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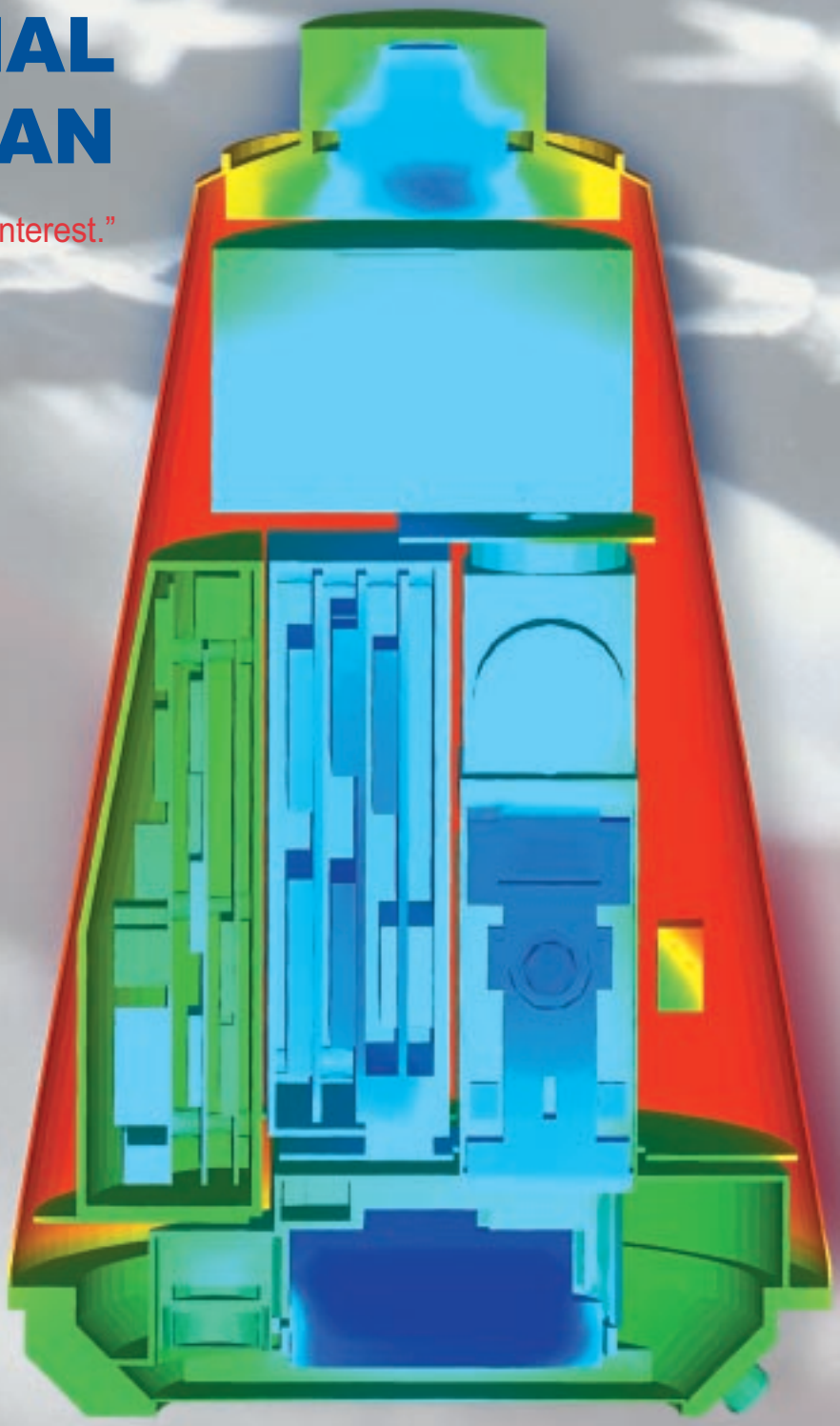
FY 2002-2007

INSTITUTIONAL PLAN

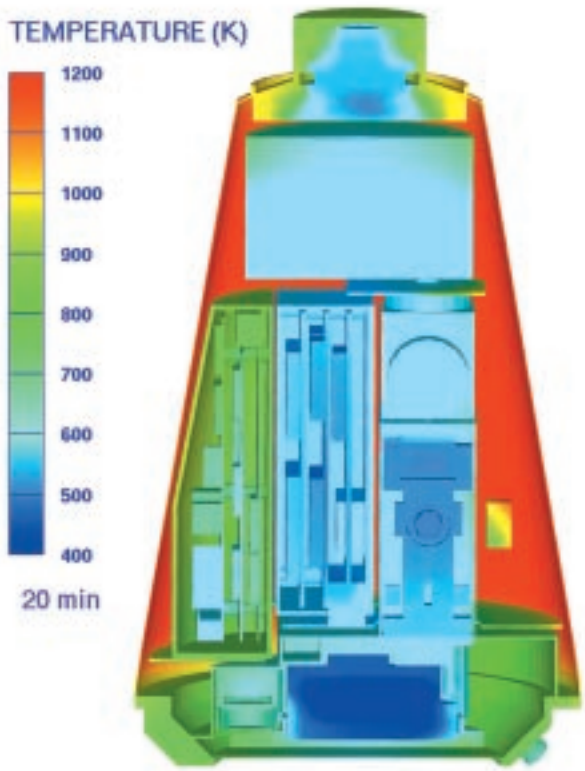
"... exceptional service in the national interest."



Sandia National Laboratories

ABOUT THE COVER

In the past Sandia's assessments of weapon component designs were based primarily on information from test data complemented by results from relatively low-fidelity computational simulations. Now, focused, highly instrumented experiments and full-scale tests are integrated with Accelerated Strategic Computing Initiative (ASCI) high-fidelity computational simulations to provide much more insight into system responses and a greater understanding of component design and performance against requirements.



The front cover shows the results of an ASCI unclassified thermal simulation of the W76 arming, fuzing, and firing subsystem exposed to a fire. Cooler regions (blue) transition to hotter regions (red) as shown by the color key insert. Understanding the temperature response of safety-critical components in abnormal environments (e.g., a fire following a transportation accident) is of paramount importance to component design.

Sandia's ASCI simulation capabilities enable us to analyze the performance of our weapon components and systems across a broad spectrum of challenging environments. Therefore, we can continue to support the design and qualification of weapon components and meet safety and reliability requirements.

Our continuously improving capabilities in simulation and experimentation will help meet Sandia's new national initiative—to "become the laboratory that the United States turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe."

