballistic objects during transportation. In addition, physical security technology has been developed to protect Russian rail cars from terrorist attack. Intrusion detection and delay systems have been produced in modular form for easy transport and installation by our Russian counterparts.

Sandia performs aboveground simulation of nuclear weapon effects for the Defense Nuclear Agency using the Saturn x-ray and High-Energy Radiation Megavolt Electron Source (HERMES) III gamma-ray facilities. Also under sponsorship of the Defense Nuclear Agency, we are developing improved security hardware, operational concepts, and tactics for military security forces. In March 1995 we signed an Addendum to the Radiation Sciences and Testing Memorandum of Agreement to ensure that both the Defense Nuclear Agency and Sandia simulation facility utilization are coordinated and optimized for maximum cost effectiveness.

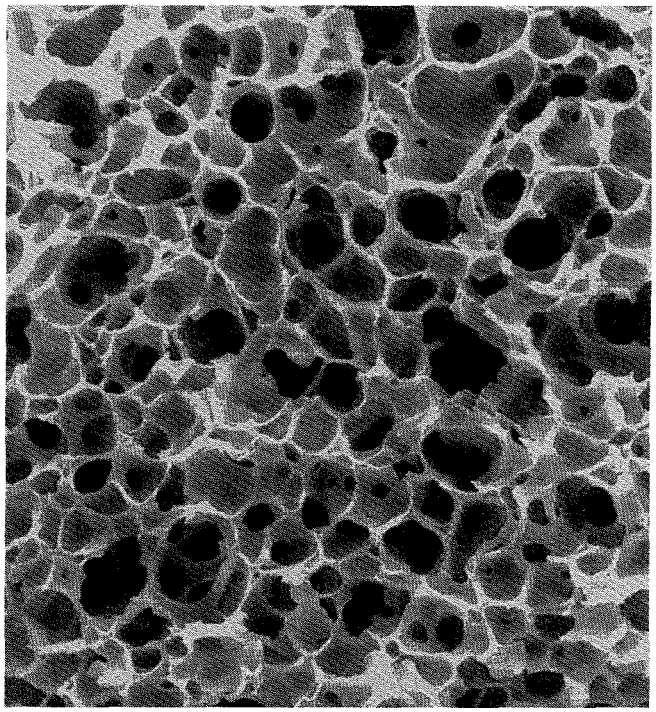
With sponsorship from the Office of the Secretary of Defense, the Defense Nuclear Agency, and DOE, we are exploring means by which the survivability and security of nonstrategic nuclear forces can be assured in the twenty-first century. The Defense Nuclear Agency also sponsors research and development in sensors for remote monitoring, tamper protection, data authentication, and adversary analysis.

At the request of the Air Force, the Defense Nuclear Agency initiated a pilot study in 1991 for the safety assessment of the Minuteman III weapon system. Sandia's facilities for accident environment simulation (fire test, cable pulldown, sled track, etc.) and experience in nuclear safety assessment are unique capabilities for nuclear safety assessment and for characterizing accidents and systems response to accidents in support of this safety assessment study.

The Defense Nuclear Agency is also supporting the development and application of advanced shock physics codes for modeling earth penetrators.

Advanced Research Projects Agency

In 1993 the Advanced Research Projects Agency began sponsoring the National Center for Advanced Information Components Manufacturing, located at Sandia, to develop partnerships among the three DOE weapons laboratories (Sandia, Los Alamos, and Lawrence Livermore) and industry in performing projects in the areas of microelectronics and flat-panel displays. This partnering will greatly compress the time needed to translate research and development from the laboratories into commercial and defense products. The



Microcellular polymers developed at Sandia are used in flat-panel displays for the Advanced Research Projects Agency.

National Center for Advanced Information Components Manufacturing currently has forty-two industrial and nine university partners and complements other DoD microelectronics, optoelectronics, and flat-panel display programs, such as SEMATECH and the US Display Consortium.

By providing space and equipment to support the development of agile manufacturing processes for large, flat-panel displays and microelectronics, the center allows industry and government researchers to exploit Sandia's wide variety of disciplines and competencies. These competencies include microelectronics and photonics, advanced electronics systems packaging, materials science and processes, printed-circuit fabrication, and smart structures and dynamic systems.

Research is concentrated on agile manufacturing technologies associated with advanced silicon integrated circuits, high-speed optoelectronic communications, and electronic systems and subsystems. Research in large flat-panel displays benefits from the consolidation of supporting technologies at a single site. Manufacturing research focuses on agile manufacturing processes for flat-panel products that have both defense and industry applications.

The National Center for Advanced Information Components Manufacturing programs benefit from several DOE manufacturing development facilities at Sandia, such as the Advanced Manufacturing Processes Laboratory, the Microelectronics Development Laboratory, the Compound Semiconductor Research Laboratory, the Center for Advanced Manufacturing Technology, the Microelectronics Quality and Reliability Center, the Smart Structures and Materials Laboratory, and the Center for Microelectronics Technologies. Industry and university researchers also have access to these facilities.

Other Department of Defense

The joint DoD/DOE Munitions Technology Development Program, enabled by the 1985 DoD/DOE memorandum of understanding, is a research effort to develop innovative warhead, explosive, and fuse technologies and to improve nonnuclear munitions technology across all service mission areas. Projects in this program include energetic materials, guidance and control, smart mines, countermines, and systems studies.

Each topical area in this program is overseen by a technology coordination group that acts as liaison between DoD and DOE and establishes a channel for technology exchange. Composed of technical experts from each agency, these groups work to ensure maximum benefit from the program. Technology coordination groups establish measurable deliverables and realistic schedules, coordinate multiservice requirements, establish classification guidance, monitor activities, and provide semiannual reports on the project status and potential new projects. The groups also conduct technical reviews and provide written assessments to the technical advisory committee. The technical advisory committee administers the program, provides policy guidance, reviews technical assessments from the technology coordination groups, evaluates new proposals, and establishes the program plan.

Because much of the technology base developed in nuclear weapons work is directly applicable to DoD needs in conventional munitions, this program has brought about major improvements in conventional munitions. The program is consistent with long-range planning at DoD and is an effective mechanism for leveraging capitalized research and development resources. At the same time, the costs associated with maintaining many of the core competencies required for the nuclear weapons program are shared by DoD, and the resources are further exercised, challenged, and strengthened.

Sandia's microelectronics and photonics research foundation supports several DoD agencies with technology development, technology evaluation, custom device design, electronic packaging, and device prototyping in our Microelectronics Development Laboratory. With industrial partners Sandia provides materials and processes to fabricate nonvolatile microelectronic memories and flat-panel displays for broad DoD applications. Similarly, Sandia provides unique components (e.g., high-voltage switch tubes) and the consultation of various technology experts (e.g., pyrotechnic device experts) as requested by DoD agencies.

Sandia has extensive partnerships with DoD to develop and apply high-performance computing technologies. Collaborations range from shock physics and electromagnetism to computer design of materials. Sandia's CTH code is the DoD code of choice for armor/anti-armor. The Air Force uses a massively parallel electromagnetic code developed at Sandia to calculate radar signatures. A partnership with Wright-Patterson Air Force Base focuses on designing optical coatings for lasers through computer simulations. In new efforts, computers are providing detailed real-time simulations of operational systems for mission rehearsals, evaluation of investment strategies, and operator training.

For the Defense Information Systems Agency, we have developed a broad range of technologies for survivable command and control centers. These technologies are being used for classified operational systems and proof-of-concept applications.

Extensive studies continue in precision, quick response weapons for regional conflicts. The Sandia approach would provide a highly integrated target acquisition, data fusion, retargeting, and hypersonic warhead delivery system to address time-critical and/or buried targets.

3.2.2 Nuclear Regulatory Commission

Since 1973 Sandia has conducted a broadly based research program for the Nuclear Regulatory Commission in

probabilistic risk assessment, severe accidents in nuclear reactors, reactor safety research experiments, engineering technology, and low-level waste management. We also provide technical assistance in the safety and reliability assessment and resolution of reactor safety issues.

We have performed many of the risk assessments sponsored by the commission, developed state-of-the-art methods, participated in major technology transfer efforts, and addressed important regulatory issues amenable to solution by risk assessment. We have developed methods to analyze power plant systems, operations, human performance, accident processes, transport of radioactive materials, and health and economic impacts. We have placed major emphasis on the treatment of uncertainties in analyzing potential plant accidents.

Our severe accident research program funded by the Nuclear Regulatory Commission involves participation with the international reactor safety research community. Several unique experimental facilities have been developed at Sandia for investigating the diverse physical phenomena that may be important in postulated severe accidents. Out-of-pile experiments to investigate loads imposed on reactor containment buildings by high-pressure melt injection accidents are done in the Surtsey Test Facility and in a one-sixth-scale model of a nuclear power plant containment. Theoretical work centers on the development and validation of mechanistic codes (such as MELCOR, CONTAIN, and VICTORIA), which integrate severe accident knowledge. Results of the severe accident research are used for developing databases and models for improving hardware and procedures to decrease plant risk, resolve safety issues, and provide the basis for accident management and emergency response.

Sandia has conducted an extensive analytical and experimental containment integrity program, including major tests on a one-eighth-scale-model steel building and a one-sixth-scale-model reinforced concrete building. Testing has evaluated the hazards of turbine and external missile impacts. As needed, evaluations of seismic and fire risks are conducted in conjunction with testing. Test facilities have been developed for quantitative measurements of fire behavior and the effects of smoke and combustion products. We have extensively tested nuclear power plant electrical equipment and components during simulated accident conditions. Such tests support equipment qualification and plant life-extension activities.

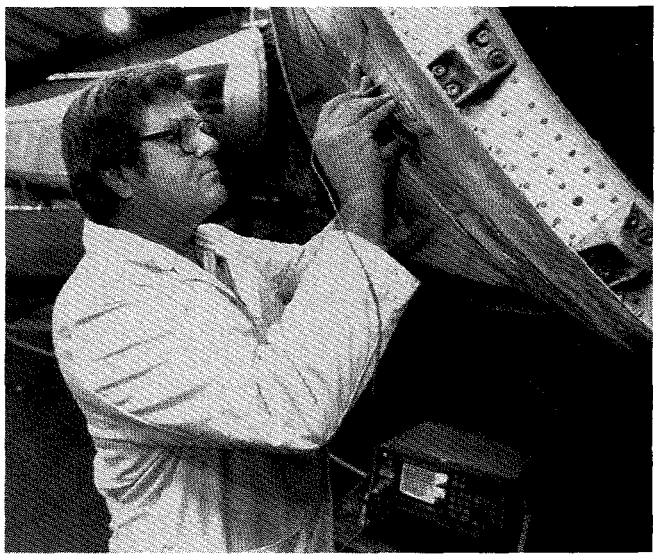
Sandia is the lead laboratory in the development and application of performance assessment methodologies for evaluating the suitability of nondefense, low-level waste disposal facilities. We are also evaluating methods for classifying waste streams as below regulatory concerns for use in setting minimum standards for radioactive and mixed wastes.

Sandia continues to support the Nuclear Regulatory Commission in transferring technology developed in DOE-sponsored safeguards programs to commission staff and inspectors and to nuclear utilities. Other technologies transferred to industry or other entities include advanced computer codes and techniques for materials and component design and evaluation.

3.2.3 Department of Transportation

Sandia performs research for and provides systems level analysis and consultation to the US Department of Transportation (DOT) and individual state transportation departments on a wide range of issues including safety, security, and efficiency of the national transportation system. These activities cover all modes of transportation (highway, rail, air, and water) and deal with the movement of both people and goods. These efforts cover a wide range of initiatives from local, state, national, and international perspectives.

As a direct corollary to our DOE efforts, Sandia is working with DOT to recommend packaging performance requirements for hazardous and radioactive materials transportation. We are developing microcomputer-based hazardous materials highway-routing guidelines incorporating a user-friendly model and a user's manual to assist in applications of the guidelines. Experimental work on the thermal characteristics of shipping casks supports DOT efforts to ensure the integrity of hazardous materials containers in fires. The work also assesses effects of the thermal mass of a shipping cask on the heat transfer



Ken Harmon uses an aircraft fuselage to demonstrate a nondestructive inspection technique at the Airworthiness Assurance Nondestructive Inspection Validation Center.

characteristics of a sooty engulfing fire. Sandia's radiant heat facility is being used to understand the radiative and connective behavior of heat transfer in such a fire. Similar efforts with the Federal Aviation Administration Technical Center are applying this technology and fire modeling and simulation to aircraft safety.

Sandia is using nondestructive testing to assist the Federal Aviation Administration in addressing the problem of aging aircraft. More information is needed about the effects of age on aircraft to forecast accurately when components should be repaired or replaced. Using funding from the Federal Aviation Administration Technical Center, Sandia has established the Airworthiness Assurance Nondestructive Inspection Validation Center in a 28,000-square-foot hangar at the Albuquerque Airport. This center will perform independent and quantitative performance and cost assessments on nondestructive inspection techniques used for transport and commuter aircraft. The center houses a B737 aircraft, large DC9 structural sections, and numerous test sections. A number of manufacturers and researchers from industry and universities are participating in development and testing of new nondestructive inspection techniques and in comparative trials of the cost and performance of various techniques. In addition, the center is working with aircraft manufacturers and airlines to develop new structural materials for patches and to determine the reliability of crack inspection methods. The center works closely with industry to transfer developed technology quickly.

Sandia is also utilizing transportation technologies and systems engineering skills developed for DOE during the last twenty years to assist the Federal Highway, Federal Transit, and Federal Rail administrations in responding to the Intermodal Surface Transportation Efficiency Act congressional mandates. For example, the Federal Highway and Federal Transit administrations have sponsored a forty-one-state, pooled-funds study at Sandia to develop a transportation planning process and support tools to enable the states to respond to the Intermodal Surface Transportation Efficiency Act. This is the largest state-pooled-funds study ever, and early reviews by the states note that it holds the potential to revolutionize the state/national transportation planning process. Sandia is also helping to revamp future national transportation programs by developing the Federal Transit Administration's functional and architectural requirements for advanced public transportation systems that will directly interface with the Federal Highway Administration Intelligent Transportation System's architecture development program. Finally, Sandia has teamed with the City of Albuquerque's transit department to test the developing national Intermodal Surface Transportation architecture.

Similarly, under both state and federal sponsorship, Sandia is studying the economic and technical feasibility of an intermodal freight center being considered for construction along the New Mexico/Mexico border near Santa Teresa, New Mexico. Sandia's expertise in systems studies and experience with sensors, control, and communication systems will be used to define an intermodal center that can more efficiently transfer cargo across the border. Sandia is working with both DOT and the State of New Mexico to understand and define how Santa Teresa, as a transportation-based agile manufacturing center, could form the basis for national and global economic opportunities.

3.2.4 National Aeronautics and Space Administration

Leveraging the experience gained from our verification and control technology and nuclear weapons programs, Sandia provides technical support for a number of National Aeronautics and Space Administration-funded projects.

For example, we support the Columbia University Astrophysics Laboratory in developing an x-ray polarimeter experiment for the Russian spectrum-x-ray gamma satellite. We are also providing instrument design support for the mechanics of granular materials, a microgravity experiment in collaboration with the University of Colorado. Similar design support is being furnished in collaboration with Los Alamos National Laboratory and Pennsylvania State University for the optical monitoring experiment for the European Space Agency's x-ray multispectral mission satellite.

Sandia was recently selected for flight definition of a space shuttle experiment designated critical dynamics in microgravity. This is a fundamental science, low-temperature physics experiment involving staff and students from the University of New Mexico, California Institute of Technology, Jet Propulsion Laboratory, and Sandia.

We developed a unique capability in radiation-hardened microelectronics for the nuclear weapons program. Such devices are useful for space applications; we have designed, fabricated, and produced radiation-hardened components for the National Aeronautics and Space Administration.

Another of Sandia's unique strengths in microelectronics is compound semiconductors. We are working with the National Aeronautics and Space Administration's Jet Propulsion Laboratory to develop longer wavelength photovoltaic arrays for electrical power supplies in space. We seek to grow stable, strained-layer superlattices that exhibit significant optical absorption at wavelengths to 15 microns and beyond. The work includes buffer design and growth, x-ray verification of structure and composition, analysis of defects, and photoluminescence characterization of the resulting superlattice. This work is a critical phase of materials development for demonstration of reproducible, spatially uniform material with the desired infrared characteristics. The follow-on task will be fabrication and optimization of detector and array structures.

Sandia is the world leader in the theory and design of high-performance parachute systems. We advise the



Sandia developed this airbag system for soft landing payloads on Mars.

National Aeronautics and Space Administration on the conceptualization, definition, and design of high-speed parachutes, including those used to decelerate the space shuttle's solid-fuel rocket boosters upon separation and the shuttle itself during landing. We have worked with the Johnson Space Center to develop a capability for soft landing and recovery of spacecraft and reusable launch vehicle hardware. We are also applying our parachute, aerodynamics, and earth penetrator expertise to develop and test an airbag system to provide soft landing of payloads on Mars and a penetrator system to deploy instrumentation beneath the Martian surface.

Sandia's microsensor expertise is being applied in a joint Sandia/National Aeronautics and Space Administration Jet Propulsion Laboratory effort to develop the Mars oxidant sensor to measure the reactivity of the Martian soil and atmosphere as part of the Russian Mars 1996 mission. In addition, similar expertise has been used to merge hydrogen-sensing alloys with microchip technology to produce hydrogen sensors that the National Aeronautics and Space Administration will use to improve the safety of its rocket operations.

Expertise from Sandia's Primary Standards Laboratory is being utilized to develop a portable Josephson volt calibration system to support the National Aeronautics and Space Administration's metrology efforts.

3.2.5 Department of State

Under sponsorship of the Department of State, Sandia provides direct technical support to the International Atomic Energy Agency in its role of verifying compliance with the provisions of the Nonproliferation Treaty. The agency employs both material accounting procedures and containment and surveillance techniques to provide the safeguards measures required by the treaty. We are developing or analyzing secure containers, spent fuel attribute testers, and item monitoring equipment. Newly developed containment and surveillance equipment is being demonstrated. We will help implement the new equipment by providing training, maintenance, and documentation. We will continue to provide containment and surveillance consultants as requested. We will also assist the International Atomic Energy Agency with training and inspection of physical security systems.

3.2.6 Environmental Protection Agency

Under an interagency agreement and other developing cooperative efforts among DOE, the Environmental Protection Agency, and various other government agencies, Sandia provides technical assistance and proposes technical courses of action for site characterization, sensor technology, remediation technologies, advanced analysis approaches, and risk-based decision approaches.

DOE and the Environmental Protection Agency have a long history of coordinating science and technology projects, including the Energy and Environment Program of the early 1970s, the National Acid Precipitation Assessment Program of the 1980s, and the National Laboratory Consortium formed by the National Acid Precipitation Act of 1980. The Environmental Protection Agency and DOE have approved thirty-five memoranda of understanding during the past two years for joint research and development under DOE's environmental restoration program. Several memoranda of understanding have also been written on general cooperation and technology transfer. These efforts are expected to accelerate because DOE has recently arranged to work closely with the National Resources Cluster of the President's cabinet to address national environmental issues.

For example, DOE and the Environmental Protection Agency have recently initiated a joint laboratory directors' forum to foster more cooperative environmental research efforts between the two agencies. The forum is composed of the directors of each agency's research and development laboratories and is actively collaborating in research and identification of topics for joint research in the areas of pollution prevention, waste minimization, environmentally sensitive engineering and manufacturing, hazardous and mixed waste treatment, ecological research, monitoring and

assessment, and environmental risk assessment. Sandia, as one of DOE's major research laboratories, will provide technical assistance and leadership in these areas.

Sandia has established a number of initiatives with the Environmental Protection Agency to assist regulators and encourage the use of innovative environmental technologies. In one initiative, DOE, the Environmental Protection Agency, Sandia, and industry are collaborating to demonstrate innovative cleanup technologies at a DOE site. This initiative provides an opportunity to develop a model for accelerated environmental cleanup operations throughout the nation. Another initiative is the consortium for site characterization technology. In this consortium, the Environmental Protection Agency's National Exposure Research Laboratory in Las Vegas, the Naval Research Engineering Laboratory, and Sandia are facilitating the implementation and commercialization of innovative monitoring and site-characterization technologies through technology demonstration and verification.

As part of a regional effort, Sandia is supporting efforts by DOE, the Environmental Protection Agency, DoD, the Department of the Interior, and the Western Governors' Association to accelerate environmental technology development and cleanup activities while enhancing economic development in the western United States. Sandia is also helping the Environmental Protection Agency in decision support systems and air pollution measurements.

3.2.7 Other Federal Agencies

Sandia continues to support the National Security Agency in adversary analysis. This support involves evaluation of communications security equipment, components, and design proposals to determine and identify vulnerabilities with potential for exploitation by an adversary.

Sandia's experience in safeguards and security for nuclear materials and facilities has been applied to other federal security needs. We are developing nonlethal alternatives for law enforcement officials under the sponsorship of the National Institute of Justice. Sticky foam has been adapted for a foam gun that can subdue a violent prisoner. We are also developing an aqueous foam system that can quell prison riots. A third project utilizes our nuclear weapons command and control expertise and our experience in surety technologies to develop a smart gun to prevent law enforcement officers from being shot with their own weapons.

Sandia is responding to requirements of federal, state, and local law enforcement agencies involved in the war against illegal drug trafficking. Sandia was explicitly named a national technical resource in the Drug Abuse Act of 1989. Our response has been sharpened by extensive interactions with interested agencies at all levels, from individual agents patrolling the US border to headquarters units involved in enforcement and research and development. We completed a study for the Immigration and Naturalization Service on the protection of the US southwestern border and presented recommendations for reducing drug traffic.

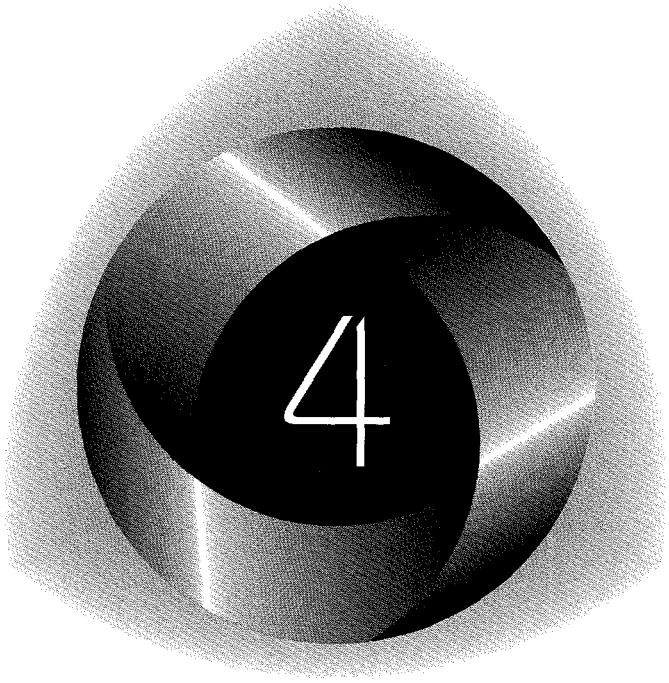
This effort has three focuses: attempting to match available technologies with requirements to provide immediate solutions, defining and proposing long-term development efforts in areas where Sandia has expertise, and offering systems analysis support to define and prioritize drug interdiction approaches more efficiently. Immediate support is available in such areas as ground sensors, communications, and radio-frequency beacons. Developmental areas include laser-induced fluorescence, compressed video communications, and passive beacons.

These efforts have produced contractual arrangements with several agencies, and we expect these programs to expand as agency research and development budgets grow and the drug war becomes better organized.

3.2.8 All Other Reimbursables

We are developing a new computer code for predicting the response of fluid-bearing rock to injection of slurries for disposal of drilling waste. The model also has application to analyses of many production problems associated with reservoir response for the oil and gas industry.

Where appropriate, Sandia also enters into projects involving state governments, private industry, universities, foreign governments, or other nonfederal entities. Criteria for these arrangements are the same as for other work-for-others endeavors. Current projects entail a variety of activities and Sandia resources, including development of numerical models for rock blasting, computer modeling to predict chemical behavior in methane/air jet flames, microelectronics development, and studies to improve nuclear reactor safety. We have projects with the United Kingdom, including electrical system and command and control support for their warhead development project; development of accident-resistant containers and associated handling gear for recovery of damaged warheads in an accident; and engineering support for US-supplied components and testers for their Trident-like reentry system.



Technology Partnerships and Commercialization

Sandia's Technology Partnerships and Commercialization Program promotes and facilitates the transfer of federally developed technologies, processes, and special technical knowledge to the private sector. Sandia has been the source of hundreds of technical advances that have proved to be relevant to a broad range of industrial needs. These include a non-chlorofluorocarbon cleaning process, reliability testers for semiconductor fabrication, robotic manufacturing processes, chemical dynamics software for controlling industrial chemical processes, advanced welding techniques, diagnostic devices for combustion chambers, and rapid prototyping techniques.

This program has a strong commitment to promoting and facilitating partnerships with industry and universities that are mutually beneficial to the sponsoring government program and to the industry partner. Closer cooperation between the national laboratories and the private sector is key to preserving and strengthening critical core intellectual and technological capabilities required to support DOE's missions in defense, energy, the environment, and the basic sciences.