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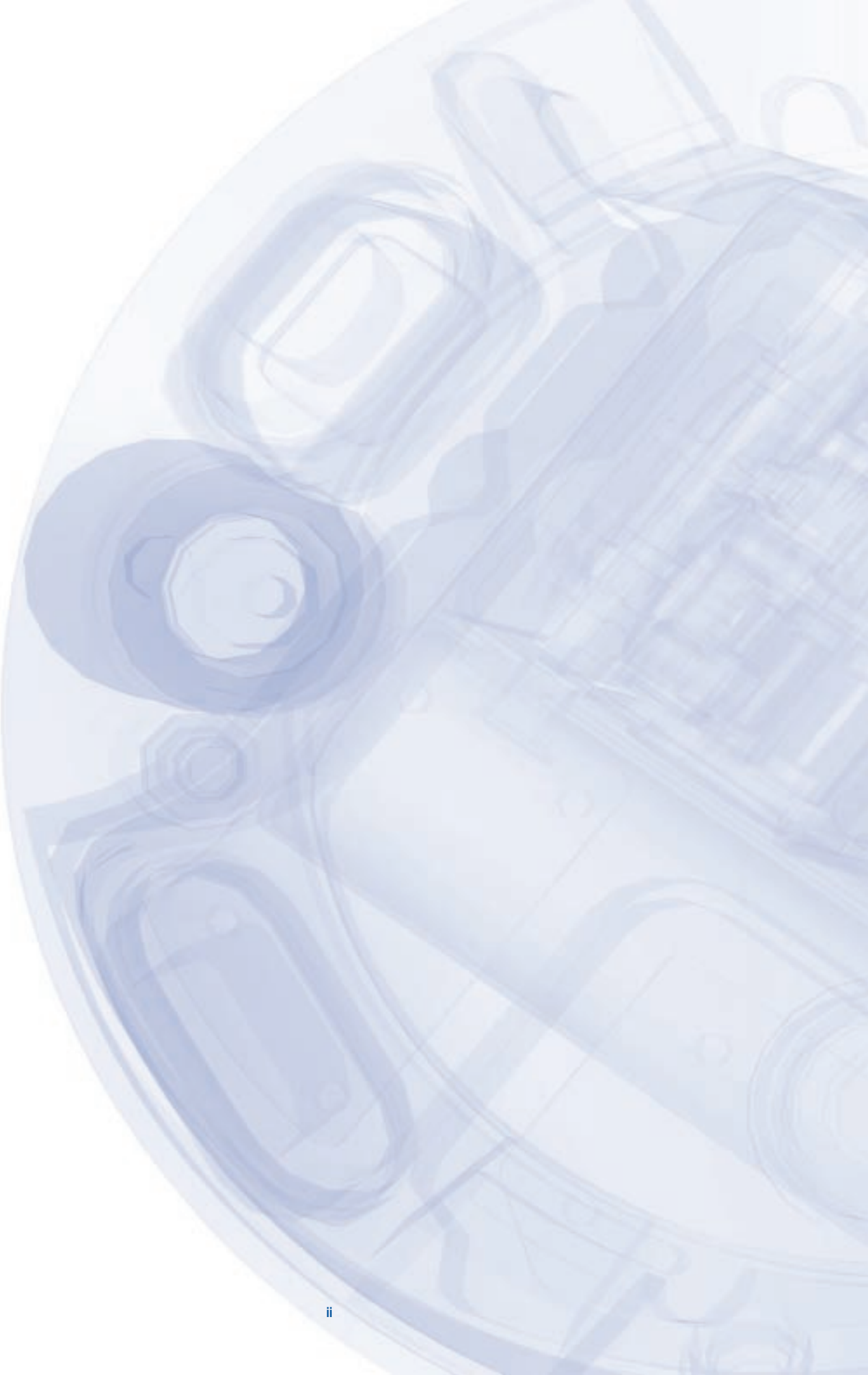
Sandia National Laboratories

December 2OO1
Albuquerque, New Mexico
Livermore, California



CONTENTS

1 • PURPOSE AND ORGANIZATION OF THIS DOCUMENT 1-1

2 • INTRODUCTION 2-1
- 2.1 Sandia's Vision 2-1
  - 2.1.1 Core Purpose 2-1
  - 2.1.2 Highest Goal 2-1
  - 2.1.3 Core Values 2-1
- 2.2 Strategic Objective History 2-2
- 2.3 Summary of Capabilities 2-2
- 2.4 Research Foundations 2-4
  - 2.4.1 Materials and Process Science 2-4
  - 2.4.2 Computational and Information Sciences 2-5
  - 2.4.3 Microelectronics and Photonics Sciences 2-6
  - 2.4.4 Engineering Sciences 2-7
  - 2.4.5 Pulsed Power Sciences 2-7

3 • STRATEGIC OBJECTIVES AND INTERMEDIATE GOALS 3-1
- 3.1 Nuclear Weapons: Our Primary Mission 3-3
- 3.2 Nonproliferation and Materials Control 3-3
- 3.3 Energy and Critical Infrastructure 3-3
- 3.4 Emerging Threats 3-4
- 3.5 People 3-4
- 3.6 Science and Technology 3-4
- 3.7 Infrastructure 3-5
- 3.8 Partnerships 3-5

4 • REPRESENTATIVE MILESTONES FOR FISCAL YEAR 2002 4-1
- 4.1 Milestones by Strategic Objective 4-1
  - 4.1.1 Nuclear Weapons 4-1
  - 4.1.2 Nonproliferation and Materials Control 4-2
  - 4.1.3 Energy and Critical Infrastructure 4-2
  - 4.1.4 Emerging Threats 4-3
  - 4.1.5 People 4-3
  - 4.1.6 Science and Technology 4-3
  - 4.1.7 Infrastructure 4-4
  - 4.1.8 Partnerships 4-4
- 4.2 Crosscutting Milestones 4-4
- 4.3 Continuous Improvement 4-4

5 • SANDIA ACCOMPLISHMENTS FOR FISCAL YEAR 2001 5-1
- 5.1 Nuclear Weapons 5-1
- 5.2 Nonproliferation and Materials Control 5-3
- 5.3 Energy and Critical Infrastructure 5-5
  - 5.3.1 Energy 5-5
  - 5.3.2 Critical Infrastructure 5-6

5.4 Emerging Threats 5-7
5.5 People 5-8
5.6 Science and Technology 5-9
5.6.1 Materials and Process Science 5-9
5.6.2 Computational and Information Sciences 5-11
5.6.3 Microelectronics and Photonics Sciences 5-11
5.6.4 Engineering Sciences 5-12
5.6.5 Pulsed Power Sciences 5-12
5.7 Infrastructure 5-14
5.8 Partnerships 5-15
5.8.1 Established Partnerships 5-15
5.8.2 Cooperative Research and Development Agreements 5-16
5.8.3 Funds-in Agreements 5-17
5.8.4 Licenses 5-17
5.8.5 Memoranda of Understanding 5-18
5.8.6 Other 5-18

6 • MAJOR PROGRAMMATIC ACTIVITIES 6-1
6.1 Programs for the United States Department of Energy 6-1
6.1.1 National Nuclear Security Administration's Office of the Deputy Administrator for Defense Programs 6-1
6.1.2 National Nuclear Security Administration's Office of Fissile Materials Disposition 6-14
6.1.3 National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation 6-15
6.1.4 National Nuclear Security Administration's Office of Transportation Safeguards 6-18
6.1.5 DOE's Assistant Secretary for Environmental Management 6-18
6.1.6 DOE's Assistant Secretary for Renewable Energy 6-22
6.1.7 DOE's Office of Civilian Radioactive Waste Management 6-25
6.1.8 DOE's Office of Nuclear Energy 6-25
6.1.9 DOE's Assistant Secretary for Fossil Energy 6-26
6.1.10 DOE's Office of Science Programs 6-27
6.1.11 Integrated DOE Activities (Work for Other DOE Locations, DOE's Contractors, and Offices) 6-34
6.2 Work for Non-DOE Sponsors 6-34
6.2.1 Work for Other Federal Entities 6-34
6.2.2 Work for Nonfederal Entities 6-40
6.3 Laboratory Directed Research and Development Program 6-41
6.3.1 Strategy 6-41
6.3.2 Impact 6-42
6.3.3 Process 6-42
6.3.4 Results 6-43
6.3.5 Future Directions 6-45

7 • MAJOR PROGRAMMATIC INITIATIVES 7-1
7.1 Nuclear Weapons 7-1
7.1.1 Microsystems and Engineering Sciences Applications (MESA) Complex 7-1
7.2 Nonproliferation and Materials Control 7-4
7.2.1 Treaty Verification/Nonproliferation Technology 7-4
7.2.2 Global Nuclear Management 7-5

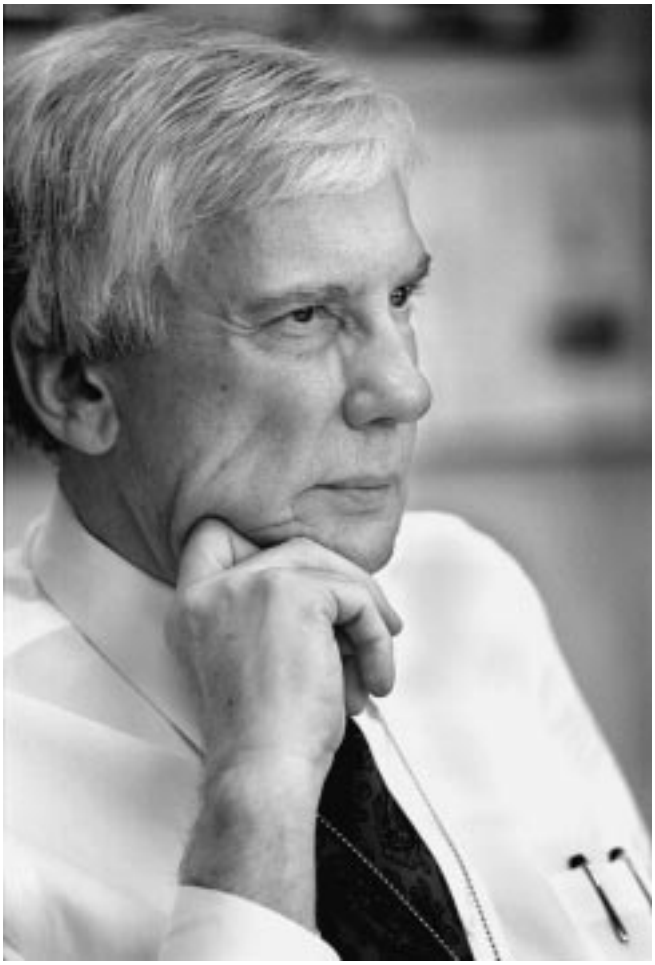
7.2.3 Materials Protection, Control, and Accounting 7-6
7.2.4 Transparency 7-6
7.2.5 Preventing the Spread of Proliferation-Relevant Knowledge and Expertise 7-7
7.2.6 Expanded Cooperative Monitoring Center and Program 7-7
7.3 Energy and Critical Infrastructure 7-8
7.3.1 The Center for Integrated Nanotechnologies 7-8
7.3.2 Energy Portfolio 7-9
7.3.3 Critical Infrastructure Surety 7-9
7.3.4 Systems and Policy Analysis 7-10
7.3.5 Nuclear Energy Initiative 7-11
7.3.6 Navajo Nation/National Laboratories Partnership 7-12
7.3.7 Hanford Site 7-13
7.3.8 Soil and Sediment Transport Laboratory 7-14
7.3.9 Water Safety, Security, and Sustainability 7-14

8 • RESOURCES AND MANAGEMENT OF RESOURCES 8-1
8.1 People 8-1
8.1.1 Laboratories Composition 8-1
8.1.2 Planning and Evaluation 8-2
8.1.3 Human Resource Programs and Initiatives 8-3
8.1.4 Outreach 8-8
8.1.5 Community Involvement 8-9
8.2 Designated Capabilities, Technology Deployment Centers, and User Facilities 8-11
8.2.1 Designated Capabilities 8-11
8.2.2 Technology Deployment Centers/User Facilities 8-14
8.3 Sites, Facilities, and Utility Systems 8-16
8.3.1 Infrastructure Management 8-17
8.3.2 General Purpose Facilities Plans 8-19
8.3.3 Inactive Surplus Facilities Plan 8-20
8.3.4 Facilities Resource Requirements 8-20
8.3.5 Sandia Facilities Investment Strategy 8-20
8.4 Information 8-23
8.4.1 Information Resources Management 8-23
8.4.2 Software Quality 8-23
8.4.3 Records Management 8-25
8.4.4 Management of Scientific and Technical Information 8-25
8.5 Protection 8-26
8.5.1 Security 8-26
8.5.2 Environment, Safety, and Health 8-27

9 • SUPPORTING DATA 9-1
9.1 Sandia Funding Summary 9-2
9.2 Sandia Funding by Assistant Secretarial Office 9-3
9.3 Sandia Funding by Program within Each Secretarial Office 9-5
9.4 Sandia Funding for Work for Non-DOE Sponsors 9-13
9.5 Personnel Summary by Major Sponsor 9-14
9.6 Sandia Organization Chart at the Vice Presidential Level 9-15
9.7 Referenced and Supporting Documents 9-16

10 • INDEX 10-1

PRESIDENT'S MESSAGE



Last year, Sandia introduced a new core purpose statement for our labs: "helping our nation secure a peaceful and free world through technology." This statement highlights that 1) we work *for* the United States in providing our assistance to achieve a peaceful and free world—not only for our citizens but for all citizens of the world; 2) we are increasingly taking a global view as we carry out our work; and 3) Sandia's advanced technologies are the primary tools we bring to the table.