4.1 Integration with Business Sectors and Core Competencies

To promote the integration of technology partnerships into all laboratory research and development, the technology partnerships and commercialization organization has realigned itself to match Sandia's corporate structure. The intent of realignment is to enable the technology partnerships and commercialization organization to support all three sectors in the development of industry partnerships and alliances that synergistically nurture Sandia's core competencies: integrated capabilities (advanced manufacturing technology, electronics technology, advanced information technology, and pulsed power technology) and research foundations (engineered processes and materials, computational and information sciences, microelectronics and photonics, and engineering sciences). Such partnerships are also expected to play a key role in strengthening and enhancing Sandia's ability to continue to perform its DOE mission responsibilities.

Customer service representatives coordinate with the appropriate staff to ensure that the sectors' technology partnership objectives are being served effectively. Also as part of the realignment, technology partnerships and commercialization staff members have been divided into three teams. To help ensure that Sandia's core competencies provide unifying points of focus for our collaborative work, these teams are aligned with specific integrated capabilities and research foundations (see 1.2.1):

- Team 1 is aligned with advanced manufacturing technology, engineered processes and materials, and engineering sciences;
- Team 2 is aligned with electronics technology, microelectronics and photonics, and pulsed power technology;
- Team 3 is aligned with advanced information technology and computational and information sciences.

The teams include licensing specialists, agreements specialists, patent attorneys, and patent agents. They are supported by market researchers, communications specialists, and agreements processors.

Licensing specialists take ownership of the intellectual properties within their respective core competency elements and are responsible for licensing those properties in ways that provide licensees with opportunities for economic and technological advantage while ensuring that Sandia shares in successes through the collection of reasonable royalties and licensing fees. Although a portion of these royalties is used to provide incentive for inventors, the greatest portion is invested in additional research and development, providing added return to the taxpayer.

Agreements specialists take primary responsibility for all partnership agreements in the team's core competency elements. They facilitate the matching of industry needs with Sandia's capabilities, the selection of the appropriate type of partnership agreement, and the negotiation of the terms and conditions of that agreement.

Patent agents are technical line staff who have been trained to prepare and file patent applications and otherwise protect Sandia intellectual property. The assignment of patent agents to the teams reflects Sandia's growing interest in licensing.

In addition, we seek to enhance the economic impact of our partnerships by improving access to Sandia's technical expertise (especially for small businesses), developing entrepreneurial talent, promoting product innovation, improving capital resources accessibility, and providing access to nontechnical professional knowledge. Specialized mechanisms have been developed for small businesses, and entrepreneurial training and mentoring are available to technical staff who wish to leave and start a business based on Sandia-developed technology. Sandia teams with intermediary organizations, such as the Technology Ventures Corporation, to accomplish the goal of enhanced economic impact. Technology Ventures Corporation, a subsidiary of Lockheed Martin, is incorporated as a nonprofit company in New Mexico to support start-up and expanding technology-based companies.

4.2 Intellectual Property Development and Licensing

Intellectual property is becoming an important part of Sandia's technology infrastructure. Throughout most of Sandia's history, the technical staff focused on publishing the results of unclassified research and development rather than on identifying, protecting, and licensing intellectual property. Since 1991, when Sandia began to implement the National Competitiveness Technology Transfer Act of 1989, the laboratory culture has been changing to meet the objectives of Sandia's technology partnerships and commercialization mission.

Historically, Sandians disclosed only about half as many inventions as their counterparts at the other weapons laboratories, and Sandia Corporation filed very few patent applications. Today, as Sandians continue to vigorously publish the results of their research and development, they are taking the time to review the results of their work performed under cooperative research and development agreements to protect commercially valuable information, and they are disclosing inventions at a rate approaching that of the other weapons laboratories. Dramatic changes are taking place at Sandia relative to intellectual property development and licensing (see Table 4-1).

As part of our commitment to these important responsibilities, Sandia has more than doubled the staff of patent attorneys and has recruited six members of the technical staff to be trained as patent agents. Also, four partnership specialists are being trained to become dedicated intellectual property licensing professionals.

In addition to the commitment of substantial resources to the patenting and licensing functions, other technical and business resources within the technology partnerships and commercialization organization are being assigned and trained to support Sandia's technical staff in the identification and development of commercially valuable intellectual property.

Although we have set ambitious goals (Tables 4-1 and Table 4-2), there is justification for our optimism. The changing culture at Sandia, the number of collaborative projects with industry, and Sandia's commitment to staffing the intellectual property development and licensing functions should serve to influence the results dramatically and positively.

Table 4-1. Intellectual Property Protection and Licensing Activities

	FY94[1]	FY95[2]	FY96[2]	FY97[2]	FY98[2]	FY99[2]	FY2000[2]
Inventions Disclosed	215	275	300	300	300	300	300
Patent Applications	67	70	80	90	100	100	100
Patents Issued	41	40	50	60	75	80	80
Copyrighted Works	27	35	40	45	45	50	50
Income-Producing Licenses	18	30	42	52	62	70	70

[1] Actual results.
[2] Projected results.

Table 4-2. Licensing Income and Uses ($K)

	FY94[1]	FY95[2]	FY96[2]	FY97[2]	FY98[2]	FY99[2]	FY2000[2]
Gross Income	80.5	375.0	750.0	2,250.0	5,600.0	11,250.0	18,750.0
Uses of Income							
Operations	0.0	56.0	112.0	337.0	840.0	1,687.0	2,812.0
Technical Support[3]	0.0	23.0	46.0	139.0	332.0	694.0	1,106.0
Awards and Inventors' Shares	24.5	96.0	192.0	574.0	1,428.0	2,869.0	4,782.0
Authorized Uses[4]	56.0	200.0	400.0	1,200.0	3,000.0	6,000.0	10,050.0

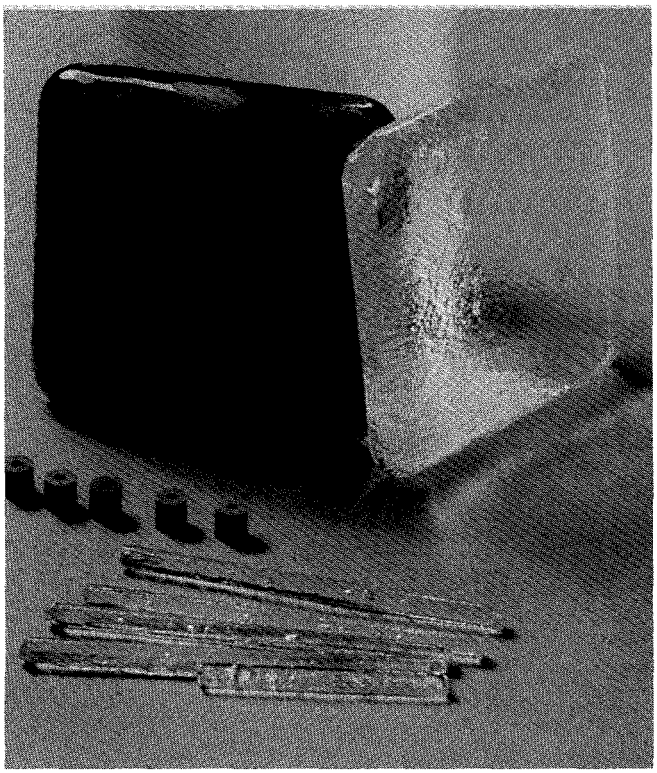
[1] Actual results.
[2] Projected results.
[3] Technical support will include income from providing samples to potential licensees, demonstration of technologies, and technology transfer support required to effectuate licenses.
[4] Authorized uses of royalties or other earned or retained income from technology partnerships activities include scientific research, development, technology transfer, and education at Sandia consistent with the research and development mission and objectives of Sandia.

4.3 Technology Partnerships and Alliances

Sandia's strategy for technology partnerships and alliances has evolved from maximizing the number of small cooperative research and development agreements to seeking large-scale alliances with industry and universities. Large-scale alliances of government, industry, and universities afford the best means of increasing US economic competitiveness and of strengthening Sandia's core competencies (see 1.2.1). One such alliance involves Sandia, Los Alamos National Laboratory, and the United States Council for Automotive Research, the latter being the automobile industry's body for cooperative research. Such alliances target major national technology goals that are market-driven, industry-defined, and precompetitive; these alliances are most effective when industry is strongly involved in setting priorities, developing plans, and moving technologies toward commercial application.

However, much continues to be accomplished through collaborative efforts with individual industry partners. One instance is Sandia's work with individual companies involving several families of special glasses. Sandia developed a low-silicon glass (TA-23) to extend the shelf life of lithium batteries for special weapon applications. Private industry subsequently found a variety of new applications for batteries using TA-23 headers. The Galileo spacecraft probe contains a pack of Honeywell's lithium batteries that continues to function after a six-year interplanetary journey, and lithium batteries with TA-23 headers are routinely implanted in human beings to drive heart pacemakers and other life-sustaining devices.

Subsequently, a family of calcium-modified boroaluminate (CABAL) glasses was developed to further extend the shelf life of lithium batteries. CABAL-12 glass withstands electrolyte corrosion ten times longer than TA-23 and is now the material of choice in most DOE lithium batteries. Private industry found a number of uses for CABAL-12 but discovered that this glass is not suitable for implantation in humans when it is in direct contact with body fluids. A third generation of glass with the advantage of thermomechanical



TA-23 and CABAL-12 special glass (top left and right), battery seal preforms (middle), and glass rods from which performs are made (bottom).

compatibility with titanium was patented by Sandia and then licensed to the private sector, where numerous applications have been found. Other glasses are now being developed that can be sealed to titanium and that will also have improved aqueous durability.

The collaborative process on special glass has benefited both the private sector and Sandia. Sandia now has a new understanding of the electrochemical reactions between aqueous solutions and glass surfaces. Sandia also has developed an infrastructure to accomodate industry in commercializing glass seal technology.

Sandia also actively works with major industry trade associations to develop precompetitive technology strategies or "road maps" that outline technical and business strategies for cooperative research on industry problems. One tool is called prosperity games. Based on defense war games, prosperity games bring together representatives from government, industry, the national laboratories, and universities to provide an opportunity for relationships that might lead to joint, long-term strategies for enhancing the nation's economic competitiveness. So far, games have been conducted with the Electronics Industries Association, the American Electronics Association, the National Electronics Manufacturing initiative, the Silicon Valley Environmental Partnership, and the University of New Mexico's Anderson Schools of Business. These games can help shape industrial road maps being developed by various industry groups.

Sandia uses a variety of mechanisms to engage in technology partnership activities with private industry. Through cooperative research and development agreements, we participate with industry and universities in mutually beneficial collaborative projects. Typically, Sandia and one or more partners from industry or academe share costs and pool the results from a particular research and development project, satisfying critical needs in the private sector while strengthening and enhancing Sandia's ability to continue to perform its DOE mission.

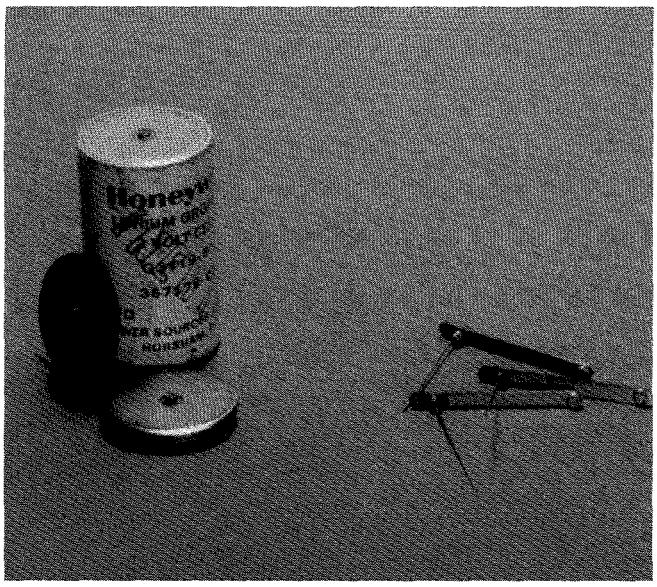
Memoranda of understanding are documents that outline activities in specific areas. They provide general understanding and guidance. However, no funding is associated with them.

Personnel exchange is the means by which a technical representative of a company may work with Sandia technical staff or Sandia technical staff may work at a company's location. This program gives companies access to technical skills or equipment not reasonably available in the private sector.

Sandia may provide technical assistance if that assistance does not compete with services available from private industry. Sandia has two processes for funding technical assistance projects. The first is total funding by the industry partner, called "funds-in technical assistance." The second process is limited to small businesses and uses funds provided by DOE. Technical assistance for small business is limited to $5,000 per project.

Sandia's user facilities are vital mechanisms for technology partnerships and can be accessed by private-sector companies, universities, and other laboratories through a simple agreement. Research and technology development activities conducted in these facilities satisfy a broad spectrum of dual-use needs for government and industry. The designated user facilities at Sandia are listed below:

- Combustion Research Facility,
- Component Modeling and Characterization Laboratory,
- Design, Evaluation, and Test Technology Facility,
- Electronics Quality and Reliability Center,
- Explosives Components Facility,
- Intelligent Systems and Robotics Center,
- Ion Beam Materials Research Laboratory,
- Laser Applications Laboratory,
- Manufacturing Technologies Center,
- Materials and Process Diagnostics Facility,
- Mechanical Test and Evaluation Facility,
- National Solar Thermal Test Facility and Design Assistance Center,
- Nuclear Facilities Resource Center,
- Primary Standards Laboratory,
- Radiation Detector Analysis Laboratory,
- Security Equipment and Systems,
- Shock Technology and Applied Research Facility, and
- TIE-IN Scientific and Engineering Computing Center.



Mockup of a D-cell battery for DOE Defense Programs applications with additional views of the header (left) and hermetically sealed headers using Sandia's patented third-generation glass (right).

Other user facilities scheduled to open soon are listed below:

- Biomedical Product Realization and Refinement Facility;
- Facility for Acceptance, Calibration, and Testing;
- Microelectronics Development Laboratory;
- Rock Mechanics Laboratory; and
- Space Integration and Test Facility.

4.3.1 Advanced Manufacturing Technology, Engineered Processes and Materials, and Engineering Sciences: Sample Projects

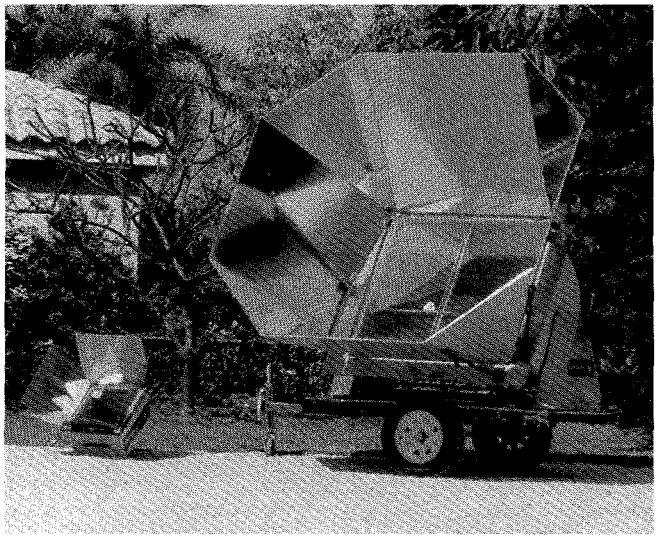
Sandia is working with MacNeal-Schwendler Corporation, PDA Engineering, Fluid Dynamics International, and Ford Motor Company under a cooperative research and development agreement to develop three-dimensional mesh-generation software to shorten the cycle time for developing production prototypes. This consortium is conducting precompetitive generic research that will benefit the entire industry, as well as the design of electromechanical components for weapons applications. Each industry participant will use the mesh-generation software to develop a commercial product or service in the area of computer-aided engineering software or in applications for finite-element analysis—a powerful numerical method for determining the physical behavior of an object and useful in many industrial fields, including structural mechanics, electrical engineering, and fluid mechanics.

The FASTCAST™ consortium is composed of seventeen companies that banded together with Sandia to advance the state of the art in investment casting. Member companies range in size from the Ford Motor Company to the Trucast Company (with five employees). Sandia uses investment casting to provide lightweight, high-strength housings for electrical assemblies in nuclear weapons. Advances by Sandia and the consortium include computer software that allows engineers at different locations to work on a casting design simultaneously, computer programs that predict how molten metal will flow into a mold (for use in mold design), mesh generation and finite-element codes that predict casting performance, and selective laser sintering and stereolithographic techniques that produce solid models of castings for use in rapid prototyping. Sandia has identified one of the consortium companies as a possible supplier of weapons housings.

We are also working with the strategically important US specialty metals industry to improve the technology base for melting processes used in manufacturing specialty metals (such as high-performance steel and titanium or nickel-based alloys). Specialty metals are critical to US economic competitiveness in areas ranging from microelectronics to airplanes and are also vital to national security. The consortium has conducted several major investigations. Most of the research has taken place within Sandia's Melting and Solidification Laboratory complex, which features the only large-scale, fully instrumented research furnace in the country. Research is generic in nature so that each member company can develop its own proprietary processes and products. Patents resulting from this work will be made available to consortium members through a *royalty-free* licensing arrangement.

Three General Motors divisions have signed cooperative research and development agreements with Sandia involving expenditures of approximately $30 million to help provide lighter, lower-emission automobiles. A project with the Saginaw Division of General Motors will improve the process of induction hardening of parts. Another project with the AC Rochester Division will develop fluid monitors jointly for use in vehicle engines, emphasizing oil quality, coolant, and battery electrolytes. An agreement with the Cadillac Luxury Car Division will develop an intelligent knowledge-based system for selecting materials for a new generation of cars.

An inventor/entrepreneur/humanitarian requested Sandia's technical assistance in evaluating and fine-tuning a solar-powered oven, an appliance invented especially for deforested and developing countries. The oven cooks foods, purifies water, and sterilizes medical supplies using only the sun's energy as its fuel. The inventor said that Sandia's Solar Thermal Design Assistance Center suggested crucial



Sandia's Solar Thermal Design Assistance Center helped test and evaluate these solar ovens, which are ideally suited to remote areas.

marketing and distribution strategies that closed the final gap between the finished product and the marketplace. The oven is now being manufactured.

Many of Sandia's weapons components are made using the same process-control techniques (sensor- and model-based control) as commercial manufacturers to enable small-lot, agile manufacturing. Sandia's automated manufacturing techniques are being used in the private sector via a cooperative research and development agreement with Rocketdyne, a world leader in rocket-engine technology. Sandia engineers created a sensor-driven controller to automate a robotic arm used in Rocketdyne's production lines. This same sensor might be used in weapons production to locate the position of a part within a work cell.

Through a technical assistance agreement, Sandia engineers assisted Roses Southwest Papers, a small, minority-owned paper-products maker, by incorporating a capacitive proximity detector in the company's production lines. The same sensor technology is used to monitor and control various process parameters in weapons production.

4.3.2 Electronics Technology, and Microelectronics and Photonics: Sample Projects

A five-year cooperative research and development agreement with the semiconductor industry's SEMATECH consortium focuses on improving manufacturing technologies for next-generation integrated circuits. The goals of the cooperative research and development agreement are aligned with the needs of the semiconductor industry as defined by the National Technology Roadmap for Semiconductors and are also consistent with the needs of the nuclear weapons program. This cooperative research and development agreement builds on a strong relationship between SEMATECH and Sandia that began with SEMATECH's formation. The agreement also embodies previous agreements with SEMATECH that led to the formation of the Semiconductor Equipment Technology Center in 1989 and the Center for Contamination-Free Manufacturing Research in 1992.

To meet the needs of industry and DOE, Sandia established the Center for Microelectronics Technologies to work with industry and academe in dual-benefit projects. The center was created by combining the existing DOE-funded Microelectronics Development Laboratory at Sandia with IBM's major donation of semiconductor manufacturing equipment and research instrumentation. The center facilitates partnerships with US semiconductor manufacturers and universities to develop critical technologies, manufacturing equipment, and advanced processes for commercial and defense electronics. The federal government benefits from this joint work through the development of custom products for government applications and by supporting the US manufacturing base that provides these products.

Sandia and Motorola are working together to improve the technology used in metallorganic vapor-phase epitaxy, a process used in the manufacture of high-performance microelectronic and photonic devices and circuits. Potential markets include high-performance integrated circuits and signal-processing circuits for computer and communications applications. The benefits to Sandia and DOE are prototype, state-of-the-art, compound semiconductor device structures for defense program applications in infrared sensing, optoelectrical modulation, and digital circuitry.

Conductor Analysis Technologies, Inc. is the creation of a Sandian on entrepreneurial leave. This company provides printed-wiring quality control and related services to the electronics industry. Its primary product is a new electrical test system with improved methods of analyzing and benchmarking conductors.

The US Optoelectronics Industry Development Association has created its technology road map. This association selected five critical areas for joint research and development at the precompetitive stage. Two of the critical enablers, optoelectronic materials and optoelectronic manufacturing processes and equipment, are areas in which Sandia has recognized technical leadership. Sandia's Compound Semiconductor Science and Technology Center provides an ideal facility where cost-leveraged partnerships involving US industry, universities, and government researchers can perform the precompetitive development of the design tools, processes, and related production equipment essential to US optoelectronics manufacturers.

Sandia's Electronics Quality and Reliability Center has

an extensive interdisciplinary capability in characterization, benchmarking, assessment, modeling, and simulation. Sandia's reliability engineering program focuses on ultra-reliability in electronic components for nuclear weapons, and those techniques are synergistic with the capabilities and needs of commercial electronics manufacturers. The Electronics Quality and Reliability Center has entered into ten cooperative research and development agreements with manufacturers of integrated circuits or related equipment or software. These projects are yielding significant benefits to the nuclear weapons program and are helping reduce the cost of this research to DOE. For example, the cooperative research and development agreement with the Philips Semiconductor Company has advanced our understanding of stress voiding, a failure mode that affected DOE Defense Programs electronics three times in the 1980s.

A cooperative research and development agreement with Intel and others perfected failure analysis techniques developed at Sandia for rapid location of problems in the stockpile. A cooperative research and development agreement with Hewlett-Packard developed software for a fast standardized approach to assessing reliability. A cooperative research and development agreement with Schlumberger developed a failure analysis expert system that will preserve DOE knowledge of diagnosing failures for the life of the enduring stockpile. Cooperative research and development agreements with Advanced Micro Devices, LSI, Analog Devices, and National Semiconductor have extended our reliability benchmarking database, which can be used to select the best manufacturers of integrated circuits for ultra-high-reliability requirements of government systems.

When completed, these cooperative research and development agreements will have brought $850,000 in cash (funds-in) and $500,000 in capital equipment and software to the DOE program. In addition, the cooperative research and development agreement with Hewlett-Packard is returning royalty income to DOE from software sales. These cooperative research and development agreements have also provided significant derivative economic benefits to the industry partners.

Military acceptance of a soldering method tested by Sandia and Motorola could significantly reduce the nation's use of ozone-damaging chemicals. In a 1992 cooperative research and development agreement project, Sandia and Motorola demonstrated that a low-residue soldering process could be effectively used in the manufacture of electronic circuit boards. Twenty to twenty-four percent of chlorofluorocarbon solvent usage in the United States is associated with the cleaning of these boards. The low-residue soldering process could replace traditional methods mandated by the military that require the use of ozone-damaging chlorofluorocarbon solvents. Now a nineteen-member task force that includes members from the Navy, Army, Air Force, and ten industry partners is developing a test program to promote adoption of this process by the military.

Sandia is also assisting three printed-wiring board manufacturers by transferring existing technologies and continuing research in materials, soldering technology, and chemical processing. Participants include three members of the National Center for Manufacturing Sciences: AT&T, Texas Instruments, and United Technologies' subsidiary Hamilton Standard. Sandia research with these consortium members involves processes for lamination, resin development and reinforcement, board defect prevention analysis, copper plating, solder wetting dynamics, the chemistry of solder flux, and development of solderability test methods.

A cooperative research and development agreement between Sandia and Buena Vista Pictures Distribution, Inc., a wholly owned subsidiary of Walt Disney, will develop an improved electronic system for igniting fireworks displays. The system will be based on a special integrated circuit developed by Sandia several years ago to replace the metal hot wires conventionally used to ignite small explosive charges. The circuit is about a hundredth the volume of a hot wire and is a thousand times faster. Both Sandia and Disney officials consider the cooperative research and development agreement a ground-breaker for future Sandia/Disney collaborations that could include noise and vibration control, intelligent vehicles, smart materials applications, and information systems technologies projects.

4.3.3 Advanced Information Technology and Computational and Information Sciences: Sample Projects

Sandia is working with Bristol-Myers Squibb, the E. I. Dupont de Nemours Company, and Cray Research, Inc. to create robust software tools that will enable more powerful simulations for modeling organic materials at a near-macroscopic scale. The project draws on theoretical methods and computational facilities sponsored by DOE Defense Programs and on technical expertise gained in support of those programs. By participating, Sandia leverages existing resources in a way that directly benefits US industry while strengthening those resources, enhancing their value to DOE, and ensuring a domestic supplier of essential parts and components.

Sterling Winthrop is working with Sandia to develop computational tools for use in drug design. This work will help reduce the time to market for new pharmaceuticals by using advanced computational chemistry codes run on massively parallel computers. Because drug development typically takes twelve of the seventeen years of patent protection allowed for the end product, reducing that time has high priority. The same advanced computational chemistry techniques developed for this project apply to weapons safety and reliability efforts.

A licensing agreement between Sandia and SunSolu-

tions, a business unit of Sun MicroSystems, Inc., led to the commercialization of breakthrough desktop video-conferencing software. The software is based on a package that Sandia developed to address its own group-productivity needs. Work groups in dispersed geographical areas can now collaborate in real time on complex technical drawings and computer-aided design models using the software on their desktop workstations.