The goal of our core purpose and the hopes and dreams for a better world suffered a major setback in the tragic terrorist attacks of September 11, 2001. For the first time since Pearl Harbor, our nation suffered a deadly attack with thousands of deaths. There is no doubt that we will rise up as a people and as a nation to avenge these cowardly acts. But during our lifetimes, it will prove difficult to ever recover the same levels of "peace and freedom" that we enjoyed prior to these events.

Many parts of our government have called on Sandia to provide help in waging the war against the terrorists now under way and to help keep future destructive acts from succeeding. We take pride in adding these missions to our other national security responsibilities.

Our fledgling and newly articulated core purpose has been bloodied, but the importance of achieving success in this important task has never been clearer.

C. Paul Robinson

PURPOSE AND ORGANIZATION OF THIS DOCUMENT

This Institutional Plan is the most comprehensive yearly "snapshot" available of Sandia National Laboratories' major programs, facilities, user facilities, human resources, and budget. The document also includes overviews of our missions, organization, capabilities, planning functions, milestones, and accomplishments. The document's purpose is to provide the above information to the National Nuclear Security Administration (NNSA), the Department of Energy (DOE), key congressional committees, Sandia management, and other present and potential customers.

Chapter 2 presents a brief history of and information about Sandia's mission and strategic objectives. Chapter 2 also includes a table of values common to Sandia, Lockheed Martin, and the NNSA/DOE—as well as a summary of our capabilities and an overview of our research foundations.

Chapter 3 is organized in accordance with the strategic objectives identified in section 2.2 and presents Sandia's intermediate goals for these strategic objectives. Chapter 3 also is referenced forward to the programmatic work described in chapter 6.

Chapter 4 is organized by strategic objective and presents representative FY 2002 milestones that allow us to measure Sandia's progress toward the goals in each of our strategic objective areas (see chapter 3).

Chapter 5, also organized by strategic objective, presents Sandia's accomplishments as of September 30, 2001.

In chapter 6, the appropriate programmatic descriptions are arranged to reflect the NNSA's campaigns. Chapter 6 also presents programmatic descriptions of work for the DOE secretarial offices and ongoing work in Sandia's Laboratory Directed Research and Development Program.

Chapter 7 presents Sandia's major programmatic initiatives.

Chapter 8 contains an overview of Sandia's human resources programs, facilities programs, information management programs, and Safeguards and Security Program.

The appropriate funding tables in chapter 9 have been rearranged to reflect the NNSA's campaigns.

INTRODUCTION

Sandia's government missions embody a philosophy of research and development derived from our industrial heritage. Our research is strategic to our missions; we perform science with the mission in mind rather than pursuing knowledge for its own sake. Sandia's strategic objectives reflect our philosophy of developing applications of new knowledge and our intent to make increasingly greater contributions to the nation, now and in the future.

Our basic overall philosophy is set forth in the Management and Operating Contract: Sandia "shall manage, operate, protect, sustain and enhance the Laboratory's ability to function as a US Department of Energy Multi-Program Laboratory, while assuring accomplishment of its primary assignment as a nuclear weapons research, development, and engineering laboratory."[1]

2.1 Sandia's Vision

In 2000, ten years after creating our first strategic plan, Sandia executives reviewed our core missions and values. During this process they reaffirmed several elements from the original plan and changed others to better align with the future responsibilities they envision for Sandia.

2.1.1 Core Purpose

Sandia's core purpose is to help our nation secure a peaceful and free world through technology.

2.1.2 Highest Goal

Sandia's highest goal is to become the laboratory that the United States turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe.

2.1.3 Core Values

In 1990, Sandia created its first Strategic Plan[2] and identified corporate values. In 2000, Sandia's executive and upper management reevaluated its corporate values in its strategic planning, and reaffirmed that Sandia values

- integrity,
- excellence,
- service to the nation,
- our people, and
- teamwork.

[1] *Management and Operating Contract Between Sandia Corporation and DOE DE-AC04-94AL8500.* Appendix B: Statement of Work, Section J of Part III as modified April 28, 1999.
[2] *Strategic Plan 1990: Sandia National Laboratories.* SAND90-0562. 1990. Albuquerque, NM: Sandia National Laboratories.

Sandia's core values are very similar to Lockheed Martin's value statements and the National Nuclear Security Administration/DOE's core values. The table of Values in Common that follows presents relevant language from each organization's statement of values, showing that we share ideals and motivations with our parent company and our principal customer.

2.2 Strategic Objective History

In early 1996, Sandia's Laboratory Leadership Team redefined our strategic objectives, involving Sandia managers at all levels. The Laboratory Leadership Team appraised Sandia's near- and long-term future and identified eight new strategic objectives for the next decade.

The first four objectives focus on what Sandia will accomplish in the areas of

- nuclear weapons,
- nonproliferation and materials control,
- energy and critical infrastructure, and
- emerging threats.

The last four objectives focus on how Sandia will accomplish work by means of our

- people,
- science and technology,
- infrastructure, and
- partnerships.

To support the first four objectives, we implemented four strategic business units (SBUs) in FY 1998. In addition, to acknowledge organizations that support those SBUs and that directly serve external customers, we implemented two strategic management units (SMUs)—one in science and technology and one in partnerships. The SBU/SMU structure implemented in FY 1999 articulates Sandia's strategic direction, coordinates Sandia's interface with its present customers, and develops new business and new customers.

The strategic objectives comprise the highest-level statement of Sandia's long-term objectives. They identify areas of strategic focus but are not an all-inclusive list of Sandia's programs.

Sandia's corporate planning elements—the strategic objectives and intermediate goals described in chapter 3 and the representative fiscal year milestones presented in chapter 4—support implementation of the Government Performance and Results Act.

2.3 Summary of Capabilities

Sandia's engineering excellence is built on a foundation of science and engineering research capabilities. Our commitment to research started in the 1960s in response to the need for assuring the safety, security, and reliability of increasingly complex nuclear weapons. Sandia's commitment to excellence in this mission remains the focus of much of our research, but the challenges have become greater. Nuclear weapons can no longer be tested, so we must ensure that the nation has a credible nuclear deterrent by using modern manufacturing capabilities to replace lost capabilities and to reduce life-cycle costs. Moreover, national security threats now include other weapons of mass destruction and attacks on critical infrastructure.

Our research programs support critical mission areas. Sandia performs science with the mission in mind to advance in many areas of science and technology. In addition to our science capabilities (known as research foundations), we will focus on several specific technology areas during the next few years: intelligent integrated microsystems; simulation-based, life-cycle engineering and manufacturing; surety science and technology; and biotechnology. We want our customers and external appraisers to recognize Sandia as a leader in each of these areas.

The invention and application of integrated circuits has had enormous impact on all aspects of human enterprise, including national security. Radiation-hardened integrated circuits remain essential to the nation's nuclear stockpile, ensuring that stockpile systems will work reliably. The next revolution in this field combines the use of integrated circuits (intelligence) with devices that can sense (detect movement, chemicals, and temperature), act (perform mechanical work), and communicate (transmit optical or radio frequency signals). This technological revolution will increase safety, security, and reliability for nuclear weapons while greatly reducing the cost of building and maintaining them. External reviewer assessments have shown that Sandia is uniquely equipped to lead this effort. These new technologies are key elements of our systems design organization's plans for inclusion in the DOE Stockpile Life Extension Program and are a natural extension of our ongoing mission in radiation-hardened microelectronics.

Revolutionary advances in engineering design, validation, and manufacturing (enabled by the DOE's Accelerated Strategic Computing Initiative and the Advanced Design and Production Technologies Initiative) are being used to improve the processes that sustain the nation's nuclear weapons stockpile. The possibility of understanding the entire life cycle of a nuclear weapon or other complex devices and systems lies in simulation-based models of components, subsystems, and systems performance and in models of materials synthesis, manufacturing processes, aging, and disposition.

Surety science is an evolving discipline with origins in Sandia's mission of nuclear weapon engineering and the need to avoid high-consequence accidents. Surety science integrates safety, reliability, and security into a balanced, systemic approach that incorporates modeling and simulation, testing and evaluation, risk management, reliability development, and physical security. Systems that operate exactly as planned—every time in every circumstance—are the goal of surety science. This discipline supports a broad range of

Values in Common

Sandia Corporate Values	Lockheed Martin Value Statements	NNSA/DOE Core Values
Integrity: We live our core values without being distracted by temporary expedience. We are honest in times of disagreement and fully discharge our trust despite temptations to unnecessary compromise.	We embrace truthfulness and trust. . . . We . . . adhere to the highest standards of ethical conduct in all that we do.	We pursue the highest standards of ethical behavior.
Excellence: We deliver superior technical and managerial performance that both meets our nation's needs and pushes forward the frontiers of science, engineering, and technology.	We demonstrate . . . a restless determination to continually improve upon our personal bests. We . . . add value for our customers with ingenuity, determination, and a positive attitude.	We are committed to excellence. We are customer-oriented. We recognize that leadership, empowerment, and accountability are essential. We value creativity and innovation.
Service to the Nation: We meet the requests of our government, anticipate its future needs, and benefit the nation and our world. We are steadfast in completing our mission in the face of ambiguity and criticism. We make the most of every opportunity to render "exceptional service in the national interest."	[We] obey all the laws of the United States and the other countries in which we do business and . . . do our part to make the communities in which we live better.	We work as a team with other Federal agencies, government organizations, and external stakeholders in pursuing broader national objectives. We are effective stewards of the taxpayer's interests. We place a high priority on the protection of public health and safety in all of our operations.
Our People: We respect the intellect, skills, initiative, diversity, flexibility, and can-do attitude of our employees. We nurture rather than hinder their development. We applaud "the best and the brightest" in our employees and their accomplishments.	We embrace lifelong learning through individual initiative, combined with company-sponsored education and development programs, as well as challenging work and growth opportunities. We . . . treat everyone with dignity and respect—as we wish to be treated ourselves.	We believe people are our most important resource.
Teamwork: We ensure shared values and focus, team internally and externally, and create mutual benefits and mutual respect.	We multiply the creativity, talents, and contributions of both individuals and businesses by focusing on team goals. Our teams assume collective accountability for their actions, share trust and leadership, embrace diversity, and accent responsibility for prudent risk-taking.	We work as a team and advocate teamwork.

applications, including the systems engineering of nuclear weapons and stewardship of the stockpile; infrastructure protection to ensure that our complex, interconnected systems of power, water, energy, public transportation, communication, and finance are not imperiled by terrorism, nature, accident, or their own interdependent complexity; architecture surety to design buildings that can withstand threats from terrorists, natural disasters, and aging materials; transportation surety to reduce fatal airplane accidents five-fold in the next decade; advanced electronics design to ensure that reliability developments keep pace with microelectronics advances and remain affordable; new crime-fighting technologies that make our communities safer; and school security to identify new approaches to combat rising violence on campuses.

Biotechnology will play an increasingly important role in national security. To continue responsibly addressing our national security missions, Sandia must develop core technical capabilities in biotechnology. We are creating information and physical systems engineering models of toxin interactions with cell membranes and are using this understanding to build improved toxin detector systems and improved nanoinstrumentation. We will expand the models to represent complete cells to develop mitigation strategies for chemical/biological warfare threats and to mimic biological structures for other Sandia national security activities (e.g., self-repairing materials for stockpile applications or new biological approaches for high-performance computing).

Success in the above major science and technology endeavors and in other important projects requires talented people and modern facilities. Partnerships with industrial laboratories and universities help maintain Sandia's modern capabilities. Industrial partnerships that bring tangible benefits to Sandia are increasing because collaboration is mutually beneficial. We also achieve similar results by teaming with universities to execute our principal missions.

2.4 Research Foundations

Sandia addresses technical issues of critical national importance. To assure that the solutions we provide are both innovative and sound, we sustain areas of scientific depth that provide technical excellence in various disciplines. This ensures each discipline a "critical mass" of experts to test new ideas and attract new talent to Sandia. These research foundations, which differentiate Sandia from universities and many other federal laboratories, are

- materials and process science,
- computational and information sciences,
- microelectronics and photonics sciences,
- engineering sciences, and
- pulsed power sciences.