The National Center for Advanced Information Components Manufacturing is a two-year, $60 million program funded by the 1993 Defense Appropriations Bill. The program integrates federal and commercial research and development to reduce the time to market for US-developed advanced information components such as flat-panel displays. The program's various projects fulfill the Advanced Research Projects Agency's dual-use goal by ensuring that lightweight, portable video displays in our military vehicles, ships, aircraft, and command centers are manufactured in the United States.

Sandia and BIOSYM Technologies, Inc. are developing advanced mathematical libraries for massively parallel computer systems. The libraries will be used by BIOSYM to develop commercial parallel processor software modules for the design and engineering of advanced catalytic, electronic, optic, and magnetic materials. Successful exploitation of the new massively parallel computer technology in materials design requires cooperation between Sandia, where computer scientists develop numerical libraries and apply the computer codes to practical problems, and BIOSYM, a computer software company that develops and owns commercial software systems that uniquely apply this type of theoretical concept to complex modeling problems. BIOSYM will enhance its position as world leader in the development of predictive software for massively parallel computers for industry. BIOSYM's molecular modeling software will be of immediate benefit to Sandia's catalyst modeling and development efforts in support of DOE programs. Also, improved knowledge of materials modeling will support Sandia's materials development activities.



Sandia's Resources: Characterization and Management

5.1 People

People make the difference at Sandia. An outstanding technical staff supported by skilled labor and administrators is key to Sandia's mission success. Our policy is to attract and keep desired personnel consistent with business needs and DOE's strategic goals.

5.1.1 Current Human Resources and Future Needs

Sandia employs more than 8,500 people; the majority are based in New Mexico. About 1,050 employees work in California, and smaller groups work at Kauai, Hawaii, Las Vegas, Nevada, and the DOE Pantex Plant in Amarillo, Texas. Approximately 60 percent of Sandia's employees are in technical and scientific positions; the remainder are in crafts, skilled labor, and administration.

Sandia's professional technical and support personnel are drawn from all disciplines of engineering and the physical sciences and average approximately fifteen years of service to the nation. The technical staff represent almost 80,200 man-years of experience and have produced fifty-six patents during the past two years. About 67 percent of the professional technical staff have engineering backgrounds, with most holding degrees in electrical, mechanical, or chemical engineering. The remaining 33 percent have expertise in a variety of technical disciplines, including mathematics, physics, computer science, and materials science. Seventy-seven percent of the professional technical staff have graduate degrees, 46 percent of which are PhDs. Sandia's present staff composition is presented in Table 5-1.

Sandia's work force is meeting new challenges in science and technology and is continuing traditional efforts in national security. Sandia's people are key to our mission success. In the current environment of evolving work priorities, continuous change, and fluctuating budgets, Sandia's intent is to maintain and fully utilize our work force of talented, creative people dedicated to "exceptional service in the national interest."

Table 5-1. Laboratory Staff Composition (3/30/95)

	PhD	MS/MA	BS/BA	Other	Total
Professional Staff					
Engineers	688	1,166	264	14	2,132
Scientists	716	407	155	25	1,303
Other Technical Areas	5	68	35	420	528
Management/Administration	49	561	233	108	951
Support Staff					
Technicians		10	133	1,220	1,363
All Other		27	188	2,038	2,253
Laboratory Staff Total	1,458	2,239	1,008	3,825	8,530

5.1.2 Human Resources Planning and Evaluation

Sandia has developed a strategic human resource planning process to achieve long-term programmatic goals within the context of changing work requirements and evolving demographic and social trends. Human Resources strategic plans are driven by Sandia's overall strategic plan. Plans are developed in partnership with human resources program managers and line executives, who are jointly responsible for strategy formulation and implementation. The process is modeled on the Malcolm Baldrige approach to quality improvement and incorporates the key Baldrige elements for human resource development and management.

The Strategic Human Resource Plan (second revision) addresses six key areas: staffing, performance management, leadership and management, training and development, health care, and diversity.

Redesign and alignment plans, developed through the strategic human resource planning process, focus on the long term. A variety of cross-functional teams addresses specific human resource issues for the shorter term. Both long- and short-term human resource input is included in Sandia's strategic and operational planning.

Sandia measures employee satisfaction and well-being using two laboratory-wide surveys, targeted surveys, and focus groups, as required. Employee satisfaction is assessed every other year using a commercially available survey instrument. The first Sandians' Perspective Survey was conducted in 1991, the second in 1993. Employees reported feeling better about their work environment in the 1993 survey; this followed a two-year period when Sandia experienced major shifts in work, a company-wide restructuring, and a transition from one management and operating contractor to another. In the second survey, Sandians' perception of job security diminished, but employees had better perceptions of their immediate managers, personnel policies and practices, and opportunities for involvement in the company. Results from follow-on Sandians' Perspective Surveys will serve as benchmarks for corporate performance metrics.

The annual upward feedback process gives employees the opportunity to give anonymous feedback to their managers regarding performance. The goal is to open lines of communication between managers and employees and to provide a tool for managers to identify areas where improvement is needed.

Other data sources used to assess employee development and well-being include the training needs assessment, the performance management process, and informal management/employee lunches and meetings. The results are used to design training curricula, identify individual performance improvement needs, and improve organization and individual management practices.

5.1.3 Awards and Recognition

For the last five years, a concerted effort has been under way to increase recognition opportunities at all levels of Sandia and to foster an environment of teamwork and open communications.

The President's Quality Award was created in 1993 to recognize outstanding contributions by teams using quality processes. Approximately half the points in the award are for process; the other half are for results. The President's Quality Award reinforces the importance of balance between process and results. Proven processes, when properly applied, optimize chances for successful results.

The Employee Recognition Award recognizes outstanding achievement of individuals in the areas of management

achievement, technical achievement, operations and support achievement, and outreach achievement.

A nonpermanent compensation program is available throughout the year for different operating units to customize team celebrations or to recognize exemplary individual contributions within specific work groups.

5.1.4 Human Resources Programs

Human Resources program managers partner with line executives to help provide proficiency in business and people management, flexible integrated staffing, competitive labor and benefits pricing, work force productivity, and a quality work life. In general, Human Resources programs apply "best practices" used by comparable research and development organizations while maintaining compliance with the terms of the management and operating contract.

Staffing

The ability to place the right person in the right job at the right time is the driving force to design a more integrated approach to Sandia's external hiring, internal movement, and labor contracting processes. Our increasingly dynamic work environment makes it even more advantageous to employ and deploy employees effectively.

A strategic staffing initiative considers the following: a hiring program based on skill needs and long-term monetary investment in degree level or job classification, a mechanism for the timely realignment of people, and a decision tool for determining when it is more cost-effective to outsource work or use contract labor. A Strategic Staffing Forum, charted in 1993, ensures that staffing each year is consistent with projected revenues and that all staffing decisions support the overall corporate strategic directions. The forum meets monthly to discuss and resolve staffing issues within a strategic corporate perspective.

Internal Agility

Sandia strives to leverage the value of its current work force while offering solutions to managers' staffing needs. The post and bid system is a mechanism for regular on-roll employees to nominate themselves or be nominated for internal job openings. The Employee Development Center, established in 1993, provides a centralized resource for employees to market their skills for internal reassignment and for managers to review the pool of internal candidates before searching external sources. A skills profile software was used in 1994 to conduct an internal inventory of employee skills. When completed, this all-inclusive inventory of Sandians will serve as a tool for defining corporate capabilities and matrixing employees to support new initiatives. A corporate realignment policy, approved in 1995, will enable employees to be retrained and reassigned, further improving work force flexibility.

External Advantage

Sandia supports a recruitment and university relations program to attract top-level, diverse talent for regular and temporary employment. Nationwide efforts are focused on leading institutions to recruit technical candidates from engineering disciplines and the physical sciences: ninety to one-hundred recruiters visit twenty-four campuses to interview PhD candidates; ninety recruiters visit thirty-six campuses to recruit BS and MS candidates; twenty-four recruiters visit twelve technical institute campuses. All recruiters have regular job assignments and recruit on a part-time basis. Each recruiter is trained before visiting campuses to ensure that Sandia is properly represented and that a diverse pool of candidates will be interviewed.

A variety of special temporary and summer work programs provides qualified students the opportunity to expand career horizons with temporary, work-related experience. For Sandia, special work programs offer a valuable mechanism to identify candidates for regular employment.

Performance Management

In 1991 Sandia began the transition from a process of appraising performance to one of managing performance. The prototype was implemented with executive management in 1992 and expanded to directors in 1993. The entire organization completed the first performance management review cycle in 1995.

The performance management system requires the establishment of specific, measurable goals connected to the organization's strategic plan, business plan, and each individual job. At the beginning of each annual review cycle, goals are established and documented through negotiation between the individual and the manager. Open communication is encouraged through ongoing feedback and a mid-cycle review.

This process ensures the direct linking of each job and its performance to organizational plans and results. It establishes employee and managerial responsibility for identifying work requirements and tracking intermediate results. It sets up a framework for soliciting ongoing feedback from customers and stakeholders, and it provides the context for making compensation and other reward decisions.

A training program for managers helps implement performance management. Elements of the training include performance planning, feedback and coaching, and evaluation and reward.

Future phases of the performance management initiative will integrate the process more fully with the larger human performance system, including revised compensation strategies, identification of competencies supporting position roles and responsibilities, succession planning, career management, training and education, and work and organization design.

Compensation

The compensation program reinforces Sandia's philosophy to hire and retain the best talent available and reward individuals and work groups that support strategic business and operational plans.

Start rates are based on a combination of factors that includes degree level, job classification, experience, strategic skill needs of the organization, and market forces. Close attention is given to compensation surveys of leading research and development firms with engineering and scientific personnel. Compensation increases, base and nonpermanent, are linked to the achievement of performance management goals.

Corporate Training and Development

Education, training, and development are investments in employees designed to maximize productivity. Products and processes are linked with corporate goals to

- assist Sandians in preparing themselves for future technological advances;
- maintain Sandia's technical and business capability; and
- meet mandated and compliance-related training, development, and education requirements.

A fourteen-member, director-level council oversees the corporate training, development, and education programs to ensure strategic alignment. The council recently published Sandia's first comprehensive education policy.

Individuals and groups are offered job-related performance improvement and development opportunities to gain and apply knowledge, skills, and abilities toward the advancement of technology, quality human processes, personal health and safety, and protection of the environment.

Training needs are determined through ongoing assessments by professional instructional designers. This approach determines the target audience and appropriate course. Case studies, tours, panel discussions, competency-based design, and facilitated learning are some of the features of Sandia's in-house courses. Current emphasis is on design for product realization; business skills and knowledge; software engineering; project management; quality; environment, safety, and health; and leadership and management development. Corporate training and development programs include

- the In-Hours Technical Education Program, which ensures the continued expertise of employees and satisfies demands of current programs and expanding technical capabilities for future programs;
- the Tuition Assistance Program, which pays tuition for employees enrolled in university continuing education courses;
- the Doctoral Study Program, which pays expenses and stipends for full-time study toward the PhD degree;
- the One-Year-on-Campus Program, which meets Sandia's affirmative action objectives by paying expenses and stipends for new employees with bachelor's degrees to study full time for master's degrees; and
- the Distance Learning Program, which provides seminars and full semester courses via video link from universities or other locations to Sandia sites. This program offers an extensive curriculum required for compliance with DOE orders related to environment, safety, and health.

In addition, the Corporate Training and Development staff recently partnered with the Job Evaluation and Compensation staff to develop training for the new Performance Management System. Staff members also work with the Employee Development Center to identify work force skill gaps and emerging business areas that might require retraining of employees.

Leadership and Management

The Leadership and Management Program is aimed at improving the ability of Sandians to lead people and manage organizations, programs, and projects in an environment of continuous change and an evolving mission.

The program has described a set of twenty competencies with thirteen skill sets that are expected to be the most critical for Sandians in the year 2000. Based on a comprehensive needs assessment of the current management population, the Leadership and Management Program has

developed a core curriculum and on-the-job development options (such as special assignments and industry exchanges) to help close management skill gaps.

Other aspects of the Leadership and Management Program include succession planning for Sandia vice presidents and directors and a Sandia mentoring program.

Benefits and Medical Services

The Benefits and Medical Services Center takes an integrated approach to individual and organizational health and provides services for employee benefits, personal health care, occupational medicine, health promotion and employee assistance programs, and emergency medical response.

Most health plans are self-funded and administered by vendors selected through a competitive procurement process. Benefits packages are benchmarked against private-sector research and development companies and other DOE management and operating contractors. Opportunities for employee well-being are balanced with careful stewardship of DOE funds and compliance with laws, regulations, and DOE orders. The result is a competitive and cost-effective employee benefits package.

In addition to a choice of health care systems and on-site medical services, Sandia offers a variety of special services to enhance employee well-being and satisfaction. These include an on-site child care resources and referral service, an eldercare resources and referral service, and an employee assistance program. The Total Life Concept is an employee health promotion program that includes assessments, seminars, classes, and special speakers and covers topics on fitness, nutrition, and employee and family well-being.

The Benefits and Medical Services Center also actively participates in mission-related technical and administrative initiatives including

- medical oversight for the proposed production of molybdenum-99, a medical radioisotope for use in therapeutic and diagnostic medical procedures,
- computerized data files for medical surveillance and a cancer registry to study cancer incidence and mortality,
- a systematic and comprehensive program for protection of human research subjects, and
- a point-of-service health care plan to manage health care provisions and cost more effectively.

Sandia is committed to a healthful work environment and supports services that attract and retain a high-quality, productive work force.

5.1.5 Diversity Leadership and Education Outreach

The Diversity Leadership and Education Outreach Center was formed in 1994 to consolidate the activities of the Education Outreach Department (created in 1990) and the Diversity Leadership Center (established in 1992). This new center is composed of the Diversity Planning Department, the Equal Employment Opportunity/Affirmative Action Department, the Community Partnering Department, the K-12 Education Outreach Department, the Post-Secondary Education Outreach Department, and the Office of Research and Development for Science Education. The mission of the Diversity Leadership and Education Outreach Center is to ensure Sandia's and DOE's mission success by promoting an inclusive, equitable work environment for a high-performing work force and by applying Sandia's technical capabilities to enhance national science education and literacy. The center has been divided into three business sectors: Diversity Leadership, Equal Employment Opportunity and Affirmative Action, and Education Outreach. Although the focus is different for each of the business sectors, the convergence occurs on work force issues.

Diversity Leadership

The Diversity Leadership Program represents a revitalized emphasis on diversity at Sandia. Before the contract was signed between Martin Marietta Corporation (now Lockheed Martin Corporation) and DOE, Martin Marietta's Chief Executive Officer accepted the challenge from the Secretary of DOE to make Sandia a model laboratory that implements diversity as a way of doing business. The objective is to develop and sustain a work environment in which the full potential of all employees is realized. Corporate goals will be reached by fostering an inclusive environment where effective communication, cooperation, and collaboration among Sandia's employees, customers, suppliers, and stakeholders yield responsible, responsive, and uniquely competitive business policies, practices, and partnerships.

The Corporate Diversity Team, established in 1993, involves Sandians from all levels of the work force. The team, a cross-section of employees and line managers, is headed by a technical director. This team helps Sandians improve the work environment and increase productivity by capitalizing on individual differences and similarities. Other parts of the diversity infrastructure include

- diversity action teams, which gather data and implement solutions to help improve our work environment;
- diversity champions and partners (upper and line

management, staff, and represented employees) who have a working understanding of diversity and its relationship to Sandia's effectiveness and who serve as catalysts for change throughout Sandia as we work toward a more inclusive work environment;

- division diversity councils, which are responsible for identifying diversity issues specific to the divisions and implementing within line organizations the actions identified at the Large Staff Human Resource Conference on Diversity; and
- the Diversity Leadership Integration Team, which is composed of the leaders of the five focus areas of diversity: work force, education outreach, community outreach, subcontracting, and technology partnerships and commercialization.

The Diversity Leadership Integration Team will develop and implement the corporate Diversity Leadership Strategic Plan and integrate the focus areas of diversity leadership under that plan. Diversity leadership has four key components: collaboration, integration, commitment, and results. Under the collaboration component, Sandia works with DOE Headquarters, DOE's Albuquerque Operations Office, the Kirtland Area Office, the Lockheed Martin Corporate Office, and the Albuquerque community to establish a strategic direction and a measure of accountability for diversity at Sandia. This collaborative process occurs formally through executive forums on diversity and informally through networks established as a result of the forums. Under the integration component, the diversity effort expands beyond the work force to include other dimensions of the business environment. The commitment and participation of Sandia's executive management in the corporate diversity program sends a strong message of support to Sandia's employees. Management participation in the Diversity Champions program and the presence of nearly one hundred Sandia managers in a two-day Human Resource Conference on Diversity in March 1995 show a strong commitment to effect change in the Sandia culture through managing and valuing diversity. In addition, DOE and Lockheed Martin are strong proponents of community involvement and partnerships and have led the way in broadening Sandia's focus beyond the workplace. Being a model of diversity leadership requires collaboration, integration, and strong commitment as well as proven results. Diversity leadership incorporates the quality principles of cost, performance, and scheduling; listening to the customer; and clear goals, strategies, processes, and metrics to achieve results. A Diversity Leadership Strategic Plan for the implementation of diversity at Sandia, published in March 1995, outlines the goals, current status, and outcomes of the program.

Equal Employment Opportunity and Affirmative Action

Although compliance with applicable equal employment opportunity and affirmative action laws and regulations is legally mandated, Sandia's approach is based on a moral commitment to all individuals regardless of race, religion, gender, age, national origin, veteran status, sexual orientation, or disability. Terms and conditions of employment affected by Sandia's equal employment opportunity and affirmative action commitments include recruiting, hiring, and training; promotion, compensation, and benefits; transfers, layoffs, and returns from layoffs; Sandia-sponsored training, education, and tuition assistance; and social and recreational programs. Sandia's personnel process assures a thorough and systematic consideration of qualifications, job requirements, and possible accommodations. Physical and mental job requirements are reviewed to ensure that such requirements are job-related and consistent with business necessity and safety.

Affirmative action programs are tools to help create a balanced work force from a broader pool of highly qualified, talented people. These compliance efforts affect our hiring and promotion decisions and actions. As part of the corporate affirmative action program, goals have been established where underutilization exists. Periodic progress reports are given to vice presidents to assist in monitoring the corporate affirmative action plan. Vice presidents are accountable for goals identified in their performance plans. A detailed profile of Sandia's diverse work force and a description of our progress toward meeting FY 1995 affirmative action objectives are documented by Sandia's Affirmative Action Program.

To support and enhance Sandia's affirmative action plan, outreach/inreach committees have been established for Native Americans, Asians, African-Americans, Hispanics, women, and the disabled. Each committee has twelve to twenty members from both the technical and administrative staffs. The outreach programs contribute to Sandia's affirmative action efforts by partnering with community contacts to identify underrepresented groups for possible employment at Sandia and increase sensitivity and cultural awareness. Examples of committee activities include career fairs, conferences, tours, lectures, and cultural celebrations.

Sandia's internal compliance review is another method for assessing progress toward affirmative action goals. This process involves an in-depth review and analysis of each component of the affirmative action plan and other relevant data, such as compensation and formal charges. The completed internal compliance review led to six self-assessment work force teams sponsored by six vice presidents; each team was headed by a technical director. The self-assessment work force teams consisted of sixty Sandians and were chartered to address the corporate human resource issues identified in the internal compliance review: data integrity, work force projection, communication, glass ceiling, internal movement, and recruit-to-hire processes.

In addition to the employment-related efforts noted above, Sandia affords maximum opportunity to business enterprises owned by women and underrepresented groups to participate as suppliers and contractors. Sandia has had a very active disadvantaged, women-owned, and small business program for many years and has received awards from organizations including the Small Business Administration and DOE.

Education Outreach

The Education Outreach Program consists of an extensive, interrelated set of projects supporting scientific and technical education for students, teachers, and faculty. The projects are designed to improve scientific and technical literacy and to increase the number of scientists and engineers from historically underrepresented groups in support of DOE's goal of a technically literate and culturally diverse work force. These efforts are funded by DOE Defense Programs and the Office of Science Education and Technical Information and by the Office of Indian Education Programs within the Bureau of Indian Affairs. These programs are described in chapter 3.

The Education Outreach Program is shifting from direct involvement in precollege science and mathematics activities toward post-secondary and precollege projects that link directly to Sandia's core competencies. This shift results in part from new requirements from DOE Defense Programs (our largest customer), which wants the education projects to align more closely with Sandia's missions. In addition to providing mutual benefit to both DOE Defense Programs and the education system, the goal of the Education Outreach Program is to offer high quality projects and to target individuals who traditionally have been underrepresented in science, engineering, and technology-related career fields.

Summer research projects are part of post-secondary through graduate school student activities and are designed to support Sandia's Affirmative Action Program by promoting the hiring of underrepresented individuals. Outreach projects also exist for teacher training and curriculum development for teachers at all educational levels from grade school through university.

5.2 Information

5.2.1 Information Resources Management

An information services group is consolidating all activities associated with information management throughout Sandia. Organizations previously performing some aspect of this function are now being coordinated by an information architecture team to achieve economies of scale by eliminating duplicate efforts. Major functional areas include information processes (data modeling, standards); applications development (business systems, electronic commerce, property, procurement); information services (electronic mail, help desk, local area network management); and computing and communication systems (mainframes, servers, telecommunications).

An advisory group of users and managers will provide Sandia-wide guidance to the information services group. User support will be provided by customer service units, a central computing help desk, and a financial information system user's group. Relevant information will be distributed electronically, as appropriate. Quarterly reviews will be held.

Long-term planning has two major focuses. First, the information services group will define Sandia's approach to a corporate information network and company-wide and external access options. Second, staffing and funding will expand through FY 1996 to establish the infrastructure, then level off in FY 1997.

The information services group will build a coherent information infrastructure and manage information as a corporate asset. Corporate information will be stored in data servers and be readily accessible via personal computers and workstations throughout Sandia. Some information will be available as utility services (e.g., electronic mail). Other information will be available on a charge-back basis.

Sandia's technical library provides published materials to Sandia staff. New library systems give staff desktop access to collections in the library and at other locations throughout Sandia. In the future, complete texts of Sandia-generated reports will be available on line.

5.2.2 Software Management

In 1992 Sandia established the Software Management Program for all software being acquired, developed, supported, and used. Although created in accordance with the requirements of DOE Order 1330.1D, the Software Management Program was implemented as a good business practice that identifies a single Sandia point of contact for software management reference; implements a uniform Sandia software management policy; establishes guidelines derived from internal organizations and industry best practices; and encourages development of organization-specific, results-oriented software management plans that incorporate the precepts of software quality assurance and software quality control.

The Software Management Program Quality Improvement Team is the software technical advisor to Sandia's vice presidents, each invited to select two members for the team.

In September 1992 the Quality Improvement Team presented its implementation plan to the DOE Albuquerque Operations Office. The strategy outlined in the implementation plan includes customer requirements, corporate software policy, corporate software processes, and organization

software methods. The corporate-level focus is on developing policy guidance and general software management methods based on existing organization best practices and known industry best practices. The organization-level focus is on identifying application-specific life-cycle models and methodologies consistent with corporate policy and processes.

The Quality Improvement Team has a charter and organizational structure and has identified specific tasks. The following tasks have been completed: revision of the implementation plan, establishment of a software management policy, and linkage with other corporate software-related initiatives. Links within the Albuquerque community and the nuclear weapons complex are being established, and software process assessments and software process improvements are under way within Sandia organizations having significant software engineering activity.

The Software Management Program policy espouses autonomy of organizations in defining their own software management practices, setting their improvement goals, and progressing in accordance with Sandia corporate policy and preferred practices. This policy was formalized as "Sandia Laboratories Policy 1011: Software Management" (4/1/93). Each organization identifies software for which it is responsible, defines applicable software management practices, and identifies applicable software plans, methodologies, and environments. Preferred practices for development and maintenance of software are in the following publications:

- July 1986. *Sandia Software Guidelines. Volume 3: Standards, Practices, and Conventions*. SAND85-2346. Albuquerque, NM: Sandia National Laboratories.
- August 1987. *Sandia Software Guidelines. Volume 1: Software Quality Planning*. SAND85-2344. Albuquerque, NM: Sandia National Laboratories.
- July 1989. *Sandia Software Guidelines. Volume 5: Tools, Techniques, and Method*. SAND85-2348. Albuquerque, NM: Sandia National Laboratories.
- May 1991. *Preferred Processes, Software Development*. SAND90-2227. Albuquerque, NM: Sandia National Laboratories.
- June 1992. *Sandia Software Guidelines. Volume 4: Configuration Management*. SAND85-2347. Albuquerque, NM: Sandia National Laboratories.

5.2.3 Computational Facilities

Scientific Computing Resources

Sandia's supercomputers include large vector architecture machines (e.g., the Cray Y-MP systems) and a growing number of massively parallel systems. Supercomputers are used primarily for solving large scientific and engineering problems. Applications include materials studies, nuclear safety calculations, particle-beam calculations (for pulsed power and other research), weapons systems development, missile defense and countermeasure analyses, facilities vulnerability analyses, and combustion chemistry. Supercomputers allow us to model three-dimensional effects and perform increasingly higher-resolution approximations.

To accommodate the computational demands of its missions, Sandia has developed a number of interlinked networks of computers based on increasingly more capable communications. Desktop computers and workstations are linked with central systems through reliable, high-speed networks. Asynchronous transfer mode switches and synchronous optical network technologies are the basis for Sandia's network backbone. Legacy fiber distributed data interface rings and ethernet technologies are integrated into the current asynchronous transfer mode environment. Fiber distributed data interface and ethernet local area networks are being systematically converted to asynchronous transfer mode.

The major delineation in the networking realm is the separation of secure (classified) and restricted (unclassified) computing resources. Individual computer systems reside in one or the other of these domains. The secure domain is capable of processing unclassified through secret restricted data.

Sandia's supercomputer systems are located at the New Mexico site. Data communications capabilities are available at 45 megabits per second to facilitate use of these systems by staff in both New Mexico and California. The secure network houses a Cray Y-MP8/264 and a two-terabyte network storage server. The restricted network houses a Cray Y-MP8/864 and a one-terabyte network storage server.

Massively parallel systems are also on the unclassified network and are accessible to our industrial partners. In this network we currently have a 1,024-node nCUBE with four gigabytes of memory operating at a peak rate of 2.5 gigaflops, two 64-node Intel iPSC/860s with a peak rating of 3.8 gigaflops, and an Intel Paragon with 1,840 nodes operating at a peak rating of 140 gigaflops.

Sandia's scientific computing acquisitions during FY 1996 through 2000 are intended to dramatically increase computational power and simulation capability and improve the performance of support servers both at the central facility and within distributed local area networks. During FY 1995 and 1996 Sandia will replace its Cray YMPs with a heterogeneous collection of vector and scalar platforms from vendors such as Cray, IBM, HP, DEC, and SGI. Plans are also being implemented to bring Sandia's network technology into the gigabit range during this time frame. Early in the planning period, massively parallel systems capable of sustained teraflop operations will become the major computer servers.

We plan to implement leading-edge, industry-supported standards in all our computing environments. Therefore, we will conduct integrated research in communications,

networking, algorithm development, and computing technologies to lead in the development and establishment of such standards.

This effort will require many collaborations with industry and other national laboratories. Several cooperative agreements are already in place. By integrating fiber optics, asynchronous transfer mode protocols, synchronous optical network technology, scientific algorithms, and massively parallel systems, it will be possible to create a computing environment that will allow customers to solve a vast array of engineering and scientific problems and visualize results quickly. The advent of synchronous transfer mode and similar technologies will also permit distributed workstations to be clustered as a single logical resource. Ultimately, it will be possible for a customer to log onto a network and have access to a single system image of resources on local- and wide-area networks.

Computer-Aided Engineering

Computer-aided engineering is an important element supporting Sandia's responsibilities for product design through manufacturing processes. Sandia has demonstrated capabilities in the management of major projects supporting pioneering efforts in computer-aided design and manufacturing. Accordingly, DOE designated Sandia as the lead laboratory for the Computer-Integrated Manufacturing Program within the Office of Military Application. An integrated computer-aided engineering capability is the primary focus of the Computer-Integrated Manufacturing Program.

A fully integrated computer-aided engineering capability should contain all the necessary elements for the creation, management, and distribution of information to support the design, analysis, definition, manufacture, and acceptance of a product, including product life-cycle information. The Engineering Support Center contributes in the two primary areas of creation and information management.

Information is created via two primary projects: NIRVANA and ACCORD. The NIRVANA project provides computer-aided engineering features to support electromechanical product design. The ACCORD project supports mechanical products. Both projects involve participation from a number of departments at both Sandia locations, at AlliedSignal's Kansas City Division, and at the Pantex plant.

The NIRVANA project is based on the concept of a standard design environment using a common set of tools and processes. The NIRVANA implementation plan includes periodic system upgrades or replacements as new technologies become available. With this approach, the design environment remains constant because all user sites will migrate uniformly to the new environment. The ACCORD project objective was to select the next-generation system supporting mechanical design for use within the weapons complex. The system is based on a parametric, feature-based solid modeler that is the foundation for the various processes. Similarly to the NIRVANA project, the design environment will be periodically upgraded to reflect newer technologies or processes.

Information management covers a range of responsibilities, including development of new systems and maintenance of older systems while applying the latest technologies (such as language-based information modeling processes and automatic code generation). The challenge is to minimize the number and types of information systems, remain affordable, and satisfy customer needs. Two examples of success in this area are the Configuration Management System and the Image Management System.

Output information from computer-aided engineering tools is managed by the Configuration Management System, which was developed during FY 1993 and implemented at the start of FY 1994. The Configuration Management System is being integrated to serve both the New Mexico and California sites. The Image Management System serves as a long-term archival information storage system for design information and allows user access from Sandia/New Mexico, Sandia/California, and AlliedSignal in Kansas City.

The integration of these related elements of computer-aided engineering have the potential to provide significant improvement to the design-through-manufacturing process. However, realizing the full potential of these capabilities will require major changes to our business and design processes, as well as to our interfaces with our business partners.

Administrative Information Systems

Integrated Information Services projects currently emerge from two areas. First, the Administrative Management Committee distributes funding to business centers. These centers establish priorities for projects they fund. A second source of projects and priorities stems from the Laboratory Process Reengineering Team. This team coordinates the efforts of a number of functional area reengineering teams. The Integrated Information Services Division participates on these functional teams and then responds to service requests that are reviewed and approved by the Laboratory Process Reengineering Team. A third source includes work-for-others activities that are negotiated among organizations within Integrated Information Services and both internal and external customers.

Separate but related project activities exist in developing messaging services. These include electronic mail messaging, enhancement of the voice mail system, and development of applications for voice and electronic mail. Work continues on voice applications, such as the invoice processing application that provides status reports to our suppliers by telephone. Messaging activities will be expanded in FY 1996 by developing applications that conform to electronic data interchange standards and connecting to Sandia's external vendors, reducing the cycle time of major corporate processes.

All centralized information systems now reside primarily on an IBM model ES9021-620, the Laboratory Information System. These applications run under the Multiple Virtual Storage operating system and IBM's DB2 database management product. Applications include human resources, payroll, financial services, property, and procurement.

In addition, Integrated Information Services is piloting several distributed, client/server applications to bring information and business functionality to every Sandian's desktop in an intuitive, user-friendly format. These applications will support a wide variety of clients (Windows, Macintosh, and UNIX) and function and data service will be provided by UNIX servers and the Sybase database management product. Initial applications include an electronic time-keeping application and the Enterprise Viewing Environment—a collection of applications offered via distributed World-Wide Web servers.

Production-related activities for centralized information systems (such as scheduling, systems support, operations, help desk services, and data administration) are provided under full cost recovery through the Administrative Computing Service Center. Cost pools have been developed for each hardware platform, and accounting transactions exist in the service center information system to automate cost recovery of usage-based and fixed-price services. As the distributed computing environment matures, mechanisms for full cost recovery will be developed. It is expected that some costs will continue to be recovered through the Administrative Computing Service Center while others will be recovered through Customer Service Units. All central computing facility machines operate twenty-four hours a day, seven days a week.

Two smaller IBM processors continue to provide other services. An IBM model 4381 runs IBM's Office Vision product under the Virtual Machine operating system and provides electronic mail services and routing, as well as detailed personnel information through the Personnel Reporting System. The Classified Information System is an IBM model ES9121-190 that runs under the Multiple Virtual Storage operating system and provides an environment for classified engineering and administrative applications. Applications on the Classified Information System support records of assembly, the technical library, engineering documentation, and document accountability. Applications currently residing on these IBM machines are candidates for movement to a client-server architecture based on the results of cost/benefit studies.

Our goal for administrative information systems is improved competitiveness through a hardware and software environment that anticipates customer needs. Two initiatives are already under way. We are conducting an external benchmark of the data center and have formed an architecture team to explore the adaptability of the framework used by commercial information services.

Based on an environmental scan and strategic planning involving major customers, we envision an expanded partnership with customers to provide solutions. An important strategic goal is greater accessibility of administrative data from customers' desktops. To achieve this, we plan to introduce a client-server architecture, provide greater leverage of software tools between the mainframe and desktop environments, and use object-oriented methodologies to improve quality and reduce delivery time. We also plan to provide increased training to line organizations in using administrative information systems to conduct their business more efficiently.

5.2.4 Telecommunications

Data Communications

The emphasis on parallel computing, outside collaboration, consolidation, technology partnerships, total quality management, and environmental safety and health management makes data communications vital to Sandia's future. A variety of technologies is being investigated and deployed, including fiber optic cables to the desk, very-high-speed local area networks, modern broadband switches, high-speed intersite links, video teleconference facilities, and modern network management systems.

Sandia's recent initiatives require unclassified communications, but our traditional mission necessitates secure communications. Sandia operates an extensive internal secure communications system. A large customer base receives services ranging from asynchronous terminal access through 100-megabit fiber-distributed data interface support. Numerous intersite links to a variety of DOE and DoD facilities exist, as well as dedicated and switched video teleconferencing capabilities to several DOE facilities.

Sandia's Engineering Science Center recently moved to a refurbished building. As part of the move, we installed an extensive, state-of-the-art optical-fiber distribution system and connected it to every desk in the new facility. Although full-bandwidth ethernet on optical fiber was installed, the distribution system will support fiber distributed data and will interface with local area networks and video. This distribution system and the high-speed networks are a model for several other facilities at the Sandia/New Mexico location.

An architecture that consists of T3 (45-megabit-per-second) intersite links, asynchronous transfer mode switches, switched multimegabit data service protocols, and high-performance routers was implemented as part of Sandia's plan to locate all its supercomputers at Sandia/New Mexico. This architecture is the standard for high-speed networking at Sandia. The architecture is being modernized to include a synchronous optical network distribution system (up to Optical Carrier 48) and broadband asynchronous transfer mode switches. We are also a participant in the AT&T-sponsored experimental university network, which is a test bed for cross-country gigabit networking.

Voice Communications

In the past, the Kirtland Air Force Base Communications Squadron provided telephone service for the Sandia/New Mexico site and for all other Kirtland Air Force Base tenants. However, recognizing the importance of telecommunications service to corporate existence, Sandia assumed direct responsibility for providing state-of-the-art services in 1993. Sandia moved and expanded the AT&T 5ESS digital electronic switch to form the cornerstone of its voice and unclassified data telecommunication services. This switch provides enhanced digital voice, video, and data services using integrated digital networks.

The Sandia 5ESS switch consists of a host system and optical remote modules to service our remote areas. We constructed a building for the host 5ESS switch and upgraded conduit systems to provide customer access. Approximately 1,200 lines are in service on the first optical remote module, and more than 17,000 lines are in service on the 5ESS host, which also serves other DOE facilities on Kirtland Air Force Base (the Albuquerque Operations Office, the Inhalation Toxicology Research Institute, EG&G, and Ross Aviation).

Sandia/California operates an AT&T 5ESS switch for its unclassified voice and data communications. The 5ESS is an integrated services digital network switch capable of handling voice, data, and signaling information on the same line. It provides access to Federal Telecommunications System 2000 and the commercial network for long-distance communications.

The Tonopah test range local voice telecommunications system terminates in a Northern Telecom SL-1 switch with twenty-four trunks to the SL-100 switch at the DOE Nevada Operations Office. Tonopah test range personnel use the Federal Telecommunications System and the Nevada Test Site tie-line network for most of their long-distance telephone requirements.

A Motorola radio trunking system (selected by competitive bid) was installed at Sandia/New Mexico in 1991. It is a basic five-channel system that will be expanded as users are moved to the system from their current frequencies. The basic system has a capacity of approximately six-hundred radio users. The site currently has about 2,200 radio transceivers in use.

Radio networks on the trunking system include the motor pool, transportation and storage, and reapplication services. The radio frequencies in use by these organizations are also available for other uses. As funding becomes available, most other services (plant maintenance, safety, emergency operations, and health physics) will have their radio communications transferred to the trunking system.

When fully implemented, the trunked radio system will become a part of Sandia's national security emergency preparedness communications system. It will fulfill emergency communications requirements mandated by the specification for emergency operations centers in the DOE Albuquerque Operations Office Complex.

5.2.5 Records Management

Records management entails planning, organizing, training, and other managerial activities related to the creation, maintenance, use, and disposition of records. The purpose of records management is to provide the right record to the right person at the right time for the right cost.

The records management program at Sandia supports core research functions and laboratory operations by improving management of information resources. The records management program fosters an understanding of the importance of recorded information generated by Sandia staff and subcontractors; teaches Sandians their responsibility in the creation, use, maintenance, and disposition of records; and explains the federal government's role in information management at Sandia.

The records management program assists line organizations in constructing manual and automated systems for timely and cost-effective information retrieval and tracking and also guides line organizations in cost- and mission-effective management of information throughout its life cycle (creation, distribution, maintenance, and destruction or long-term preservation). The administrative portion of the Sandia-wide retention schedule has been delivered. Environmental safety and health, research and development, and defense programs retention schedules will be delivered by the end of CY 1995. The retention schedules identify unique groupings of records, assign responsibility for such records, and indicate when and how such records may be disposed (i.e., destruction or transfer to corporate archives).

Sandia's records management program and retention guidelines ensure compliance with regulatory requirements implemented with good business practices. All records held by Sandia (except for personnel, medical, and certain legal records) are government property and subject to federal statutes and regulations, including those found in the US Code, the Code of Federal Regulations, DOE orders, our prime contract, requirements specific to particular Sandia projects, and other regulatory requirements imposed by various government agencies.

The records management system reviews line organization information management procedures for adherence to good business practices and compliance with regulatory requirements. The records management system also provides leadership and partnering activities that

- facilitate the integration of information services by teaming with other information resource providers;
- preserve and make available Sandia's corporate memory and evidence of Sandia's service in the national interest;
- work with nuclear weapons complex design agency and production agency engineers to ensure that

records to support changing mission assignments of nuclear weapons component production during reconfiguration remain available to Sandia product engineers and stockpile evaluation engineers; and

- assist DOE in identifying, preserving, and improving retrievability of weapons data vital to the national defense.

One effort will develop the Technology Transfer Software Repository in partnership with the Technology Partnerships and Commercialization organization. This repository will house software developed at Sandia that is waiting for marketing opportunities and license waiver from DOE. Coordination of these activities will allow Technology Partnerships and Commercialization to develop markets for Sandia's software and provide for licensed packages to be submitted to DOE's Energy and Science Technical Software Center in Oak Ridge, Tennessee.

An updated Sandia history video was produced in early FY 1995, replacing a twelve-year-old version. Additionally, history displays have been well received at the Atomic Museum, Sandia Day, and the Science, Engineering, and Technology Career Expo XII. A general history of Sandia is planned for completion by the end of CY 1995.

A records management activity transfer group composed of design and production engineers, procurement, and corporate records management personnel identified production-related records at the Pinellas, Mound, and Rocky Flats plants that needed to be transferred to Sandia and Los Alamos national laboratories and AlliedSignal in Kansas City. The Knowledge Preservation Project team, composed of defense program and corporate records management personnel, is interviewing and capturing essential weapons information previously unrecorded and therefore unavailable to future weapons engineers. This videotaped information will be digitized, compressed, and stored on a network server; the audio track will be transcribed into a fully indexed text file linked to the digitized video by time code. User access will be provided from desktop personal computers.

5.2.6 Management of Scientific and Technical Information

Sandia established the Scientific and Technical Information Management Program to protect the public's interest in research performed at Sandia. Scientific and technical information encompasses all aspects of work at Sandia, including some administrative, financial, and environmental safety and health efforts. Because such work is largely funded by government expenditures, the public has a considerable interest and investment in Sandia's operations. More specifically, the public has legitimate concerns that

- technical staff manage scientific and technical information to facilitate continued success in research and to promote cost- and mission-effective operations;
- results and progress on all significant scientific efforts are reported to DOE so that findings may be made available to appropriate individuals in the research community;
- research staff control the dissemination of information to protect national security interests; and
- technical staff generate adequate documentation of their work to assure accountability and protect against fraud, waste, and abuse.

Sandia addresses these concerns through its Scientific and Technical Information Management Program. The program trains staff members about their roles in generating information needed to document research efforts and in their responsibilities as custodians of such documentation. Sandia and DOE have formal review and approval processes to ensure that scientific and technical information has undergone required reviews prior to external release.

5.2.7 Management of Personal Property

In 1994 Sandia established a Personal Property Management Program to consolidate and integrate personal property functions throughout Sandia. The program encompasses all personal property owned, rented, borrowed, or leased by the government in the possession or under the control of Sandia, including property loaned to other entities. Personal property is defined as all tangible possessions except real property, nondurable goods (e.g., office supplies), records, and special source materials (e.g., special nuclear material). The program has eight major components: receiving and distribution; property control; property utilization; loans and government-furnished property; storage; reapplication and disposal; motor vehicles; and California general stores.

This program provides Sandia line organizations with management, control, reapplication, and disposal services for approximately $1.3 billion of government-owned personal property. The Personal Property Management Program is closely coordinated with the accounting and procurement programs.

During the past eighteen months, program operations have been significantly enhanced in several areas. Employees have been made aware of their responsibilities for protecting and maintaining property. In addition to frequent communications, a personal property awareness week has been conducted.

Six new structures have been constructed so that the reapplication and disposal organization has adequate inside storage space during property processing. Reapplication pickup time has been reduced. A formal management review process to ensure timely reapplication of idle equipment has been reinstated.

The property database user interface has been upgraded to provide increased capabilities and easier access to data. The Personal Property Management Program Manual documents the mission, vision, objectives, roles, and responsibilities of the program. A process manual being developed describes the implementation of each program process. A user's manual is also being developed to define customer roles and responsibilities, describe personal property management services, and give customers step-by-step instructions to access these services.

The Personal Property Management Program provides timely and cost-effective services to Sandia's line organizations in compliance with DOE property management requirements.

5.3 Sites and Facilities

Sandia's executive management offices and larger laboratory location are on Kirtland Air Force Base on the southeastern edge of Albuquerque, New Mexico. Another Sandia laboratory complex in Livermore, California, adjoins Lawrence Livermore National Laboratory. Test ranges are operated near Tonopah, Nevada and at the Navy Pacific Missile Range on Kauai, Hawaii.

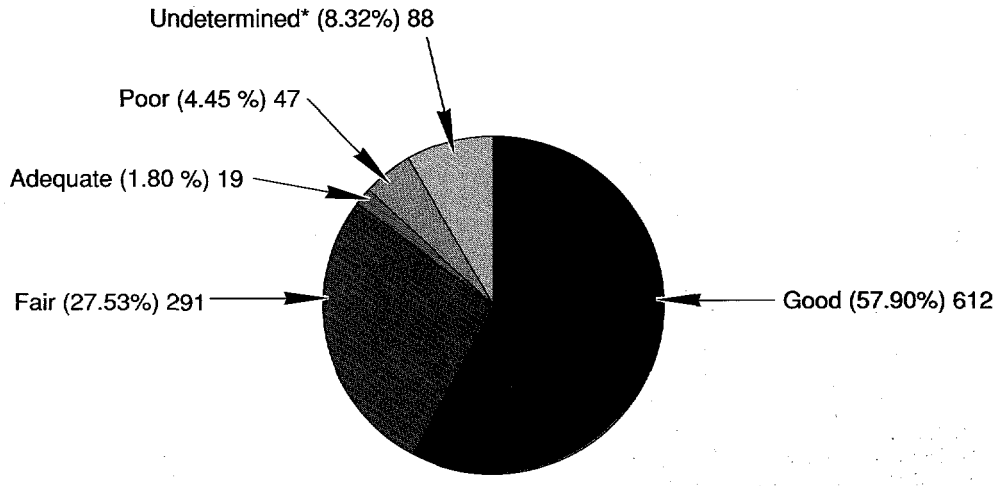
Overviews of Sandia National Laboratories' New Mexico and California facilities are provided in section 1.3.3.

5.3.1 Facilities Plans and Options

Site Development

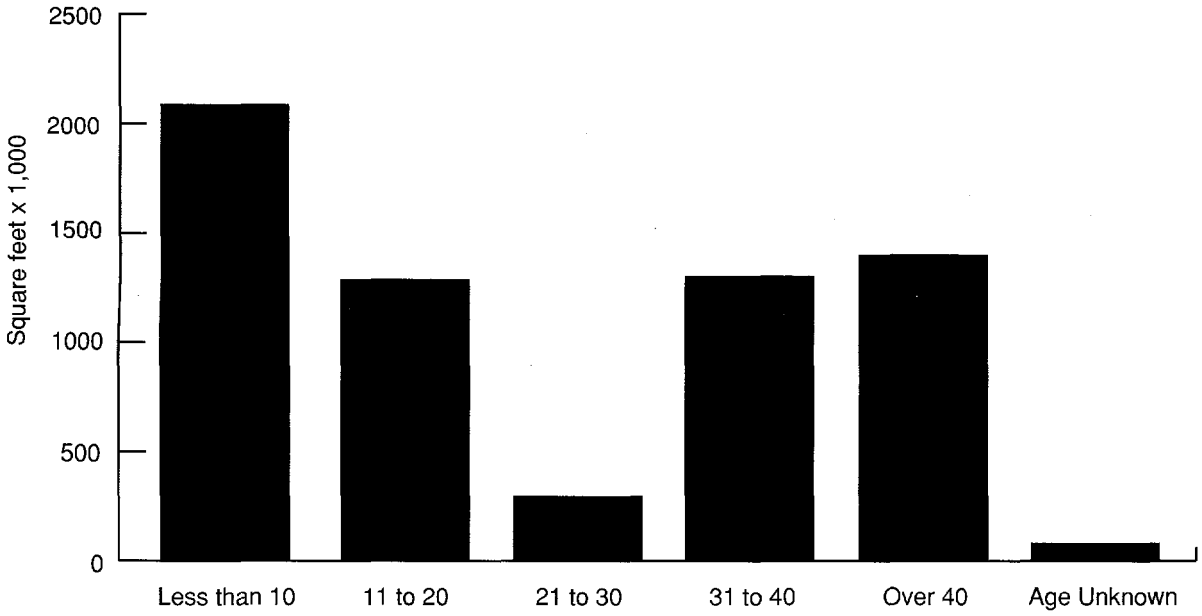
Sites and Facilities develops plans to support Sandia missions, identifies and develops capital- and expense-funded projects that support those plans, and formally documents these plans and projects.

The plan development process evaluates DOE and Sandia missions and strategic plans, translates them into site physical requirements to accommodate these missions, and compares physical requirements to existing site capabilities. Site physical requirements we consider include buildings and infrastructure, environmental impacts, and future land uses. Existing site capabilities are determined by tangible factors (such as condition and current use) and intangible

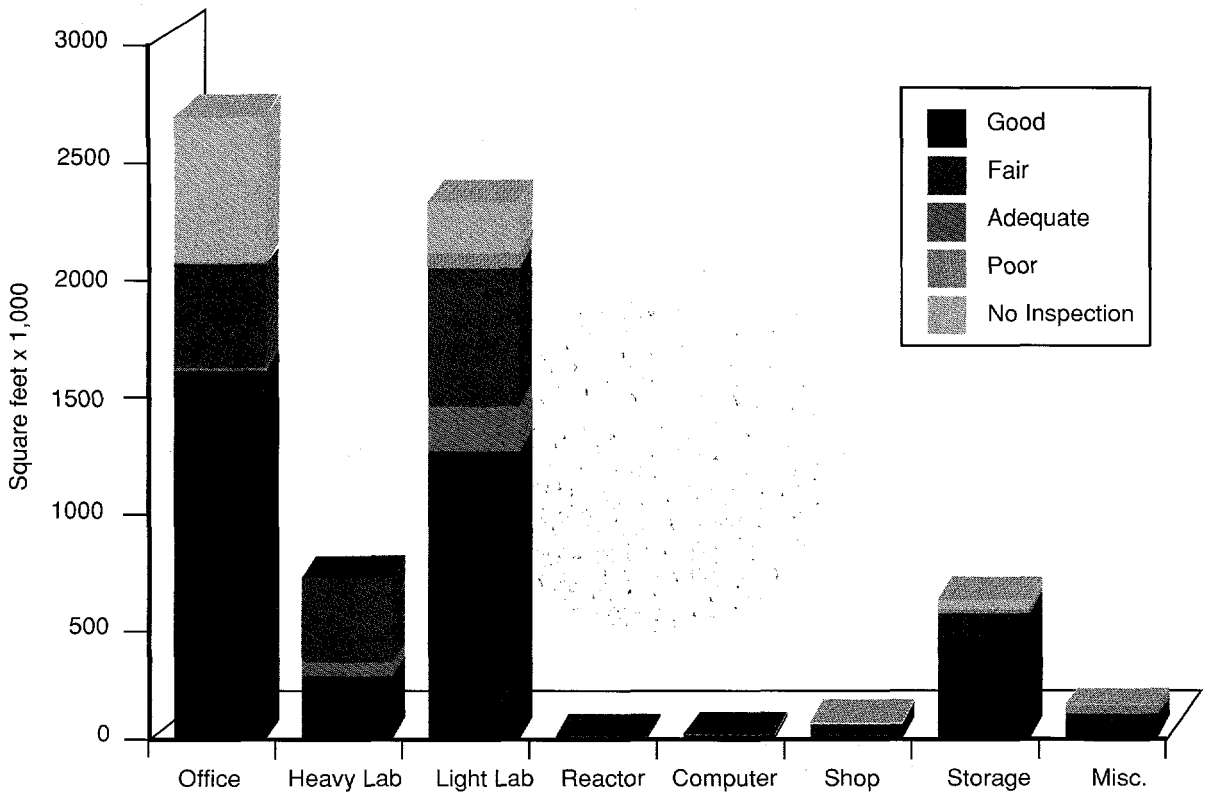


*Undetermined refers primarily to facilities occupied but not owned or maintained by Sandia. This designator also includes buildings not yet inspected because of testing conditions, security, etc.