2.4.1 Materials and Process Science

Sandia's research foundation in materials and process science provides the scientific basis for technical options and decisions about polymers, ceramics, and metals and the interfaces among these material combinations in nonnuclear components for the stockpile. We estimate times for component replacement, choose replacement materials, and determine the means of manufacturing replacement components. We synthesize and process materials and select

Sandia's surety science capability provides a broad range of anti-terrorist and crime-fighting technologies such as this vehicle portal, which can detect explosives in vehicles.

methods for controlling the resultant microstructure and chemical composition. We fabricate piece parts using geometries and properties that fully satisfy design intent and allow us to predict how these properties change with time.

Three major types of research subprograms support this research foundation: scientifically tailored materials, materials processing, and materials aging and reliability.

The scientifically tailored materials subprogram addresses the need for materials with specific properties or performance characteristics for use in the stockpile. We seek to understand how materials properties depend on composition and microstructure.

The materials processing subprogram seeks to understand new and existing processes critical for National Nuclear Security Administration Defense Programs current and anticipated needs. Emphasis is on the means of processing, reduced process/product development cycles through scientific model-based processing, and fabrication of parts with fewer defects and at lower cost.

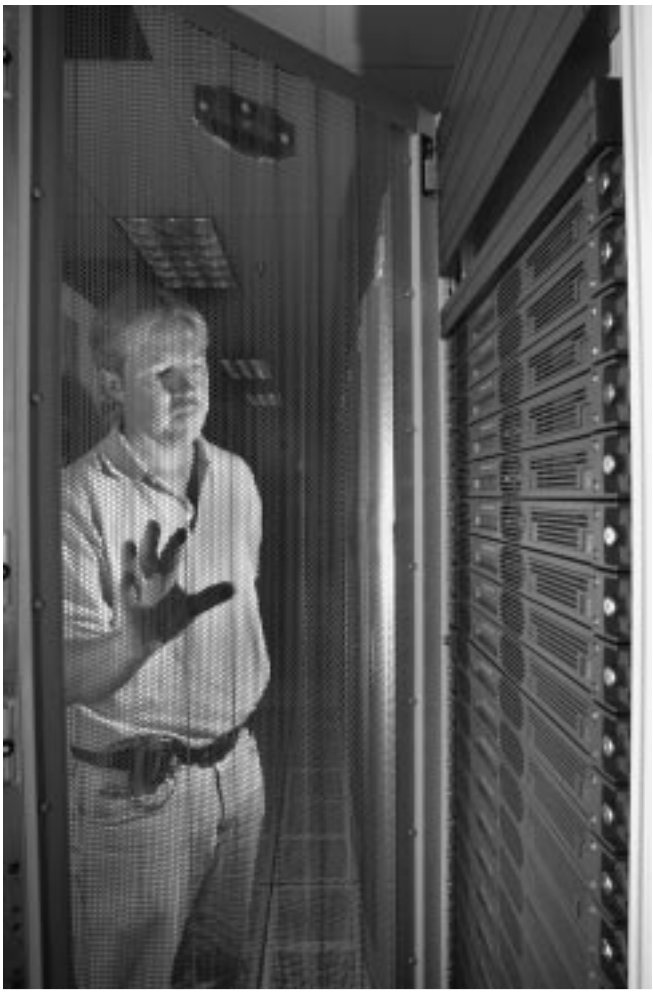
The materials aging and reliability subprogram quantifies the chemical and physical mechanisms that cause materials properties to change with time and identifies the modes of failure. Mechanisms involve both extrinsic environmental drivers and intrinsic thermodynamic drivers associated with the materials. This subprogram provides the scientific basis for quantitative prediction of component reliability as a function of time in the stockpile.

2.4.2 Computational and Information Sciences

Sandia's research foundation in computational and information sciences develops technology to revolutionize scientific studies and engineering practices. We need tremendous increases in supercomputing power to analyze complicated accident scenarios, monitor and assess weapons components and systems, predict the aging of key stockpile materials, and design replacement components. We are developing technology to support the Accelerated Strategic Computing Initiative (ASCI) and other weapons programs that will ensure the safety and reliability of the nuclear stockpile under the aegis of the National Nuclear Security Administration Science-Based Stockpile Stewardship Program.

Research areas include new mathematical methods, algorithms, and software; new parallel solvers for linear and nonlinear systems of equations; new methods to solve highly nonlinear optimization problems; and tools to handle the results of large-scale computations. Such research has led to national awards, major patents, and numerous commercial licenses.

Research is under way in the area of scalable commodity (i.e., using commercially available components) supercomputing and distributed computing over long-distance networks. We emphasize high-speed networking, storage systems, encryption, and scalable operating systems. Sandia's initiative in distributed computing is providing technology for next-generation, high-performance cluster computing. Such computing systems will make greater use of high-volume commodity building blocks and will be constructed over greater lengths of time, leading to more heterogeneous systems than we had in the past. Within the National Nuclear Security Administration/DOE Distance Computing and Distributed Computing (DisCom^2) Program, Sandia is now implementing such a computational plant (known as Cplant™), portions of which are located in New Mexico and California.



Sandian Carl Leishman looks at one of the many racks of computers that form Cplant™, the largest Linux cluster in the world.

Other research foundations are providing the technology to support the Distance Computing and Distributed Computing Program and are developing the scalable systems and applications software needed for program success. A primary concern is the need to provide tools that continue to operate properly as the system is degraded by one or more component failures.

Developing software for such environments has produced significant advances in the creation of component-based software environments. Sandia is designing component-based software architecture and associated frameworks to enable interoperability between modeling tools and other engineering software.

A broad range of massively parallel applications is being developed within this research foundation to address important areas for the Science-Based Stockpile Stewardship Program, including chemically reacting flows, shock physics, electromagnetics, and material design and aging. New programs in systems-level simulation and web-based delivery of analytic tools are delivering modeling capabilities to the desktops of weapon component and system engineers. Simultaneously, initiatives in evolutionary computing are advancing our ability to simulate the entire nuclear weapons defense decision-making structure and to optimize strategy, tactics, and designs.

2.4.3 Microelectronics and Photonics Sciences

Sandia's research foundation in microelectronics and photonics provides the underlying science and technology to ensure state-of-the-art implementation of Sandia's electronics systems. This research foundation includes activities ranging from fundamental solid-state physics to the design and fabrication of radiation-hardened integrated circuits and integrated microsystems. It includes the complete computer-aided design, fabrication, testing, packaging, and reliability infrastructure necessary to transition research concepts into qualified products. Continued advancement of radiation-hardened technologies, microelectromechanical systems, sensors, and optoelectronics remains a driving element of our microelectronics and photonics sciences.