Condition of Laboratory space by building (total number of buildings = 1,057).



Age in years of laboratory buildings.



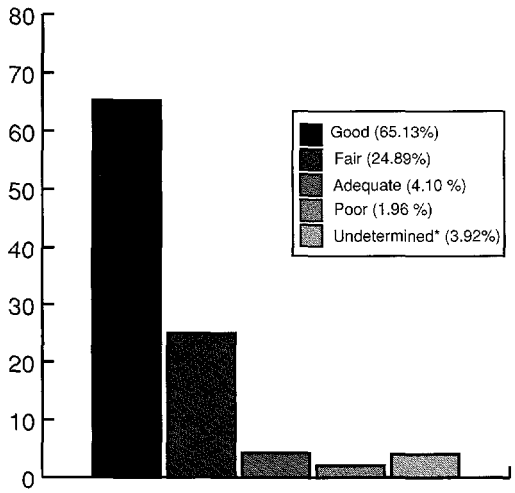
Use and condition of laboratory space excluding mobile offices and transportable buildings.

factors (such as social, cultural, and economic impacts of planned activities). This process results in site master plans from which project proposals are generated.

Because DOE thought that Sandia requests for new facilities were not always well coordinated with mission needs, we developed new processes to identify, evaluate, prioritize, and develop line item project proposals to request approval and obtain funding. A Building and Facilities Planning Committee at the vice-president level had traditionally made corporate facilities-related decisions, but their breadth of responsibility and quarterly meeting times precluded an in-depth evaluation. Therefore, a group of directors representing the programmatic customers and facilities-related services formed an Integrated Sites Planning Council. The council reviews materials prepared by a matrixed staff, prioritizes projects from a corporate perspective, and presents the prioritized project list to the Building and Facilities Planning Committee. The resulting approved projects reflect Sandia corporate missions, and the project descriptions have been refined to provide DOE with enough information to make informed decisions about Sandia's conceptual design efforts.

The above process has worked so well for line-item proposals that it will now be used for development and prioritizing of all major Sandia project requests (general plant, major renovation, demolition, and overall campus development).

These two processes roll up into documents such as the Sandia Institutional Plan and Operational Plan, which in turn become the blueprint for a comprehensive set of plans that demonstrates the overall link between plans and projects. Such plans include district plans, strategic space forecasts, architectural and landscape guidelines, and the new comprehensive plan.



*Undetermined refers primarily to facilities occupied but not owned or maintained by Sandia. This designator also includes buildings not yet inspected because of testing conditions, security, etc.

Condition of laboratory space in percentages of gross square feet (total = 6,471,448).

The comprehensive plan is being developed by the Sites Planning Department in response to the Life Cycle Asset Management Order and will integrate mission, economic, ecological, social, and cultural factors into the planning process. This plan is composed of three main segments. The first segment includes an introduction to the mission and vision linkages to the DOE/Sandia strategic plans, planning goals, context of the sites, and resulting scenario plans. The second segment describes the site master plans, including site conversion plans, land use, campus design guidelines, and space management. The third segment discusses the project development process and resulting projects, resource requirements, and schedule requirements.

Sandia's Site Development Plan, updated annually, contains a comprehensive description of planned facility changes. The plan contains a long-range outlook for each of the four principal Sandia sites. In the current dynamic environment, this plan is becoming an evolutionary document in which site locations for future facilities are tentative. Exact locations of future facilities, site infrastructure, and the types of activities they will support are determined through business planning and site evaluations. Although the Life Cycle Asset Management Order may eliminate the requirements of the Site Development Plan, Sandia will continue to develop a similar executive-level summary document.

Sandia's site development planning is intended to relieve space shortages and construct permanent buildings to replace temporary ones, while converting sites to support more open access and unclassified activities. As the construction program permits, we will retire mobile offices, trailers, transportable buildings, and other substandard space. In addition, our site development planning will consider the requirements of the National Environmental Policy Act and site environmental restoration activities.

Five essential factors underlie Sandia's plan for sites and facilities. One factor has existed from Sandia's founding, when the nation urgently needed to build a nuclear arsenal. Sandia did not have adequate permanent buildings then, and the problem has never been fully corrected.

A second factor is that profound changes have occurred in engineering practice and the supporting scientific disciplines since Sandia was founded. In 1950 much of Sandia's engineering work was checked with extensive field testing. However, in recent years, cost-conscious engineering has been intensely analytical, relying heavily on elaborate, sophisticated instrumentation and measurements that require special-purpose buildings.

A third factor is Sandia's increasing involvement in technology partnerships, economic competitiveness, and private sector collaborations in unclassified research and development. These involvements will require changes to the site, including easier access for unclassified work and more flexible facilities to support changing missions.

The fourth factor is a shrinking DOE budget that requires



Sandia National Laboratories, Albuquerque, New Mexico.

consolidation of some manufacturing operations and closure of some DOE production complex sites. Sandia has inherited some of those manufacturing operations, leading to renovation of former research, development, and technology facilities to support these new activities. As the Science-Based Stockpile Stewardship Program progresses, Sandia may need to reprogram additional space to support stockpile management activities.

A fifth factor is Sandia's need to become involved with DOE, Kirtland Air Force Base, City of Albuquerque, Bernalillo County, and State of New Mexico planning. Fortunately, the February 1995 Air Force recommendation to withdraw from Kirtland was vetoed in July 1995 by the Base Realignment and Closure Committee. However, the need for scenario planning is now evident.

Sandia's increasing work with nondefense US industry requires on-site visits by uncleared persons. Consequently, Sandia is working to increase areas for unclassified business and to improve traffic circulation, parking, and other infrastructure. Although several major facilities have been moved from limited-access to unclassified areas, funding is not available for additional moves or other reconfiguration for community outreach activities.

The Sandia Albuquerque site has been evolving for many years. Because many structures were approaching fifty years of age, planners began to evaluate the condition and function of such buildings. A three-year plan was developed and maintained to identify buildings that could be vacated and demolished. The first group of buildings has since been cleaned (mostly asbestos removal) and demolished. Demolished buildings have been cleared for other construction or parking. This demolition process is controlled by a working subgroup of the Integrated Sites Planning Council, which is responsible for coordinating planning and construction at



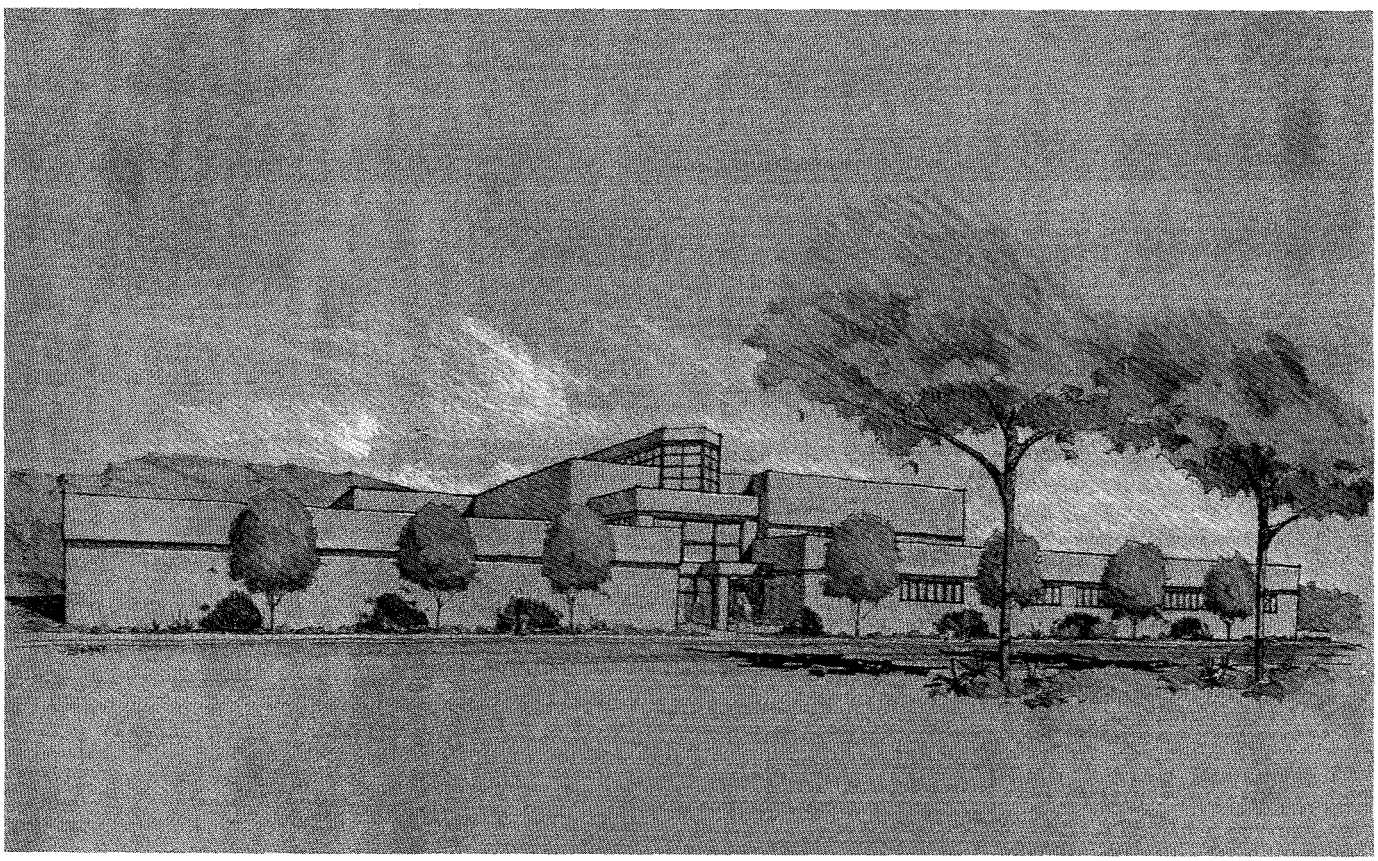
Sandia National Laboratories, Livermore, California.

Sandia. In 1995 the demolition plan was lengthened to five years, allowing more time for auditing and prioritizing projects as well as identifying funding sources. Future demolition activity will focus on the northwest part of Area I and the whole of Area II at the Albuquerque site. At this time, no demolition is planned at the California site.

Other important factors in our facilities planning are the need to conserve energy; new environment, safety, and health regulations; changing physical security requirements; and the requirement to provide special purpose buildings for certain applications.

More stringent requirements for protecting the environment and the safety and health of employees and visitors make continued use of some of these facilities impractical. Changes in physical security regulations (allowing such concepts as islands of security) and the nature of the materials and data being protected (from weapons-related to proprietary information) will allow dramatic reconfiguration of the limited areas. New technologies and activities will demand that facilities be designed to support unique requirements. New facilities will be required to accommodate microstructure fabrication, pulsed power machines, special instrumentation systems, environmental and energy research, rapid prototyping and advanced manufacturing techniques, and computer centers.

Sandia presently depends on buildings borrowed from the military and off-site commercial leases to help alleviate the shortage of space. The amount of off-site commercial leased space utilized in New Mexico has grown dramatically. Although certain types of space (e.g., a hangar for aircraft aging testing) are impractical to duplicate on-site, other types (e.g., offices and light laboratories) can be accommodated. The primary conditions causing some Sandia organizations to move off site are persistent space shortages



This artist's conception shows the Explosive Components Facility presently under construction at Sandia/New Mexico.

and the impediments to public access presented by the current closed-site configuration. The impacts of such moves include both the costs of obtaining and occupying leased space and the dispersion of personnel, leading to increased travel time and a loss of synergy among related organizations and activities. Proposed construction and reconfiguration of the campus to support improved unclassified visitor access should help alleviate problems.

Future Use Planning

In January 1994 the DOE Associate Deputy Secretary for Field Management directed site managers to work with stakeholders to identify future use options for DOE installations by December 1995. This directive resulted from the Land and Facility Use Policy, which requires that all DOE land and facilities be managed as valuable national resources.

In response, a Future Use Working Group was established for the Kirtland Federal Complex. This working group includes representatives from DOE and its affiliates (Sandia, the Inhalation and Toxicology Research Institute, the Central Training Academy, the Transportation Safeguards Division, Ross Aviation, and AlliedSignal), Kirtland Air Force Base, The New Mexico Environmental Department, the US Environmental Protection Agency, the US Forest Service, and a neutral facilitator. The working group will develop summary information on the sites, support the newly formed Citizen's Advisory Board in identifying future use options, and report recommendations to DOE Headquarters. A site summary will be provided to the Future Use Project Office at DOE Headquarters in December 1995.

Facilities Maintenance

Sandia's Site Action Plan was prepared in accordance with DOE's Maintenance Management Program as described in DOE Order 4330.4B, "Chapter 1: Guidelines for the Conduct of Maintenance at DOE Nonnuclear Facilities." The Site Action Plan describes Sandia's mission, maintenance program strategy, initiatives and accomplishments, planned initiatives, maintenance quarterly performance indicators, and maintenance process improvements.

Sandia's Maintenance Implementation Plan was prepared in accordance with DOE's Maintenance Management Program as described in DOE Order 4330.4B, "Chapter 2: Guidelines for the Conduct of Maintenance at DOE Nuclear Facilities." The Maintenance Implementation Plan describes the DOE 4330.4B requirements, deviations from DOE Order 4330.4B, and the implementation schedule.

DOE has proposed new orders that will replace DOE Order 4330.4B. These proposed orders are "DOE/Life-Cycle Asset Management", Title 10 Code of Federal Regulations 830.340 ("Maintenance Management"), and/or DOE Order 450 ("Maintenance Management Program").

Energy Management

Sandia conducts a formal in-house energy management program to adhere to the requirements of DOE Order 4330.2D. This program is managed by Sandia's Facilities Program Management Center as a part of the Maintenance Management Program Office. The energy program manager reports to the Maintenance Management Program Office and oversees the operation of Sandia's New Mexico and California sites.

The in-house energy management program has established a comprehensive energy management plan that maps out the strategy to be used to attain efficiency goals through FY 2005. DOE Order 4330.2D mandates energy efficiency improvements for buildings, metered processes, vehicle fuels, and petroleum use against FY 1985 baseline consumption.

The in-house energy management program has elements in aspects of facility design, operations, and construction. Distinct in-house energy management program categories are

- in-house energy management studies,
- in-house energy management projects,
- energy consumption reporting,
- new buildings,
- awareness activities,
- monthly billing, and
- a metering program.

Condition Assessment

The Sandia Condition Assessment Survey of critical systems began in FY 1993 using the Condition Assessment Survey and Condition Assessment Information System pilots developed by DOE. Full condition assessment of capital assets began in FY 1995. The Sandia Condition Assessment Survey uses DOE-supplied manuals and hand-held data collection devices. Prior to condition assessment survey training, the facilities condition inspection method outlined in DOE Order 4330.4A was used to assess the condition of buildings.

In response to the Life-Cycle Asset Management order and the possible end of funding for the Condition Assessment Survey Program, the inspection of important assets will continue. The information will be rolled into the Facilities Management Information System, which will be used for high-level performance measures.

5.3.2 General Purpose Facilities Plans

General Purpose Plant Requirements

In previous years general purpose plant projects have been funded through capital funds, which have been 1.0 and 1.5 percent of total operating funds. Congress has recommended merging general plant projects and capital equipment with operating funding to expedite the allocation of resources for operating, maintenance, and other infrastructure activities and to ensure that Sandia operations are efficient and cost effective. The $2 million limitation on a general plan project would be maintained. This proposal should provide Sandia with the flexibility to determine the amount of general plant project and capital equipment funding needed to maintain our infrastructure and to respond immediately to changes in requirements. Maintenance of Sandia's infrastructure is critical for directing program needs.

A new process is being implemented to identify, prioritize, and develop general plant projects. This new process will develop brief project summaries in a standard format for all submittals so that projects can be compared on the same basis. A criteria-based scoring system for prioritizing submittals has been developed for purposes of comparing the merits of project proposals. The prioritization scoring system incorporates Sandia's and DOE's mission needs. The prioritization exercise for the next fiscal year will develop a list of projects from which to choose a candidate for funding.

The Integrated Sites Planning Council will determine the criteria weighting and the preliminary prioritization. Once the most important projects have been identified, the council will concentrate available resources on these top-priority projects.

General Purpose Equipment Requirements

General Purpose Equipment is used in laboratory administrative and management activities. Funding is provided by applying a surcharge of 10 percent on DOE capital equipment and 0.5 percent on non-DOE funding.

5.3.3 Inactive Surplus Facilities Plan

To identify surplus facilities, Sandia inventoried its major buildings and the primary missions conducted in each, then categorized them according to their condition and missions. This process revealed that most buildings house multiple programs that change often. The useful life of a building may be shortened more by mission change than by age or obsolescence.

Buildings judged to be surplus must be substandard or contaminated to such an extent that they are unfit for reuse. Because of the shortage of permanent space in satisfactory condition, any satisfactory space that becomes available through organizational movement or program reductions is quickly filled.

5.3.4 Facilities Resource Requirements

Some laboratories are being upgraded and new ones are being proposed. Several new construction projects address long-standing insufficiencies. Other projects accommodate changing functions and requirements.

Environment, safety, and health (ES&H) concerns are actively addressed in planning for all facilities. Accordingly, all new buildings and major renovations are reviewed internally and by DOE for the adequacy of ES&H design features. In the area of environmental protection, DOE now requires that contractors comply with the provisions of the National Environmental Policy Act. This act stipulates that major construction projects be reviewed for potential impacts on the environment and for compliance with environmental laws. For each new facility and major renovation, Sandia prepares an environmental checklist/action description memorandum for circulation within DOE. If DOE deems that further documentation is necessary, an environmental assessment or an environmental impact statement is prepared and made available to the public.

Projects required to meet environmental laws, regulations, and DOE orders are included in Sandia's Five-Year Plan for Waste Management Operations and Environmental Restoration. DOE also requires a safety review of new construction projects and major renovations.

Adequate funds are not available to convert to a more cost-effective operation involving unclassified areas. Environmental remediation activities are already placing a serious burden on operating funds. Conversion of portions of our sites to accommodate economic competitiveness and other unclassified activities will require significant investment and should be budgeted and appropriated in line with our evolving integrated site planning.

We are collecting information via our strategic space surveys and implementing our space forecasting process to help determine the extent that we can open the site. In addition to the Technical Information and Outreach Center, other projects may result from this data. However, any determination of resource requirements at this point would be premature.

Authorized Construction

The principal goals of Sandia's construction plan are to provide the facilities needed to achieve programmatic objectives, eliminate substandard conditions, and replace temporary space with permanent facilities. Major construction projects are discussed briefly below and summarized in Table 5-2 at the end of this chapter. In addition to these items, a number of major alteration projects with a price range of $150,000 to $4 million are performed using expense funds.

Technology Support Center (New Mexico)

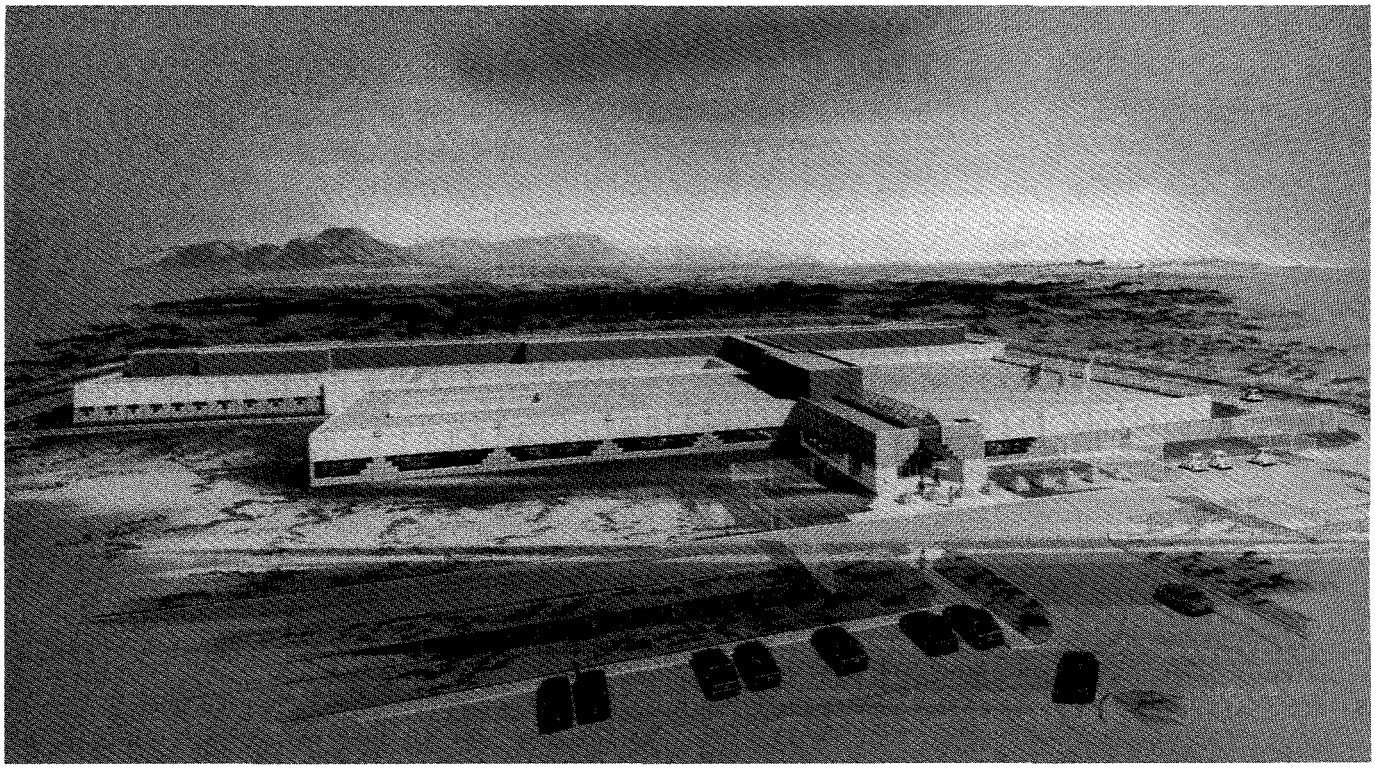
The Technology Support Center will reduce the Technical Area V population to minimize potential radiation exposures by providing a new office, light laboratory, and conference center for staff who support the reactors. An improved facility is particularly important because Technical Area V receives many visitors as a consequence of its development and testing programs for DOE, DoD, and other agencies.

Robotics Manufacturing Science and Engineering Laboratory (New Mexico)

This laboratory will facilitate progress in the development of robotics and automation technologies, which have been identified as strategically important. These technologies will achieve the objectives of minimizing the need to use humans in hostile environments or near potentially hazardous materials; accomplishing tasks that stretch normal human capabilities for complexity and reliability; and reducing production and operating costs within both the weapons complex and the domestic industrial sector.

Investment Casting Addition (New Mexico)

This addition to the Liquid Metal Processing Laboratory will provide a safe and efficient investment casting process-



The new Explosives Components Facility at Sandia/New Mexico will support component development for the Nonnuclear Reconfiguration Project.

ing operation. The new casting furnace is needed to prove concepts of emerging technologies that will significantly enhance the flexibility of future weapons design/fabrication streams and will reduce the costs of component housing and lead-time to complete a casting.

Nonnuclear Reconfiguration (New Mexico)

This project involves renovating space to support the fabrication and assembly of various nonnuclear components of nuclear warheads at Sandia/New Mexico as some DOE production facilities are closed.

Power Systems Modernization (New Mexico)

Electrical distribution systems at Sandia/New Mexico are aging and/or obsolete, as is the series-connected security lighting system. This project includes converting to higher distribution voltage, replacing aging and obsolete transformers and switchgear, and replacing cable as required. This project will also replace the remaining series-connected security lighting system and begin replacement of aging master unit substations.

Center for National Security and Arms Control (New Mexico)

This facility will bring together work in four areas: systems analysis and advanced concepts, arms control and verification technology, intelligence, and threats and countermeasures. The facility will substantially improve Sandia's ability to respond effectively in these areas.

Combustion Research Facility, Phase II (California)

This facility will provide specialized resources, including state-of-the-art laser diagnostic systems, to address the

combustion-related needs of the next decade. In addition to enhanced basic research, the facility will enable research on new generation automotive engines and improved industrial processes featuring high-energy efficiencies and minimal air pollutant emissions.

Proposed Construction

To provide DOE with proposals better coordinated with its mission needs, Sandia has implemented a new process to identify, prioritize, and develop line-item and other major projects by standardizing submittals, thus allowing projects to be compared equally. A new criteria-based scoring system incorporates Sandia's and DOE's mission needs with other criteria. An Integrated Sites Planning Council determines criteria weighting and first-cut prioritization for the Building and Facilities Committee. After identification and approval by the council, available resources are appropriated for developing top-priority projects. Proposed construction projects are listed in Table 5-2 at the end of this chapter and are briefly discussed below.

Processing and Environmental Technologies Laboratory (New Mexico)

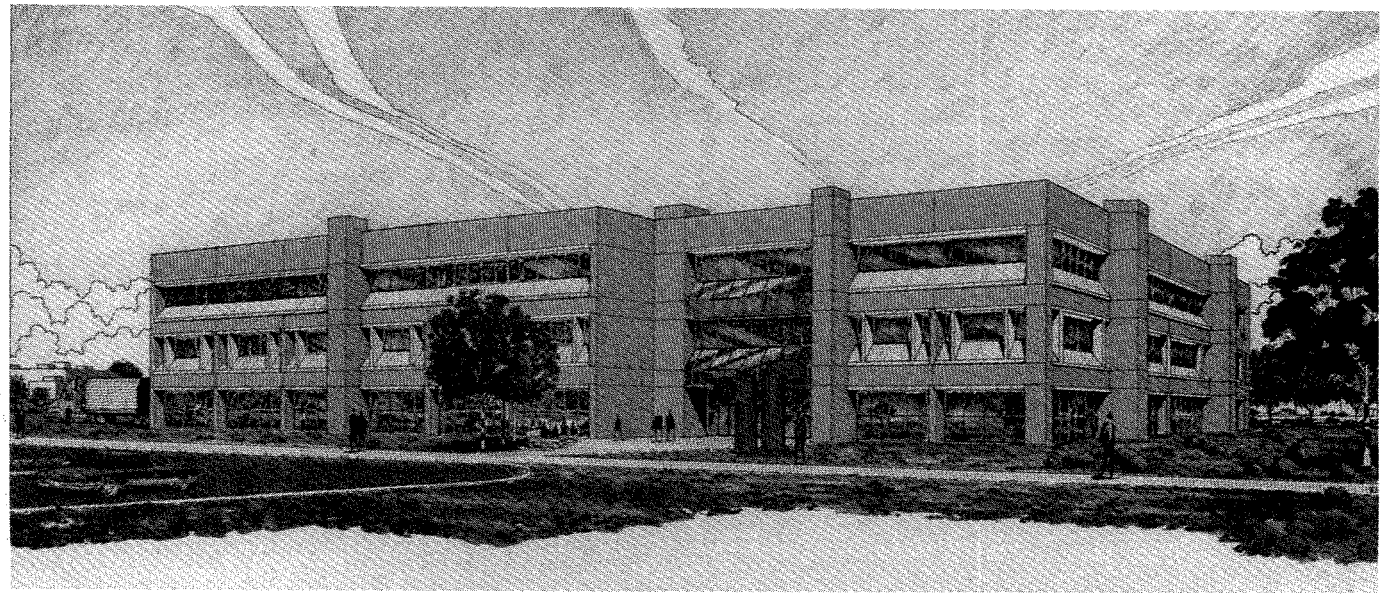
This construction item is part of the nuclear weapons research, development, and testing facilities revitalization project. The laboratory will be used for process technology related to the minimization and management of hazardous materials during nuclear weapons production. Office space will house personnel involved with environment, safety, and health compliance and staff support for environmental compliance, transportation of hazardous materials, detoxification, site restoration, and burial of hazardous materials from production. These activities will directly support the DOE nuclear weapons complex reconfiguration program.

Technical Information and Outreach Center (New Mexico)

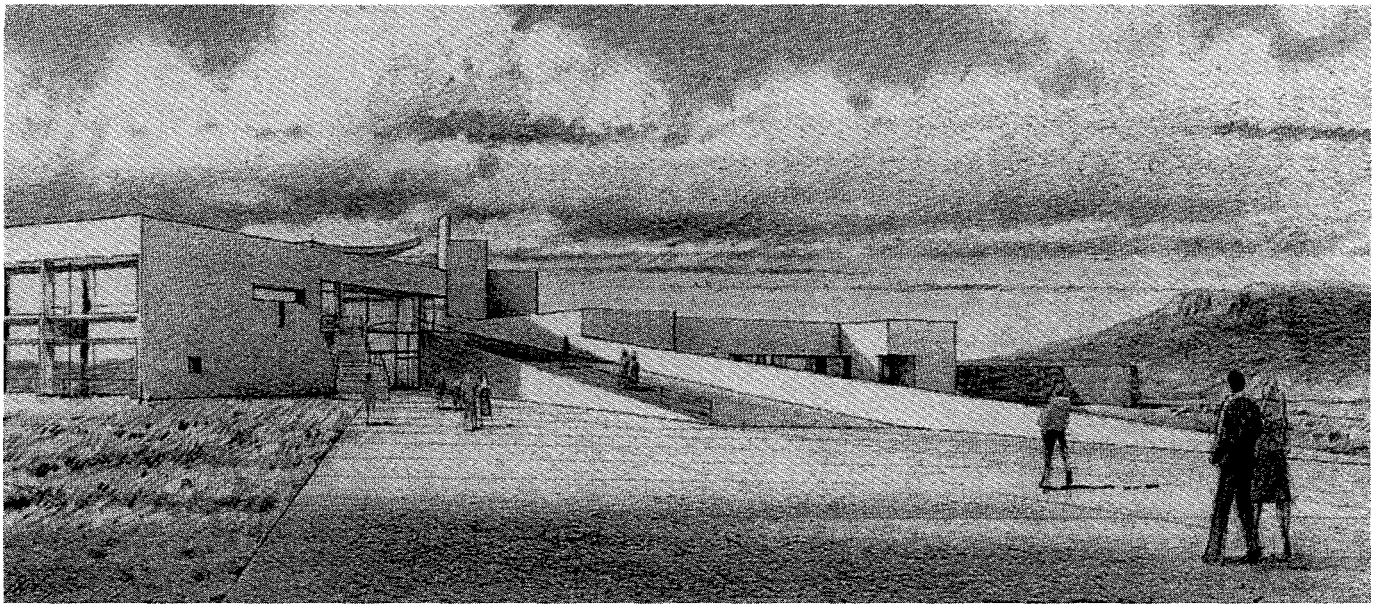
This highly visible facility outside perimeter fences will be a control point for visitors to Sandia. The Outreach Center will also support the new weapons complex via commercial partnerships and economic initiatives. The center will have a state-of-the-art communications system.

Joint Computational Engineering Laboratory

This laboratory will support Sandia's thrusts in defense and industrial applications of high-performance computing and communications and computer-aided engineering. The laboratory will be a hybrid open/secure facility for dual-use programs.



This artist's conception shows the proposed Processing and Environmental Technologies Laboratory at Sandia/New Mexico.



This artist's conception shows the Technical Information and Outreach Center proposed at Sandia/New Mexico.

Storm Drain, Sanitary Waste, and Domestic Water Systems Modernization (New Mexico)

This project will focus on rehabilitation of sanitary sewers, storm drains, and domestic water systems. The improvements will prevent soil and groundwater contamination, increase flood protection, and increase reliability of fire protection.

Area III Full-Scale Test Center (New Mexico)

The test center will house twenty technical and administrative staff members and will feature modern command, control, communications, and data acquisition systems to efficiently operate the full-scale testing facilities in Area III.

Nuclear Weaponization Design and Training Center (New Mexico)

This facility will house certification, qualification, and other records concerning Sandia's stewardship of the enduring stockpile. The center will serve as a library to preserve knowledge for the Science-Based Stockpile Stewardship Program and therefore as a university for the new generation of nuclear weapons engineers. Areas of study will include nuclear weapons engineer education and certification, training for DOE and DoD weapons custodians, accident/incident response, and technology demonstration.

Site Infrastructure Modernization (California)

This is a multiphase project to renew deteriorated and obsolete site systems. It will also add to the infrastructure of facilities as necessary to meet current requirements so that Sandia's efforts to meet our mission will not be disrupted.

Jupiter X-Ray Simulation Facility (New Mexico)

Jupiter will be constructed in response to the moratorium on underground nuclear testing. This facility will support three main activities: weapon effects testing in the cold-to-warm x-ray region, inertial confinement fusion, and pure weapons physics research.

Hardin Boulevard Expansion (New Mexico)

Although only two lanes have been constructed, Hardin

Boulevard was designed as a four-lane road from Wyoming to Eubank. Hardin needs to be expanded to four lanes to permit increased traffic volume across the south side of Area I.

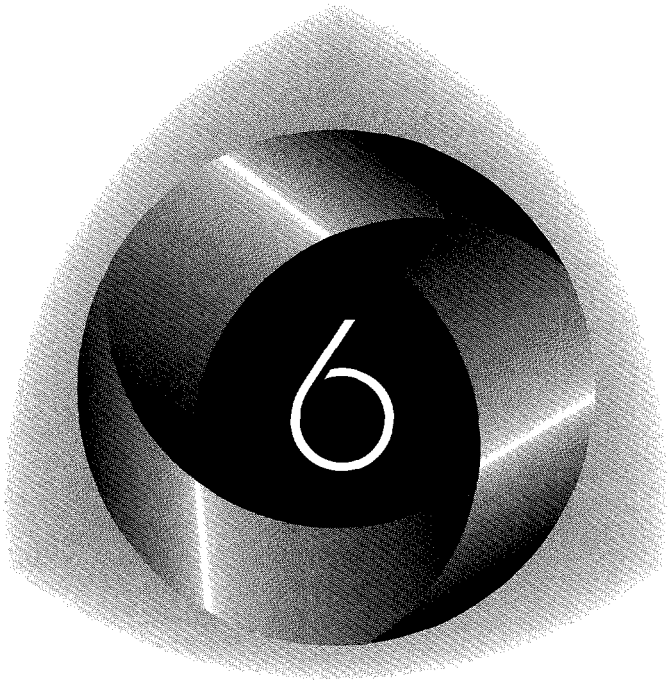
Geosciences Research Laboratory (New Mexico)

This laboratory will provide a unique center for Sandia and the scientific community to study active processes in the earth's crust. The facility will allow Sandia to meet both our research and Drilling Research Office responsibilities in the Continental Scientific Drilling Program. The laboratory will also perform research in fossil and geothermal energy, waste disposal, and seismic verification. The laboratory will accommodate mechanical and geophysical testing of large samples as well as development and testing of advanced instrumentation.

Table 5-2. Major Construction Projects (Fiscal Year Budget Authority in Millions)

Authorized Construction	Site	Sponsor	TEC	TPC	BA thru FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01
Technology Support Center	NM	DP	30.0	30.2	17.5	8.5	4.0						
Robotics Manufacturing Science and Engineering Laboratory	NM	DP	33.0	33.3	7.9	10.1	15.0						
Investment Casting Addition	NM	DP	3.7	3.9	3.1	0.6							
Nonnuclear Reconfiguration	NM	DP	54.6	56.4	9.2	0.9	28.0	16.5					
Power Systems Modernization	NM	DP	37.0	37.4		4.0	13.0	12.2	7.8				
Total DP			158.3	161.2	37.7	24.1	60.0	28.7	7.8				
Center for National Security and Arms Control	NM	IS	34.5	34.5	26.0	8.5							
Combustion Research Facility, Phase II	CA	ER	23.7	27.1	4.8		9.4	9.5					
Total Authorized			216.5	222.8	68.5	32.6	69.4	38.2	7.8				

Proposed Construction	Site	Sponsor	TEC	TPC	BA thru FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01
Processing and Environmental Technologies Laboratory	NM	DP	45.9	49.0				1.8	14.1	19.1	8.6	2.3	
Technical Information and Outreach Center	NM	DP	22.4	23.2					2.4	12.1	7.9		
Joint Computational Engineering Laboratory	NM	DP	58.5	61.6						6.1	17.0	19.6	15.8
Storm Drain, Sanitary Waste, and Domestic Water Systems Modernization	NM	DP	13.3	14.5						1.4	6.8	5.1	
Area III Full-Scale Test Center	NM	DP	6.5	7.5							0.8	4.0	1.7
Nuclear Weaponization Design and Training Center	NM	DP	16.8	18.1								1.8	9.2
Site Infrastructure Modernization	CA	DP	13.3	13.8								1.9	11.2
Jupiter X-Ray Simulation Facility	NM	DP	80.0	240.0									20.0
Hardin Boulevard Expansion	NM	DP	2.9	3.4									0.6
Total DP			259.6	431.1				1.8	16.5	38.7	41.1	34.7	58.5
Geosciences Research Laboratory	NM	ER	27.6	33.4								1.6	12.0
Total Proposed			287.2	464.5				1.8	16.5	38.7	41.1	36.3	70.5



Protecting Our Resources and the Community

6.1 Security

6.1.1 Program Overview

The Safeguards and Security (SAS) Program is responsible for protection of DOE assets at all Sandia sites in accordance with the requirements of our DOE primary customer, our Sandia customers, and other stakeholders. The major activities of the SAS program include

- program planning and management,
- protection program operations,
- operations security,
- information security,
- personnel security,
- facility surveys and approvals,
- material control and accountability,
- nuclear material management, and
- special programs.

The missions of both DOE and Sandia have changed in response to the fluctuating world situation. DOE's requirements are changing and Sandia's customer mix is shifting. In response the security infrastructure is being adjusted, placing an added burden on Sandia's limited resources and requiring development of new cost-effective solutions to SAS needs.

6.1.2 Protection Philosophy

The overall SAS Program philosophy is to design strategies to protect nuclear materials, classified matter, government property, and other security interests from unauthorized access, theft, diversion, sabotage, espionage, or other hostile acts that may cause risks to national security or the health and safety of DOE and contractor employees, the public, or the environment.

Levels of protection and other safeguards must be commensurate with DOE's design threat guidance, locally identified risks, and other programmatic requirements. In the past our protection strategies were based on total compliance. However, we have begun designing and implementing protection strategies that offer equivalent but cost-effective protection.

The Sandia SAS Program is based on risk management. In this context, risk management means that complexity of analysis, thoroughness of documentation, and levels of effort are commensurate with risk, consequences of loss or compromise, value of assets, cost of implementation, and other factors. The higher the risk, the greater the protection should be. This risk management approach is used to eliminate unnecessary features or activities that add to costs of implementation but do not add value to the protection system.

6.1.3 Evolving Site Security Needs

Protection requirements have been modified because of decreasing weapons research and development coupled with an increase in partnerships with private industry to improve economic competitiveness through technology transfer. Modifications include the introduction of the L clearance, the reduction in secret matter accountability requirements, and the restructuring of security areas. We anticipate more changes in DOE requirements over the next few years.

Sandia's changing customer mix requires increased protection of proprietary information and easing of site access for Sandia partners. The new customer mix requires SAS programs to be rapidly adapted to provide protection with greater flexibility. This new customer set also encourages the development of administrative controls, placing more responsibility on all Sandians. We will become proactive in questioning badged individuals about information access, be more responsible for asset protection, and participate in security self assessments. Security awareness and training will be critical in assisting employees to assume these added responsibilities.

Major initiatives play a large role in the modification of protection systems. As a result, Sandia line organizations and customers now participate in making decisions about protection systems established for their programs and facilities.

6.1.4 The Changing Face of Security

The new mission of DOE and Sandia requires changes in the security infrastructure. In the future our sites will be reconfigured to enhance customer access. Many of our fenced security areas will be opened. Visitor access will be controlled by line personnel rather than armed security police officers at the gates. We will create more compartmented security areas within facilities accessible to our uncleared customers. SAS will partner with line organizations, their customers, and DOE to implement cost-effective, risk-based security strategies documented in customized security plans. This planning and facility integration will lead to customized, more cost-effective, efficient protection systems.

6.2 Environment, Safety, and Health

Sandia is committed to protecting the environment and preserving the health and safety of individuals and the community. We conduct a comprehensive program to ensure that operations are at the leading edge of industry standards and that Sandia is in compliance with all applicable laws and regulations on environment, safety, and health (ES&H). Sandia's program has been structured to address environmental issues in a timely fashion, thereby maintaining public confidence in our ability to conduct operations without harming the environment. A major part of our vision is to be considered a leader within the DOE complex by being an example of a safe and healthful workplace.

Sandia also participates with DOE in a pilot ES&H Oversight Program to improve the way assessments are conducted and develop increased confidence that Sandia's ES&H Program is effective. The operating assumption is that assessments should become performance-oriented. A significant decline in the number of DOE audits and inspections at Sandia is expected to result in demonstrated savings in costs associated with preparation, logistics, and follow-up activities.

6.2.1 Goals and Objectives

Sandia's ES&H program is designed to

- make Sandia a safe, healthful, and environmentally sensitive workplace;
- comply with applicable laws, orders, and regulations; and
- demonstrate this capability to DOE and the public.

Seven objectives support achievement of the three goals. These objectives employ both long- and short-term strategies.

Our first objective is to ensure safe and healthful workplaces for our employees, contractors, visitors, and communities. This requires compliance with applicable laws and regulations, including DOE orders, directives, and requests aimed at meeting this objective.

Our second objective is to use the Sandia quality process to continually strive for a responsible ES&H program and to meet our customers' requirements. Sandia will continue to employ total quality management methodologies for all ES&H activities. Such methodologies will be used for

identifying, developing, and improving necessary ES&H processes, correcting root causes of ES&H problems, and applying lessons learned from Sandia and DOE experiences. Sandia's total quality management initiative establishes an overarching implementation strategy for all of our activities, including those in the ES&H program.

Our third objective is open, timely communication of ES&H problems, lessons learned, plans, and status to achieve appropriate, uniform actions throughout Sandia. We continue to enhance communications on ES&H issues both to Sandia's ES&H professionals and to other staff. Current communications on new requirements are achieved through a working group representing all Sandia divisions and bargaining units, through lessons-learned processes, and through training courses. Sandia has also established procedures whereby any employee may anonymously express an ES&H-related concern or report an ES&H-related problem or condition.

Our fourth objective is to team Sandia employees, customers, suppliers, and community representatives to strongly promote protection of the environment and the safety and health of all. Our goal is to use the capabilities of all staff in ES&H activities. Current cross-organizational projects are under way with staff having expertise in materials, instrumentation, geoscience, and field operations. Interactions with universities and high schools occur through temporary employment of students, Sandia participation in the university-based Waste-Management Education and Research Consortium, and contacts with teachers and students in classrooms. Sandians serve in various state and local government organizations, and staff from Sandia's ES&H organizations interact formally and informally with regulatory agencies.

Our fifth objective is to manage ES&H risks and hazards through formal, established processes in conjunction with an active awareness of ES&H by every Sandian. A key step in identifying hazards is the preliminary hazard assessment (PHA) that line organizations must complete for all facilities and activities. The PHA identifies all hazards in the workplace. ES&H standard operating procedures (SOPs) describe processes to control the hazards identified in the PHA. ES&H SOPs are used by one or more organizations and must include

- responsibilities,
- specific training and experience requirements,
- waste management requirements, and
- hazard identification and mitigation.

ES&H operating procedures are written and owned by organizations conducting operations. Operating procedures provide step-by-step instructions for specific operations (normal, postulated abnormal, and emergency) to ensure that activities are performed correctly, safely, and consistently.

To assist in a graded approach in management of risks, all PHAs are assigned a preliminary hazard classification (PHC) and all activities are assigned a programmatic risk classification (PRC). The PHC and PRC values are used to guide the appropriate level of rigor with which a facility or activity is managed and when facilities or activities are reviewed by upper management. Additionally, the PHC ratings establish both Sandia corporate and DOE understanding of the relative hazard levels of all Sandia facilities.

Our sixth objective is to support our employees in personalizing Sandia's ES&H awareness at work and at home. Sandia will continue disseminating ES&H information helpful to Sandians' families. Sandia has a process for recognizing and rewarding outstanding ES&H contributions.

Our seventh objective is to ensure that every Sandian has necessary ES&H training and that visitors and contractors comply with Sandia's ES&H requirements. We maintain a records system for tracking ES&H training requirements and the training status of employees. Experts from Sandia line organizations are involved in developing and improving corporate and organization-specific training courses. Trainers teach additional trainers, where possible, to allow staff members to instruct their own organizations in good ES&H practices. Management is responsible for ensuring that all visitors and contractors in their areas receive training about the presence of hazards and protection from those hazards.

6.2.2 Regulatory Environment

Laws and Regulations

Sandia must comply with many federal environmental laws and implementing regulations. These laws and regulations include the following: the Clean Air Act; the Clean Water Act; the Resource Conservation and Recovery Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Toxic Substance Control Act; the Comprehensive Environmental Response, Compensation, and Liability Act; the Safe Drinking Water Act; the Oil Pollution Control Act; the Marine Protection, Research, and Sanctuaries Act; and the Noise Control Act of 1973. In addition, DOE is promulgating and implementing the following regulatory requirements via publication in the Code of Federal Regulations (CFR): Quality Assurance (10 CFR 830.120), Radiation Protection of the Public and Environment (10 CFR 834), and Occupational Radiation Protection (10 CFR 835). Compliance with 10 CFR 835 will be mandatory by January 1, 1996. These rules will be enforced through the Price-Anderson Amendments Act of 1988. Sandia is developing a strategy for achieving compliance with all rules related to the Price-Anderson Amendments Act.

DOE orders implement other federal laws affecting Sandia, including the National Environmental Policy Act, the Occupational Safety and Health Act of 1970, the National Historic Preservation Act, the Coastal Zone Management Act of 1972, and the Mine Safety and Health Act. The contract for the operation of Sandia National Laboratories by the Sandia

Corporation requires that Sandia's ES&H operations be conducted in accordance with all applicable DOE orders and directives communicated to Sandia by the DOE contracting officer.

The Defense Nuclear Facilities Safety Board, through its recommendation to the Secretary of Energy, focused on a select subset of these contractual orders. This prompted an effort to perform facility-specific order compliance self-assessments at Sandia's nuclear facilities. These facilities are grouped into reactor operations, Technical Area V operations, and the Manzano storage facilities, with specific plans for each group. Sandia is implementing an institutionalization process for self assessments of requirements on a facility-specific and site-wide basis. This includes new requirements (e.g., new DOE orders), revised requirements, or reassessment of requirements based on an established schedule. Criteria are being developed to determine risk categories of requirements to guide the level of rigor applied. Sandia's goal is to extend these criteria to all contractual orders and eventually to incorporate all requirements identified by the Standards/Requirements Identification Document.

To ensure that resources are used where they will add the most benefit, Sandia is applying a graded approach to the formal requirements of DOE Order 5480.19 (Conduct of Operations) and DOE Order 5700.6C (Quality Assurance). All Sandia nuclear facilities and high hazard operations and facilities must strictly comply with applicable DOE requirements. For other Sandia activities, quality assurance and conduct of operations are presently implemented through Sandia's Management Integration and Implementation Project. The Laboratory Process Reengineering effort, a formal redevelopment of all Sandia administrative and technical work processes, provides a unique opportunity to further inculcate the principles of quality assurance and conduct of operations in Sandia work processes. Eventually, activities at all Sandia sites will use these standard work processes to ensure consistency, efficiency, reliability, and accountability. As funding permits, Sandia is working on a database for the seismic implementation plan required by DOE Order 5480.28 (Natural Phenomena Hazards Implementation Plan).

Sandia must also comply with state and local legislation applying to laboratory sites in New Mexico, California, Nevada, Hawaii, and diverse field locations in the United States and other countries. Such legislation in New Mexico includes the New Mexico Air Quality Control Act, the Environmental Compliance Act, the Water Quality Act, the Hazardous Waste Act, and the Solid Waste Act. In addition, there are local regulations for air quality and sewage pretreatment.

Applicable legislation in California includes the California Clean Water Act, the Air Toxics "Hot Spots" Information and Assessment Act, and the Tanner Act. Sandia/California must also comply with local regulations such as Bay Area Air Quality Management District rules. Similar laws in Nevada and Hawaii affect the Tonopah test range and the Kauai test facility.

An example of cooperation between Sandia and environmental agencies is the 1990 Agreement in Principle between the States of New Mexico and California and DOE to monitor cleanup and environmental activities. The agreements were the result of a 1989 initiative by the governors of several states with DOE nuclear facilities. The agreements give state officials access to DOE facilities to monitor (but not to regulate) cleanup operations. Under this agreement, New Mexico's Environmental Department has five full-time employees stationed at Sandia/New Mexico. DOE provides about $3 million per year to the state for staff and equipment for this on-site monitoring at DOE sites in New Mexico.

Sandia ES&H Requirements Documents

The contract between Sandia's operating contractor and DOE specifies that Sandia National Laboratories will comply with all applicable federal, state, and local laws and regulations and all applicable DOE directives.

Requirements from laws, regulations, DOE orders, and other documents pertaining to ES&H are forwarded to the appropriate ES&H operations center for action. The appropriate director assigns an order expert, who determines whether laboratory ES&H documents need to be amended or a new document written. If action is necessary, the document owner becomes involved. If requested, the Line Implementation Working Group assists in developing implementation approaches. This assures that requirements are identified, assigned to an individual, tracked, assessed for effectiveness, and monitored for compliance.

Requirements are translated into specific actions delineated in Sandia ES&H requirements documents. The first of these documents is Sandia Laboratories Policy 2001 (Environment, Safety, and Health), which defines ES&H policy. This document defines a hierarchy of ES&H requirements documents through which requirements flow from sources (i.e., laws, regulations, and DOE orders) to Sandia employees, on-site contractors, and visitors. Documents such as preliminary hazard assessments, safety assessments, safety analysis reports, and plans for achieving compliance augment the documents in the hierarchy.

Sandia's ES&H Manual provides guidance and compliance tools and interprets/condenses requirements for use by line management to help ensure

- the safety and health of employees, on-site contractors, and the public;
- the preservation of the environment; and
- the performance of work activities in compliance with applicable laws, regulations, DOE orders, and best management practices.

The requirements in the ES&H Manual and its supplements are implemented by Sandia organizations.

The legal and regulatory environment affecting Sandia's ES&H activities is likely to remain dynamic as public concerns and government administrations evolve. For example, the Federal Facilities Compliance Act of 1992 clarified the ability of the Environmental Protection Agency and states to enforce hazardous waste regulations at federal facilities such as Sandia. We anticipate a general trend of laws and regulations requiring more attention to procedures, processes, and documentation to ensure the ability to audit environmental compliance.