Sandia has a major strategy for creating the small, low-power, high-functionality devices called integrated microsystems. These devices use integrated circuit fabrication technology to put many functions (including processing electronics, sensors, communication devices, and microelectromechanical systems) on a single substrate or in very small multichip modules. An external review committee of microtechnology experts from industry, universities, and other federal laboratories reviewed Sandia's microtechnology capabilities in FY 2001 and concluded that we have unique capabilities and are recognized leaders in integrated microsystems. Sandia's microelectronics and photonics sciences are organized to support the major technologies for integrated microsystems (silicon microelectronics, sensors, and compound semiconductor devices), along with the associated infrastructure. The Microsystems and Engineering Sciences Applications complex major initiative (see section 7.1.1) is funded to provide the infrastructure and program support necessary to achieve Sandia's microsystems strategy.

A Sandia hand-held integrated microsystem can analyze fluids and gasses for explosives.

2.4.4 Engineering Sciences

Sandia's research foundation in engineering sciences supports core research, development, and applications that ensure the highest caliber of experiments, theory, and computations in support of Sandia's missions. Engineering sciences supports diverse Sandia program elements such as weapons systems and components performance and safety; energy and environmental issues; and the design, fabrication, and performance of microelectromechanical systems. Engineering sciences also has strong collaborations with industry (including Goodyear and Dow Chemical) and other government agencies (such as the DOD and the Federal Aviation Administration) to apply Sandia's mechanics expertise to solve external problems that also improve Sandia's mechanics capabilities. In addition Sandia provides national leadership in the engineering sciences community through activities that range from participation on national review boards to cosponsoring university research with the National Science Foundation. Our research includes experiments, physical model development, and new computational capabilities in aerosciences, fluid mechanics, thermal sciences, reactive processes, solid mechanics, material mechanics, structural dynamics, computational technologies, uncertainty quantification, and electrical engineering/electromagnetics.

The engineering sciences research foundation and the Accelerated Strategic Computing Initiative integrate experiments and computation to validate modeling to support Sandia's missions. We develop and apply advanced diagnostics for experiments to discover physical phenomena and constitutive behavior that provide a basis for computational models. We use spatially and temporally resolved experimental data to validate models ranging from submodels within a given discipline to integrated multiphysics models bridging multiple disciplines. These science-based computational capabilities will permit us to design and certify Sandia products more rapidly, cost-effectively, and (most importantly) with greater confidence from a thorough understanding of the governing physical phenomena.

2.4.5 Pulsed Power Sciences

Sandia's research foundation in the pulsed power sciences applies technological advances to problems of national importance in collaboration with the Lawrence Livermore and Los Alamos national laboratories, US industry, and universities. We contribute to the Stockpile Life Extension Program and to the High Energy Density Physics Program within the National Nuclear Security Administration's Stockpile Stewardship Program. Our submicrosecond pulsed power provides intense x-ray radiation to certify the survivability and performance of strategic systems in the nation's weapons stockpile and ultra-high magnetic fields to measure the properties of materials at high energy density. Our experimental capabilities are critical to certify weapons in the absence of underground nuclear testing. We balance experimental innovation with guidance obtained from extensive time- and space-resolved diagnostics and from suites of design and simulation codes. Our long-term vision is to achieve high yield in the laboratory to enhance the nation's capabilities in radiation effects, weapons physics, and inertial fusion for energy applications.

Pulsed power contributes to seven National Nuclear Security Administration Defense Programs weapon science campaigns (see table on work breakdown structure in chapter 6): Primary Certification, Dynamic Materials Properties, Advanced Radiography, Secondary Certification and Nuclear Systems Margins, Inertial Confinement Fusion Ignition and High Yield, Nuclear Survivability, and Defense Applications and Modeling. Pulsed power supports Directed Stockpile Work activities associated with the certification of specific weapons and contributes to the science and technology programs of other federal agencies. Advances in x-ray power output and in repetitive, high-average-power accelerator technology resulting from the efficient conversion of stored electrical energy into a short pulse of x-rays or charged particles have also led to basic science applications at energies that can exceed a megajoule. Our pulsed power endeavors include

- generating a high-brightness, compact radiographic source for stockpile certification experiments in Nevada;
- providing experimental capabilities for stockpile stewardship on pulsed power facilities;
- obtaining accurate material equation-of-state data and opacities for simulation codes;
- interpreting spectra from astrophysical objects and from imploding inertial confinement fusion capsules using data from the Z Accelerator;
- developing the technology to modify material surfaces, pasteurize food and pharmaceuticals, and sterilize medical instruments and medical wastes;
- assessing hypersonic flow in wind tunnels for the Air Force;
- detecting land mines for the Army; and
- developing technologies to evaluate short-pulse, high-voltage aircraft wiring for the Federal Aviation Administration.

STRATEGIC OBJECTIVES AND INTERMEDIATE GOALS

Since we wrote our first strategic plan in 1990,[1] Sandia has been conscientious about aligning its values and strategic objectives with those of the National Nuclear Security Administration (NNSA)/DOE at the field office and headquarters level. The table that follows shows the alignment between Sandia's current strategic objectives and DOE Headquarters' current Strategic Plan.[2] We also align with other NNSA/DOE planning documents, such as the NNSA/DOE Albuquerque Operations Office Strategic Plan[3] and the NNSA/DOE Defense Programs "Green Book."[4]

Cooperative planning has benefited both Sandia and the NNSA/DOE. Sandia contributed to the DOE Laboratory Operations Board Missions Plan[5] and reviewed the DOE's Strategic Plan.

Sandia's annual planning process integrates and aligns all its planning elements. In response to suggestions to simplify and consolidate corporate plans and to synchronize planning, the Laboratory Leadership Team significantly revised corporate plans and planning processes in the spring of 1999. As a result, the corporate planning elements now consist of strategic objectives with a twenty-year horizon, intermediate goals covering a three- to fifteen-year period, and representative fiscal year milestones. At the organizational level, managers may use as many planning levels as they need and whatever horizons are appropriate. To balance long- and short-term planning, Sandia used a two-year planning cycle in FY 2000 and 2001. The first year used scenario planning to identify major trends affecting Sandia through 2015. The second year focused on steps Sandia will take in FY 2002 through 2004 to respond to those trends.

As a formally designated, federally funded research and development center, Sandia provides engineering and science for the security of our nation. To many Americans, national security has historically meant defense against foreign military threats. However, over time the threats to our nation have become increasingly varied and complex. Our security is now challenged from within as well as without; by economic as well as military action; by rogue groups as well as by foreign states; and by control of global distribution of energy, information, and other vital resources (infrastructures). Therefore, Sandia develops technology that responds to a wide range of national security threats. Most

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[1] *Strategic Plan 1990: Sandia National Laboratories.* SAND90-0562. 1990. Albuquerque, NM: Sandia National Laboratories.