6.2.3 ES&H Policies, Organization, and Management

The following is extracted from the policy stated in Sandia's *ES&H Manual, Volume I: Environment, Safety, & Health* (page 1A-1):

> Sandia National Laboratories considers the protection and preservation of the environment and safety and health of its personnel, contractors, visitors, and the public to be critical to its success.
>
> Accordingly, Sandia personnel design products, develop manufacturing processes, and conduct operations while encouraging recycling, waste minimization, and reduction of the use of hazardous materials. Sandians also ensure the protection of people and the environment while complying with applicable federal, state, and local laws and regulations, agreements, consent decrees, and DOE directives.
>
> Sandia employees who oversee contractors and who host site visitors assure that they are adequately informed of this policy and of their obligation to comply with it. In addition, Sandia continuously evaluates regulatory requirements, corporate policies, customer needs, and lessons learned, and adjusts its operations to meet these changing needs in seeking to continuously improve ES&H processes.
>
> Matters pertaining to environment, safety, and health are the responsibility of all Sandia employees, contractors, and visitors. All Sandians are expected to abide by the following credo: No job is more important than your health, your safety, and the protection of our environment.

The president of Sandia National Laboratories has overall responsibility for ES&H. He is advised on ES&H matters by the Sandia Quality Leadership Council, which he chairs. The directors of the Sites Planning and Integration Center, the Sites Operations Center, the New Mexico Safety and Health Center, and the New Mexico Environmental Operations Center report to the Vice President of Laboratory Services. The directors of the New Mexico Medical Center, the manager of the California Medical Department, and the director of the California Security, Facilities, and ES&H Center report to their respective vice presidents. The directors of the centers responsible for ES&H-related functions have overall management of Sandia's ES&H activities.

ES&H professionals at both the New Mexico and California sites support Sandia organizations in improving the safety of work activities. This support includes

- occupational medicine,
- industrial hygiene,
- radiation protection,
- safety engineering, and
- fire, electrical, and building codes integration.

The Environmental Operations Center at Sandia/New Mexico and the Security, Facilities, and ES&H Center at Sandia/California are responsible for managing Sandia's environmental restoration projects by ensuring that all permit requirements are met and by working with federal and local environmental regulators. Environmental restoration and waste management activities are coordinated with the DOE Office of Environmental Restoration and Waste Management through Sandia's Energy and Environment programs. Independent internal assessments are performed and each level of management provides periodic self assessments of its own operations.

Each of Sandia's corporate divisions is responsible for the ES&H activities in its area. Every division has a designated ES&H coordinator who works closely with the ES&H centers at New Mexico and California to ensure that effective ES&H processes are incorporated into the programs. Each division ES&H coordinator also serves on the Line Implementation Working Group. In addition, all Sandia center directors (who report to division vice presidents) have designated ES&H coordinators available to work directly with researchers doing studies of ES&H issues. Each level of management oversees and assesses its own ES&H processes to ensure safe operations and comply with requirements.

6.2.4 ES&H Plans and Initiatives

The DOE ES&H Tiger Team assessments of Sandia/California in 1990 and Sandia/New Mexico in 1991 led to major changes in Sandia's ES&H effort, including significant increases in financial and human resources. Emphasis on compliance with DOE orders and directives resulted in major restructuring of ES&H activities. Formal processes are in place or are being developed to achieve compliance and to accommodate expanding requirements.

Sandia manages all ES&H activities on the basis of risk assessment. The Integrated Services Management Plan contains processes to identify, describe, and prioritize work based on averted risk and benefit to Sandia. These processes ensure that the limited resources available are used for

activities that have the greatest benefits and averted risks. Emphasis is placed on working more efficiently and effectively by better understanding customer requirements and by eliminating redundant activities. These processes are reflected in the input to the DOE ES&H Management Plan.

A laboratory-wide ES&H program strategy document issued in February 1995 provides direction for further improvements. The plan will emphasize the safety and health of employees, contractors, visitors, and residents in surrounding communities. ES&H responsibilities will be increasingly assumed by Sandia line organizations as a part of their normal operations.

ES&H training is operated as a service center. Prioritization processes are being implemented to focus training resources on areas of greatest importance. Training intensity will increase as greater emphasis is placed on performance-based and on-the-job training.

Changes in DOE programs and Sandia management initiatives will influence the direction of ES&H activities. The growing number of requirements and requests during this period of diminishing budgets requires a strong prioritization system to identify critical activities. Regulatory inconsistencies among federal, state, and local agencies will continue to require resolution. We are improving our processes for handling the diverse ES&H requirements at our permanent facilities as well as at many field operational sites throughout the world.

ES&H activities at Sandia fall into four major categories of sponsorship and funding:

- The DOE Office of Environmental Restoration and Waste Management directly funds specific environmental restoration and waste management projects; program plans and budgets are defined directly with DOE through Sandia's Energy and Environment programs.
- The core activities of Sandia's ES&H program are funded through indirect budget under the management of Sandia's Administrative Management Committee.
- DOE Defense Programs has the "landlord" responsibility for Sandia.
- Individual projects support ES&H professionals directly for services unique to their operations. This budget also supports the ES&H service centers.

ES&H Work for the Office of Environmental Management

The DOE Office of Environmental Management (EM) oversees research and technology development programs for environmental cleanup and waste management (including the Waste Isolation Pilot Plant). A portion of this funding is for Sandia operations and is managed as part of our ES&H program.

This funding by EM is for the remediation of hazards at waste sites and the development of processes to handle hazardous wastes. Projects are managed and updated annually by EM. Non-EM activities are then funded directly by other programs or through Sandia's indirect budget.

EM-sponsored environmental remediation of waste sites is expected to continue during cleanup of critical sites and to then decline. As processes are developed to handle hazardous wastes, direct EM support is expected to decline while the indirect budget sustains funding to improve the developed processes.

Core ES&H Programs

The core programs supported by Sandia's indirect budget are the base for all laboratory ES&H efforts. This base includes most activities in policy development and implementation, safety and health, and specific activities in environmental operations. In addition, this budget supports independent assessment and core training.

Program Management

Responsible translation and integration of new laws, regulations, orders, directives, and requests into effective operations is increasing in complexity due to changes in requirements. New requirements are integrated into operations through Sandia organizational ES&H coordinators as a part of the Line Implementation Working Group.

An effective prioritization system is needed as requirements continue to increase and budgets decrease. An integrated services management system (ISMS) is being developed that will be piloted during FY 1995 and 1996 and will serve as a model for Sandia. The ISMS will integrate policies, strategic planning, issues management, operational planning, resource management, commitment management and accountability, and process and project planning. The goal is to provide the tools needed to meet customer requirements efficiently. The ISMS is a part of the DOE prioritization project.

The overall tracking and management of occurrences and assessment responses is being reviewed along with other management information systems to define the most cost-effective way to maintain and interconnect databases. Better ways are needed to interface with the data systems used by various DOE and other regulatory agencies.

Risk management, including safety assessment and analysis reporting, is a growing effort. Programs for managing risks and hazards are being implemented in compliance with DOE orders. Hazard assessments of all sites are being completed to upgrade emergency preparedness.

Assessments

ES&H assessments of Sandia by external organizations are coordinated through the ES&H Appraisal Management Department. The department interacts with assessors to assure that their logistical needs are met, works with all parties to develop appropriate responses to assessment findings, tracks the status of all responses, submits closure documents, and is the official records manager for assessment documents. Emphasis is now being placed on assuring that multiple assessments are appropriately documented and tracked and that records storage requirements are met. Quality review processes are being developed to assure that responses meet the intent of findings.

Training

The ES&H Training Department is responsible for developing and maintaining administrative training systems and processes for Sandia. Department staff members work with ES&H professionals and line personnel to design, develop, and present laboratory-wide and organization-specific courses for the Sandia work force. Costs to deliver training are recovered through the ES&H Training Service Center. Additionally, the ES&H Training Department is responsible for maintaining training records and managing the reporting function. Emphasis on training continues to increase and new methods and technologies are being introduced.

Waste Management

Waste management projects implement steps to manage Sandia's hazardous, radioactive, and mixed wastes safely and efficiently. This effort includes projects in minimization, treatment, storage, disposal, and project management.

Sandia's program for waste management requires staff training, equipment and supplies, contractor support, and funding associated with the management, collection, packaging, storage, transportation, treatment, and disposal of chemical, radioactive, and mixed wastes at Sandia in California, New Mexico, and Nevada. The waste management program encompasses guidance to Sandia generators of waste, surveillance of compliance, provision of qualified personnel to interact with DOE and the Environmental Protection Agency and states on waste issues, preparation or review of waste permit applications, and review of requirements changes to assess programmatic impact. The program also collects, stores, and arranges off-site shipment, treatment, and disposal of wastes. Resource Conservation and Recovery Act storage occurs at ninety-day accumulation areas, at interim status facilities, and at the permitted hazardous waste management facility. Radioactive and toxic wastes are stored on-site at various facilities.

Sandia/New Mexico holds a 1992 operating permit for hazardous waste management. All radioactive waste is either stored on-site or sent to disposal facilities authorized by DOE. Hazardous waste is temporarily stored in the hazardous waste management facility, then transported off-site for recycling, treatment, or disposal at commercial facilities with Environmental Protection Agency (EPA) permits. Mixed wastes are held on-site in storage areas that were included in the interim status permit application for mixed waste units submitted to the New Mexico Environmental Department in 1990. Also included in the permit application was a facility (not yet operational) that will be used for repackaging and storage of low-level radioactive waste and mixed waste.

Sandia/California has a Resource Conservation and Recovery Act permit for operation of its hazardous waste management facility. Hazardous wastes at Sandia/California are disposed at various permitted commercial disposal facilities. Compatible waste streams are consolidated at Sandia's hazardous waste storage facility to decrease costs. These consolidated streams are analyzed before disposal in accordance with the hazardous waste facility permit that was approved by the federal EPA and the California EPA. Low-level waste is disposed at the Nevada Test Site (NTS) in compliance with DOE orders, EPA and State of California requirements, and NTS criteria. "Scintillation cocktails" (small vials of low-level radioactive liquids) from the Tritium Research Laboratory are transported to a permitted commercial facility for incineration. Other low-level mixed waste streams will be stored at Sandia/California until off-site disposal options are developed.

Hazardous materials generated at the Tonopah test range are shipped to commercial facilities for disposal within ninety days of generation. The NTS has stopped accepting radioactive wastes, and several drums of legacy radioactive materials are stored on-site, pending determination of a repository. No radioactive wastes are currently generated by operations at Tonopah. No mixed wastes have been or are generated at the site.

The Kauai test facility generates small quantities of hazardous wastes, which are handled through the Navy Pacific Missile Range waste management program. No radioactive or mixed wastes have been or are being generated at this facility.

Safety and Health

The occupational safety program at Sandia makes the safety of personnel its first priority. The bases of our technical support are the programs and procedures developed to reflect DOE orders, regulations of the Occupational Safety and Health Act (OSHA), and other safety laws and best practices.

We are working to institutionalize safety training and procedures. Risk management, including support for safety



Safety training exercises at Sandia/New Mexico included a multiagency emergency preparation exercise. Here members of the Kirtland Air Force Base fire department evacuate a mock victim.

assessments and safety analysis reports, is a large effort that will continue to grow. Sandia is completing a hazard assessment for all sites so that emergency plans and procedures can be upgraded. We are continuing our efforts to improve programs in fire protection and emergency preparedness and in electrical, pressure, reactor, hoisting and rigging, and traffic safety.

Sandia's security organization established a committee to review costs of operating vehicles. A list of accidents involving security vehicles was compiled and the causes analyzed. As a result, pickup trucks are being replaced by Jeep Cherokees, which are better suited to security work. Shift lieutenants are now required to inspect 50 percent of assigned vehicles each shift for damage. A vehicle safe use campaign is under way, a defensive driving class is being established, and a safe driving class is mandatory for new employees.

We remain committed to conducting operations at remote sites in a manner that meets all ES&H requirements. In addition, an acute need exists to modify older facilities and obtain proper equipment for safe operations at such sites.

We have initiated a long-term ergonomics effort that will meet the requirements of DOE orders and upcoming OSHA regulations. This program has the potential to interface with other preventive medicine programs and to provide a vehicle for addressing ES&H concerns.

The objective of the health management program is to maintain the physical and psychological health of Sandia's work force through timely evaluation, diagnosis, and management linked to analysis of the work site and occupational environment. This objective requires that we interpret and apply health codes, standards, and regulations promulgated by several federal and state agencies and national standards organizations. Core activities provide protection from chemical and physical hazards in the workplace and furnish oversight, monitoring, contamination control, and other radiation protection assistance for workers. Medical intervention programs and educational and fitness programs promote safe and healthful worker lifestyles.

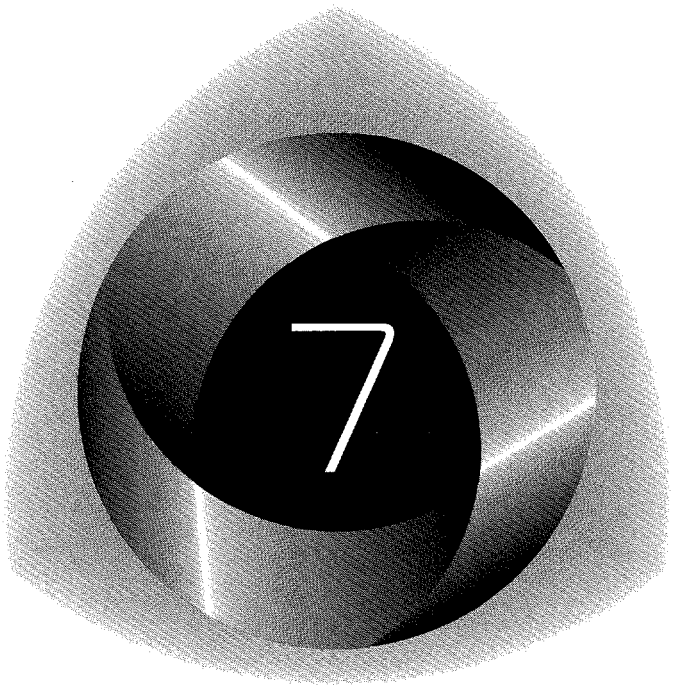
A radiological control manager leads a radiation protection program that enables Sandia to comply with the DOE Radiological Control Manual and applicable federal regulations. Planning for compliance with these directives and regulations began in 1992 and continues as requirements change.

Safety and health compliance activities identify remedial actions necessary to move Sandia toward compliance with applicable OSHA regulations and DOE orders. Specific remedial activities address audit findings and concerns in accordance with a completion schedule approved by DOE or other audit groups.

Environmental Protection

Environmental protection activities provide Sandia organizations the support necessary for compliance with the Clean Water Act, the Clean Air Act, DOE Order 5400.1, and various other requirements and permits issued by local, state, and federal agencies. Activities include management of sanitary sewer waste, storm water discharges, spills, air quality, and environmental compliance.

The pollution prevention program will use antipollution technology and employee education to ensure that environmental protection becomes an integral part of everyday activities at Sandia. The program will incorporate pollution prevention into the design and implementation of new projects, will continuously improve existing projects, and will provide a comprehensive system of employee and contractor incentives.

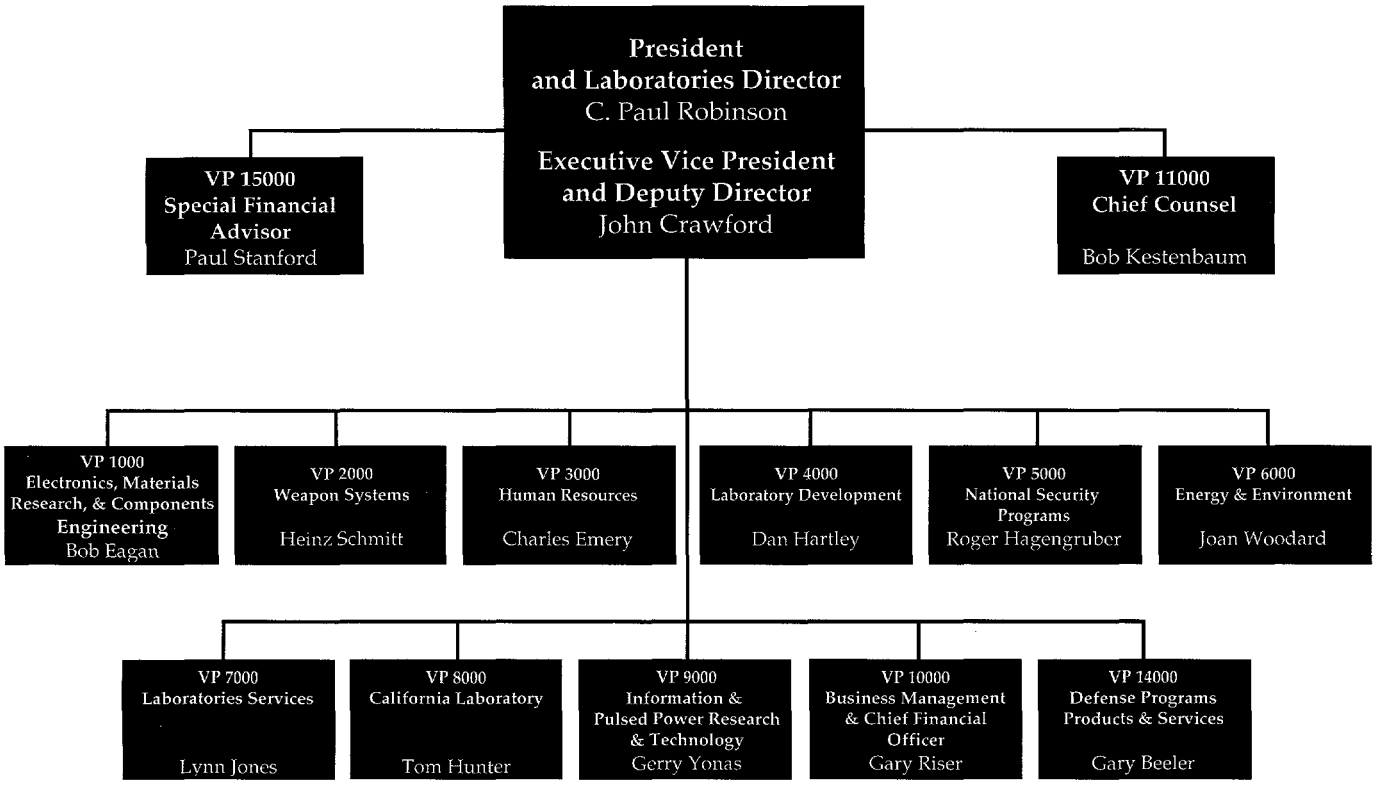


Supporting Data

This supporting data section includes the Sandia organization chart at the vice presidential level, the funding summary, the FTE summary, the funding trend charts, and the funding tables by assistant secretarial office.

The funding tables by assistant secretarial office include a five-year budget projection. Budget authority dollars are in millions; personnel are in annual average full-time equivalents (FTEs). Amounts for operating, capital equipment, and general plant project funds in FY 1994 through FY 1997 are expressed in the dollars of their respective years. For FY 1998 and beyond, operating, capital equipment, and general plant project estimates are in FY 1997 dollars. Estimates for major construction projects are expressed in dollars of the year of commencement of each project. Figures shown for FY 1996 and 1997 are based on our FY 1997 Annual Budget Submission and conform to targets provided by DOE.

7.1 Organization Chart



7.2 Laboratories Funding Summary

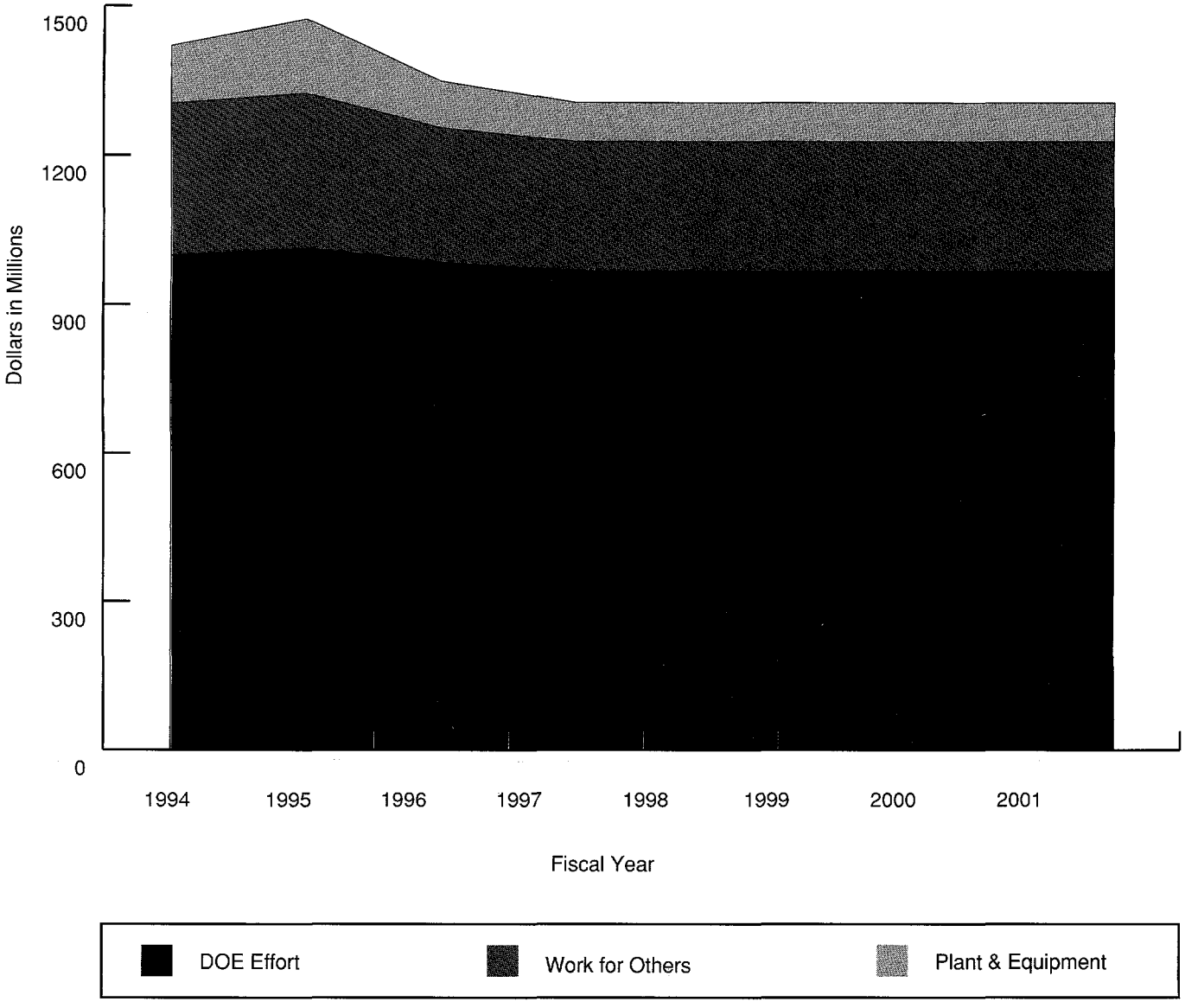
Laboratories Funding Summary
(Fiscal Year Budget Authority in Millions)

	1994	1995	1996	1997	1998	1999	2000	2001
DOE Effort	999.2	1,013.5	986.0	969.4	969.4	969.4	969.4	969.4
Work for Others	305.6	311.8	270.6	259.8	259.8	259.8	259.8	259.8
TOTAL OPERATING	1,304.8	1,325.3	1,256.6	1,229.2	1,229.2	1,229.2	1,229.2	1,229.2
Capital Equipment	50.2	58.9	49.2	51.2	51.2	51.2	51.2	51.2
General Plant Projects	8.0	6.5	3.6	2.8	2.8	2.8	2.8	2.8
Major Construction	56.5	83.0	40.0	24.3	24.3	24.3	24.3	24.3
TOTAL FUNDING	1,419.5	1,473.7	1,349.4	1,307.5	1,307.5	1,307.5	1,307.5	1,307.5

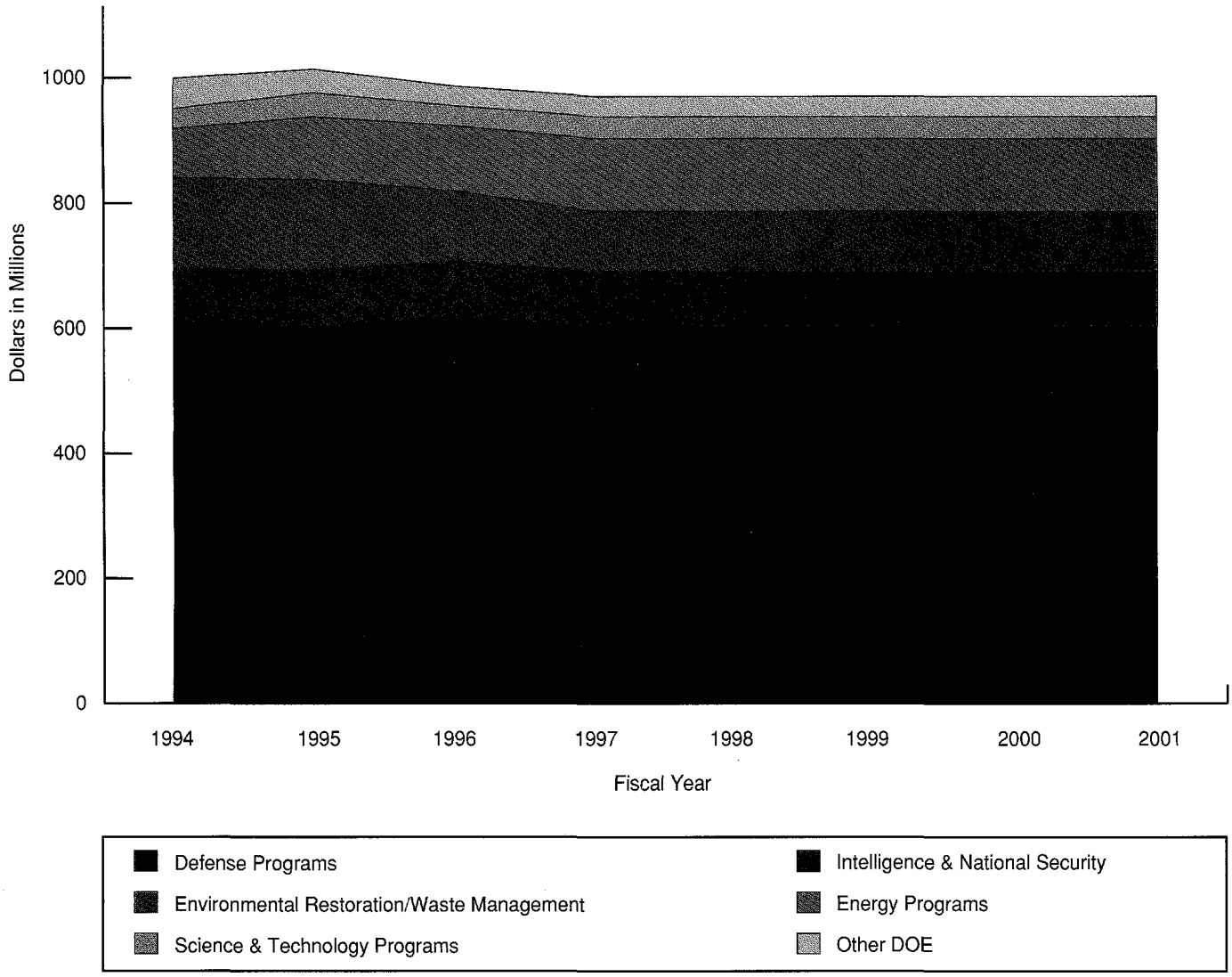
7.3 FTE Summary by Major Sponsor

Personnel Summary by Major Sponsor (FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
DOE PROGRAMS								
Weapons and Waste Cleanup Programs								
Defense Programs	2,033	1,981	2,005	1,975	1,975	1,975	1,975	1,975
Intelligence and National Security	359	320	343	354	354	354	354	354
Material Disposition	6	26	25	27	27	27	27	27
Environmental Restoration and Waste Management	347	354	345	318	318	318	318	318
Energy Programs								
Energy Efficiency and Renewable Energy	123	128	133	144	144	144	144	144
Fossil Energy	36	35	43	46	46	46	46	46
Civilian Radioactive Waste Management	51	47	77	81	81	81	81	81
Nuclear Energy	12	38	55	62	62	62	62	62
Science and Technology Programs								
Energy Research	99	96	93	101	101	101	101	101
Science Education	1	1	0	0	0	0	0	0
Other DOE Work	142	123	102	118	118	118	118	118
Total DOE Programs	3,209	3,149	3,221	3,226	3,226	3,226	3,226	3,226
PROGRAMS OTHER THAN FOR DOE								
Department of Defense	644	597	522	386	386	386	386	386
Department of Transportation	16	18	17	17	17	17	17	17
National Aeronautics and Space Administration	15	19	16	16	16	16	16	16
Nuclear Regulatory Commission	55	61	53	61	61	61	61	61
Other Federal Agencies	92	109	13	3	3	3	3	3
Sandia CRADA Partners	34	24	64	86	86	86	86	86
All Other	36	40	65	90	90	90	90	90
Total Work for Others	892	868	750	659	659	659	659	659
TOTAL DIRECT PROGRAMS	4,101	4,017	3,971	3,885	3,885	3,885	3,885	3,885
Laboratory-Directed R&D	220	257	235	210	210	210	210	210
Direct Support	2,428	2,324	2,265	2,246	2,246	2,246	2,246	2,246
Indirect	1,745	1,853	1,829	1,759	1,759	1,759	1,759	1,759
TOTAL LABORATORIES	8,494	8,451	8,300	8,100	8,100	8,100	8,100	8,100



Laboratory Funding Profile Summary.



Laboratory Program Funding for DOE.

7.4 Funding by Assistant Secretarial Office

Funding by Assistant Secretarial Office
(Fiscal Year Budget Authority in Millions)

	1994	1995	1996	1997	1998	1999	2000	2001
Weapons and Waste Cleanup Programs								
Total Assistant Secretary for Defense Programs								
Operating	606.1	593.5	611.9	596.1	596.1	596.1	596.1	596.1
Capital Equipment	39.6	43.3	40.5	43.2	43.2	43.2	43.2	43.2
General Plant Projects	6.4	4.5	3.0	2.4	2.4	2.4	2.4	2.4
Major Construction	46.7	73.7	30.5	24.3	24.3	24.3	24.3	24.3
Total Cost	698.8	715.0	685.9	666.0	666.0	666.0	666.0	666.0
Total Office of Nonproliferation and National Security								
Operating	89.2	94.1	88.0	88.0	88.0	88.0	88.0	88.0
Capital Equipment	3.8	4.7	3.4	3.4	3.4	3.4	3.4	3.4
Major Construction	8.8	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	101.8	106.4	91.4	91.4	91.4	91.4	91.4	91.4
Total Office of Material Disposition								
Operating	0.3	6.0	6.5	6.5	6.5	6.5	6.5	6.5
Total Assistant Secretary for Environmental Management								
Operating	145.5	144.5	112.8	96.2	96.2	96.2	96.2	96.2
Capital Equipment	3.1	4.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Major Construction	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	150.2	150.8	112.8	96.2	96.2	96.2	96.2	96.2

Funding by Assistant Secretarial Office
(Fiscal Year Budget Authority in Millions) (Continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Energy Programs								
Total Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	46.4	61.2	55.2	62.2	62.2	62.2	62.2	62.2
Capital Equipment	0.9	1.7	1.2	1.2	1.2	1.2	1.2	1.2
Total Cost	47.3	62.9	56.4	63.4	63.4	63.4	63.4	63.4
Total Assistant Secretary for Fossil Energy								
Operating	11.4	11.5	11.7	13.2	13.2	13.2	13.2	13.2
Total Office of Civilian Radioactive Waste Management								
Operating	16.6	16.5	25.1	28.3	28.3	28.3	28.3	28.3
Capital Equipment	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	16.8	16.6	25.1	28.3	28.3	28.3	28.3	28.3
Total Office of Nuclear Energy								
Operating	4.1	10.7	12.6	12.1	12.1	12.1	12.1	12.1
Capital Equipment	0.0	0.0	1.2	0.5	0.5	0.5	0.5	0.5
Total Cost	4.1	10.7	13.8	12.6	12.6	12.6	12.6	12.6
Science and Technology Programs								
Total Office of Energy Research								
Operating	29.6	34.7	30.4	34.2	34.2	34.2	34.2	34.2
Capital Equipment	2.6	4.7	2.9	2.9	2.9	2.9	2.9	2.9
General Plant Projects	0.1	0.2	0.6	0.4	0.4	0.4	0.4	0.4
Major Construction	0.0	0.1	9.5	0.0	0.0	0.0	0.0	0.0
Total Cost	32.3	39.7	43.4	37.5	37.5	37.5	37.5	37.5
Total Office of Science Education and Technical Information								
Operating	1.5	3.3	0.7	0.8	0.8	0.8	0.8	0.8
Other DOE Work								
Operating	48.5	37.5	31.1	31.8	31.8	31.8	31.8	31.8
Major Construction	0.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	49.4	39.0	31.1	31.8	31.8	31.8	31.8	31.8
Total DOE Programs								
Operating	999.2	1,013.5	986.0	969.4	969.4	969.4	969.4	969.4
Capital Equipment	50.2	58.9	49.2	51.2	51.2	51.2	51.2	51.2
General Plant Projects	8.0	6.5	3.6	2.8	2.8	2.8	2.8	2.8
Major Construction	56.5	83.0	40.0	24.3	24.3	24.3	24.3	24.3
Total Cost	1,113.9	1,161.9	1,078.8	1,047.7	1,047.7	1,047.7	1,047.7	1,047.7

Assistant Secretary for Defense Programs
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
GB0108 Stockpile Stewardship [1]								
Operating	337.3	297.8	319.4	304.4	304.4	304.4	304.4	304.4
Capital Equipment	28.2	32.0	25.8	30.8	30.8	30.8	30.8	30.8
General Plant Projects	5.8	4.0	3.0	2.4	2.4	2.4	2.4	2.4
Major Construction	36.9	46.7	14.0	24.3	24.3	24.3	24.3	24.3
Total Cost	408.2	380.5	362.2	361.9	361.9	361.9	361.9	361.9
Direct Personnel	1,125	1,004	1,032	1,050	1,050	1,050	1,050	1,050
GB0106 Technology Transfer Initiative[2]								
Operating	72.1	90.8	80.0	80.0	80.0	80.0	80.0	80.0
Capital Equipment	0.5	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Total Cost	72.6	92.0	81.0	81.0	81.0	81.0	81.0	81.0
Direct Personnel	233	280	250	250	250	250	250	250
GB0107 Newly Independent States Partnership								
Operating	0.1	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
GB02 Inertial Confinement Fusion								
Operating	27.0	25.5	26.8	27.0	27.0	27.0	27.0	27.0
Capital Equipment	1.2	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Cost	28.2	26.2	27.5	27.7	27.7	27.7	27.7	27.7
Direct Personnel	63	58	60	63	63	63	63	63
GB03 Stockpile Management and Support								
Operating	147.3	148.0	156.0	177.0	177.0	177.0	177.0	177.0
Capital Equipment	9.5	9.0	13.0	10.7	10.7	10.7	10.7	10.7
General Plant Projects	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Major Construction	4.5	4.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	161.9	161.9	169.0	187.7	187.7	187.7	187.7	187.7
Direct Personnel	539	522	550	582	582	582	582	582

[1]Same as Research and Development (GB0103) and Testing (GB0104) during FY 1994 and 1995.
[2]Technology Transfer Initiative funding will be redirected toward advanced manufacturing and advanced computing technologies beginning in FY 1997. Technology Transfer will become an integrated part of the Stockpile Stewardship Program.

Assistant Secretary for Defense Programs
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs) (Continued)

	1994	1995	1996	1997	1998	1999	2000	2001
GB05 Program Direction								
Operating	3.1	4.0	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	3.3	4.4	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	14	15	0	0	0	0	0	0
GB06 Complex Reconfiguration								
Operating	17.9	23.0	28.4	6.2	6.2	6.2	6.2	6.2
Major Construction	5.3	22.6	16.5	0.0	0.0	0.0	0.0	0.0
Total Cost	23.2	45.6	44.9	6.2	6.2	6.2	6.2	6.2
Direct Personnel	55	96	110	27	27	27	27	27
GB Weapons Activities								
Operating	604.8	592.1	610.7	594.7	594.7	594.7	594.7	594.7
Capital Equipment	39.6	43.3	40.5	43.2	43.2	43.2	43.2	43.2
General Plant Projects	6.4	4.5	3.0	2.4	2.4	2.4	2.4	2.4
Major Construction	46.7	73.7	30.5	24.3	24.3	24.3	24.3	24.3
Total Cost	697.5	713.6	684.7	664.6	664.6	664.6	664.6	664.6
Direct Personnel	2,029	1,978	2,002	1,972	1,972	1,972	1,972	1,972
GE Materials Production – Reactor Operations								
Operating	1.3	1.4	1.2	1.4	1.4	1.4	1.4	1.4
Direct Personnel	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total Assistant Secretary for Defense Programs								
Operating	606.1	593.5	611.9	596.1	596.1	596.1	596.1	596.1
Capital Equipment	39.6	43.3	40.5	43.2	43.2	43.2	43.2	43.2
General Plant Projects	6.4	4.5	3.0	2.4	2.4	2.4	2.4	2.4
Major Construction	46.7	73.7	30.5	24.3	24.3	24.3	24.3	24.3
Total Cost	698.8	715.0	685.9	666.0	666.0	666.0	666.0	666.0
Direct Personnel	2,033	1,981	2,005	1,975	1,975	1,975	1,975	1,975

Office of Nonproliferation and National Security
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
GC Verification and Control Technology								
Operating	68.5	74.7	66.5	66.5	66.5	66.5	66.5	66.5
Capital Equipment	2.7	3.2	2.4	2.4	2.4	2.4	2.4	2.4
Major Construction	8.8	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	80.0	85.5	68.9	68.9	68.9	68.9	68.9	68.9
Direct Personnel	271	220	242	251	251	251	251	251
GD Nuclear Safeguards and Security								
Operating	9.8	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Capital Equipment	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Cost	10.8	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Direct Personnel	45	35	37	38	38	38	38	38
GJ Export Control and Nonproliferation								
Operating	6.8	7.5	10.0	10.0	10.0	10.0	10.0	10.0
Capital Equipment	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	6.9	7.8	10.0	10.0	10.0	10.0	10.0	10.0
Direct Personnel	27	50	52	52	52	52	52	52
NB Emergency Preparedness								
Operating	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
NT Intelligence								
Operating	3.6	3.4	3.0	3.0	3.0	3.0	3.0	3.0
Capital Equipment	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	3.6	3.6	3.0	3.0	3.0	3.0	3.0	3.0
Direct Personnel	15	15	12	13	13	13	13	13
Total Office of Nonproliferation and National Security								
Operating	89.2	94.1	88.0	88.0	88.0	88.0	88.0	88.0
Capital Equipment	3.8	4.7	3.4	3.4	3.4	3.4	3.4	3.4
Major Construction	8.8	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	101.8	106.4	91.4	91.4	91.4	91.4	91.4	91.4
Direct Personnel	359	320	343	354	354	354	354	354

Office of Material Disposition
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
GA Material Disposition Operating	0.3	6.0	6.5	6.5	6.5	6.5	6.5	6.5
Direct Personnel	6	26	25	27	27	27	27	27

Assistant Secretary for Environmental Management
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
EW Environmental Management (Defense)								
Operating	144.7	142.0	112.8	96.2	96.2	96.2	96.2	96.2
Capital Equipment	3.1	4.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Major Construction	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	149.4	148.3	112.8	96.2	96.2	96.2	96.2	96.2
Direct Personnel	345	346	345	318	318	318	318	318
EX Environmental Management (Nondefense)								
Operating	0.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Assistant Secretary for Waste Management								
Operating	145.5	144.5	112.8	96.2	96.2	96.2	96.2	96.2
Capital Equipment	3.1	4.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Major Construction	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	150.2	150.8	112.8	96.2	96.2	96.2	96.2	96.2
Direct Personnel	347	354	345	318	318	318	318	318

Assistant Secretary for Energy Efficiency and Renewable Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
AK Electric Energy Systems								
Operating	1.7	1.3	1.0	1.2	1.2	1.2	1.2	1.2
Direct Personnel	6	6	5	6	6	6	6	6
AL Energy Storage Systems								
Operating	3.2	5.8	5.3	5.9	5.9	5.9	5.9	5.9
Capital Equipment	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	3.5	6.3	5.3	5.9	5.9	5.9	5.9	5.9
Direct Personnel	5	8	8	9	9	9	9	9
AM Geothermal Systems								
Operating	4.7	6.1	5.6	6.3	6.3	6.3	6.3	6.3
Capital Equipment	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Total Cost	4.9	6.5	5.8	6.5	6.5	6.5	6.5	6.5
Direct Personnel	13	17	17	18	18	18	18	18
AR Hydrogen Research								
Operating	1.4	1.8	1.6	1.8	1.8	1.8	1.8	1.8
Direct Personnel	5	6	6	6	6	6	6	6
EB Solar Energy								
Operating	29.8	39.2	35.5	40.0	40.0	40.0	40.0	40.0
Capital Equipment	0.3	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Total Cost	30.1	39.9	36.1	40.6	40.6	40.6	40.6	40.6
Direct Personnel	76	70	75	81	81	81	81	81
EC/ED/EE Energy Conservation (Buildings/Industrial/Transportation)								
Operating	5.6	6.5	6.2	7.0	7.0	7.0	7.0	7.0
Capital Equipment	0.1	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Total Cost	5.7	6.6	6.6	7.4	7.4	7.4	7.4	7.4
Direct Personnel	18	20	22	24	24	24	24	24
EF/EH Other Energy (Tech Assistance/Policy)								
Operating	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	0	0	0	0	0	0

Assistant Secretary for Energy Efficiency and Renewable Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs) (Continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Total Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	46.4	61.2	55.2	62.2	62.2	62.2	62.2	62.2
Capital Equipment	0.9	1.7	1.2	1.2	1.2	1.2	1.2	1.2
Total Cost	47.3	62.9	56.4	63.4	63.4	63.4	63.4	63.4
Direct Personnel	123	128	133	144	144	144	144	144

Assistant Secretary for Fossil Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
AA Coal								
Operating	3.8	3.9	2.4	2.7	2.7	2.7	2.7	2.7
Direct Personnel	12	11	8	8	8	8	8	8
AB Gas								
Operating	0.6	1.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	2	3	1	1	1	1	1	1
AC Petroleum								
Operating	2.9	3.1	6.3	7.1	7.1	7.1	7.1	7.1
Direct Personnel	8	9	22	24	24	24	24	24
SA Strategic Petroleum Reserve								
Operating	4.1	3.3	2.8	3.2	3.2	3.2	3.2	3.2
Direct Personnel	14	12	12	13	13	13	13	13
Total Assistant Secretary for Fossil Energy								
Operating	11.4	11.5	11.7	13.2	13.2	13.2	13.2	13.2
Direct Personnel	36	35	43	46	46	46	46	46

Office of Civilian Radioactive Waste Management
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
DB Nuclear Waste Fund								
Operating	16.6	16.5	25.1	28.3	28.3	28.3	28.3	28.3
Capital Equipment	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	16.8	16.6	25.1	28.3	28.3	28.3	28.3	28.3
Direct Personnel	51	47	77	81	81	81	81	81

Office of Nuclear Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
AF Nuclear Energy Research and Development								
Operating	3.5	3.0	3.6	4.1	4.1	4.1	4.1	4.1
Direct Personnel	10	9	11	12	12	12	12	12
CD Uranium Enrichment								
Operating	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	0	0	0	0	0	0
KK05 Nuclear Energy Management								
Operating	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
ST Isotope Production								
Operating	0.1	7.0	9.0	8.0	8.0	8.0	8.0	8.0
Capital Equipment	0.0	0.0	1.2	0.5	0.5	0.5	0.5	0.5
Total Cost	0.1	7.0	10.2	8.5	8.5	8.5	8.5	8.5
Direct Personnel	0	28	44	50	50	50	50	50
Total Office of Nuclear Energy								
Operating	4.1	10.7	12.6	12.1	12.1	12.1	12.1	12.1
Capital Equipment	0.0	0.0	1.2	0.5	0.5	0.5	0.5	0.5
Total Cost	4.1	10.7	13.8	12.6	12.6	12.6	12.6	12.6
Direct Personnel	12	38	55	62	62	62	62	62

Office of Energy Research
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
AT Magnetic Fusion								
Operating	7.0	7.6	7.9	8.9	8.9	8.9	8.9	8.9
Capital Equipment	0.5	0.7	0.4	0.4	0.4	0.4	0.4	0.4
Total Cost	7.5	8.3	8.3	9.3	9.3	9.3	9.3	9.3
Direct Personnel	23	25	28	31	31	31	31	31
KC Basic Energy Sciences								
Operating	22.2	25.8	21.1	23.7	23.7	23.7	23.7	23.7
Capital Equipment	2.1	4.0	2.5	2.5	2.5	2.5	2.5	2.5
General Plant Projects	0.1	0.2	0.6	0.4	0.4	0.4	0.4	0.4
Major Construction	0.0	0.1	9.5	0.0	0.0	0.0	0.0	0.0
Total Cost	24.4	30.1	33.7	26.6	26.6	26.6	26.6	26.6
Direct Personnel	75	70	64	69	69	69	69	69
KP Biological and Environmental Research								
Operating	0.4	1.3	1.4	1.6	1.6	1.6	1.6	1.6
Direct Personnel	1	1	1	1	1	1	1	1
Total Office of Energy Research								
Operating	29.6	34.7	30.4	34.2	34.2	34.2	34.2	34.2
Capital Equipment	2.6	4.7	2.9	2.9	2.9	2.9	2.9	2.9
General Plant Projects	0.1	0.2	0.6	0.4	0.4	0.4	0.4	0.4
Major Construction	0.0	0.1	9.5	0.0	0.0	0.0	0.0	0.0
Total Cost	32.3	39.7	43.4	37.5	37.5	37.5	37.5	37.5
Direct Personnel	99	96	93	101	101	101	101	101

Office of Science Education and Technical Information
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

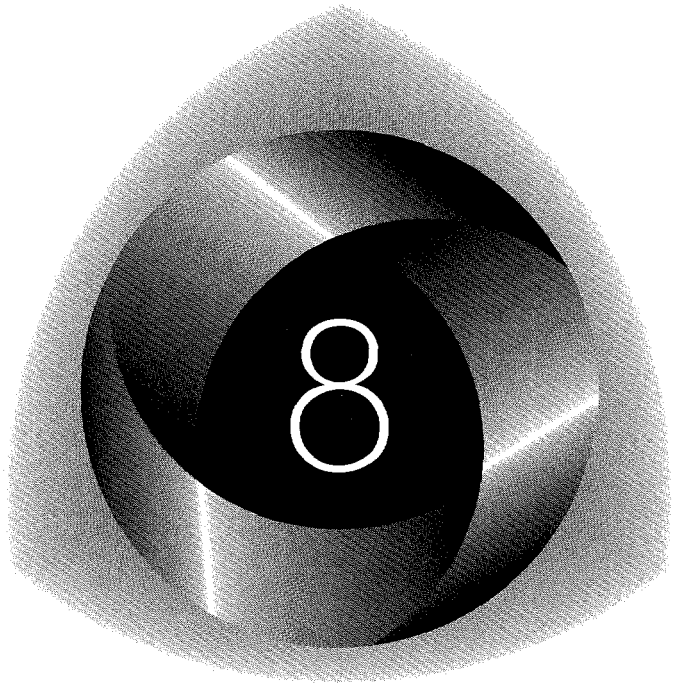
	1994	1995	1996	1997	1998	1999	2000	2001
KT/KV University and Science Education Operating	1.5	3.3	0.7	0.8	0.8	0.8	0.8	0.8
Direct Personnel	1	1	0	0	0	0	0	0

Other DOE Offices and Locations
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
HA Environmental R&D								
Operating	0.4	0.2	0.3	0.4	0.4	0.4	0.4	0.4
Direct Personnel	0	0	1	1	1	1	1	1
NA International Policy Studies								
Operating	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
NP New Production Reactors								
Operating	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
NS Risk and Policy Analysis								
Operating	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	0	0	0	0	0	0
PE Environmental Analysis								
Operating	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
TA Energy Information								
Operating	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
WA Minority Economic Impact								
Operating	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
WB In-House Energy Management								
Operating	0.3	0.3	2.3	2.6	2.6	2.6	2.6	2.6
Major Construction	0.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	1.2	1.8	2.3	2.6	2.6	2.6	2.6	2.6
Direct Personnel	0	0	6	6	6	6	6	6
YN1901 Other DOE Locations/M&O Contractors								
Operating	47.0	36.4	28.4	28.7	28.7	28.7	28.7	28.7
Direct Personnel	140	122	95	111	111	111	111	111
Total Other DOE Offices and Locations								
Operating	48.5	37.5	31.1	31.8	31.8	31.8	31.8	31.8
Major Construction	0.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost	49.4	39.0	31.1	31.8	31.8	31.8	31.8	31.8
Direct Personnel	142	123	102	118	118	118	118	118

Work Other than for DOE
Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

	1994	1995	1996	1997	1998	1999	2000	2001
Department of Defense								
Operating	228.6	219.3	187.7	147.7	147.7	147.7	147.7	147.7
Direct Personnel	644	597	522	386	386	386	386	386
Department of Transportation								
Operating	4.5	6.2	5.4	5.4	5.4	5.4	5.4	5.4
Direct Personnel	16	18	17	17	17	17	17	17
National Aeronautics and Space Administration								
Operating	4.6	8.9	6.7	6.7	6.7	6.7	6.7	6.7
Direct Personnel	15	19	16	16	16	16	16	16
Nuclear Regulatory Commission								
Operating	13.1	14.9	14.0	14.5	14.5	14.5	14.5	14.5
Direct Personnel	55	61	53	61	61	61	61	61
All Other Federal Agencies								
Operating	32.6	35.7	11.3	12.1	12.1	12.1	12.1	12.1
Direct Personnel	92	109	13	3	3	3	3	3
Sandia CRADA Partners								
Operating	11.3	11.6	24.0	37.0	37.0	37.0	37.0	37.0
Direct Personnel	34	24	64	86	86	86	86	86
All Other								
Operating	10.9	15.2	21.5	36.4	36.4	36.4	36.4	36.4
Direct Personnel	36	40	65	90	90	90	90	90
Total Work Other than for DOE								
Operating	305.6	311.8	270.6	259.8	259.8	259.8	259.8	259.8
Direct Personnel	892	868	750	659	659	659	659	659



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This work was performed at Sandia National Laboratories for the United States Department of Energy under Contract DE-AC04-94AL85000.

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