[2] *U.S. Department of Energy Strategic Plan (Strength through Science: Powering the 21st Century).* 2000. Electronic files are available at http://www.cfo.doe.gov/stratmgt/plan/doesplan.htm. Page numbers refer to the hard copy printed from the pdf version.

[3] *U.S. Department of Energy Albuquerque Operations Office Strategic Plan: Fiscal Year 1997 Update.* 1997. Copies on file at US NNSA/AL, Albuquerque, NM.

[4] U.S. Department of Energy Stockpile Stewardship Plan: Second Annual Update (FY 1999). 1998.

[5] *Strategic Laboratory Missions Plan-Phase 1: Volume I and Volume II (Mission Activity Profiles).* Laboratory Operations Board, US DOE. 1996. Copies available from Office of Public Affairs, US DOE, 1000 Independence Avenue SW, Washington, DC (electronic version available at http://vm1.hqadmin.doe.gov:80/seab/aboutpln.html).

Alignment of Sandia and DOE Strategic Plans

Sandia Strategic Objectives	DOE Headquarters Strategic Plan Business Lines[a]
Nuclear Weapons Ensure that the nuclear weapons stockpile is safe, secure, reliable, affordable, and fully capable of supporting our nation's deterrence policy indefinitely.	"... maintain the safety, security, and reliability of the nation's nuclear weapons stockpile in the absence of underground nuclear testing." (page 5)
Nonproliferation and Materials Control Reduce the vulnerability of the United States to threats of proliferation and use of weapons of mass destruction, nuclear incidents, and environmental damage.	"... detect and help prevent the proliferation of materials, technology, and expertise related to nuclear, chemical, and biological weapons." (page 5)
Energy and Critical Infrastructure Enhance the surety (safety, security, and reliability) of energy and other critical infrastructures.	"... respond to the challenges of providing current and future generations with energy that is clean, efficient, reasonably priced, and reliable." (page 5) Protect the nation's infrastructure, which "... is more and more dependent on computer technology and telecommunications to provide vital services, such as those provided by the energy sector." (page 37)
Emerging Threats Develop high impact responses to emerging national security threats.	"... enhance national security through the military application of nuclear technology and by reducing global danger from weapons of mass destruction." (page 5)
People Inspire people to achieve excellence in their contribution to the Laboratories' mission.	"... identify critical hiring needs and strengthen our technical and management capabilities." (page 8)
Science and Technology Pursue "science with the mission in mind," thereby providing solutions and options for the customers of Sandia's current and future business units.	"Programs in the Science Business Line are the foundations for DOE's applied missions, a basis for US technological innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy." (page 5)
Infrastructure Provide necessary infrastructure for Sandia's mission by enabling individuals and organizations to succeed in conducting our business. This includes enabling Sandia's missions today and preparing to meet future mission needs, supporting Sandia's superb reputation as a national security laboratory, creating a physical and business environment that supports our world-class work force, and improving the overall cost effectiveness of mission work.	"The Department must ensure that it has the necessary skills available to carry out its critical missions, and it must begin the process of rebuilding a pipeline of skills for the future." "... facilities need to be upgraded, modernized, and maintained scrupulously." (page 8)
Partnerships Maximize our beneficial use of strategic partnerships to support Sandia's strategic business and management units.	"... ensure interagency cooperation, coordination, and crosscutting activities with other federal, state, and local agencies ...." (page 78)

[a] *U.S. Department of Energy Strategic Plan (Strength through Science: Powering the 21st Century).* 2000. Electronic files are available at http://www.cfo.doe.gov/stratmgt/plan/doesplan.htm. Page numbers refer to the hard copy printed from the pdf version.

often, we undertake national security assignments for our principal customer, the NNSA/DOE, and, as appropriate, for the DOD. We also apply Sandia's capabilities to specific needs of other federal agencies and private concerns. We remain alert to opportunities that could lead to technologies or new capabilities that meet our customers' needs and simultaneously enhance our ability to perform our national security mission.

Because Sandia's customers include some non-NNSA/DOE federal agencies, our plans include some non-NNSA/DOE goals and objectives that are consistent with our mission assignments and technology base. Because Sandia is an extremely diverse multiprogram laboratory, our strategic objectives, intermediate goals, and fiscal year milestones represent major efforts rather than individual programs.

The following sections identify the strategic objective and intermediate goals for each of our eight strategic areas. Sections 3.1 through 3.4 correspond to our market-focused strategic business units and address what we will accomplish. Crosswalks are included to match these sections with the program descriptions in chapter 6.

3.1 Nuclear Weapons: Our Primary Mission

Sandia will ensure that the nuclear weapons stockpile is safe, secure, reliable, affordable, and fully capable of supporting our nation's deterrence policy indefinitely. Our intermediate goals for this strategic objective are to

- nurture the critical capabilities required for the current and future needs of the stockpile while ensuring a balance between meeting near-term deliverables and maintaining a healthy science and technology base;
- deploy a stewardship program for critical capabilities required for the current and future stockpile that identifies required capabilities and evaluates investments and resource impacts;
- be the recognized national leader deploying information technologies in support of engineering design, modeling and simulation, science and technology, and stockpile maintenance, testing, and production for the Stockpile Stewardship Program;
- demonstrate leadership in the balanced refurbishment of the nuclear weapons stockpile;
- champion and support an advanced and exploratory systems program to enable weapon concepts and capabilities addressing new and evolving weapon needs;
- develop the Microsystems and Engineering Sciences Applications (MESA) complex to provide the nation with the essential facilities and capabilities necessary to assure that surety solutions are delivered to support the Stockpile Life Extension Plan schedule;
- attract, develop and retain exceptionally talented people to maintain the viability of the nuclear weapons stockpile indefinitely; and
- demonstrate exceptional performance in manufacturing low-volume, high-complexity, and high-consequence hardware for the nuclear weapons stockpile.

For descriptions of programmatic work related to this objective, see the following sections of chapter 6:

6.1.1 National Nuclear Security Administration's Office of the Deputy Administrator for Defense Programs
- 6.1.1.1 Directed Stockpile Work
- 6.1.1.2 Campaigns
- 6.1.1.3 Readiness in Technical Base and Facilities

6.3.4 Laboratory Directed Research and Development Program Results

3.2 Nonproliferation and Materials Control

Sandia will reduce the vulnerability of the United States to threats of proliferation and use of weapons of mass destruction, nuclear incidents, and environmental damage. Our goals for this strategic objective are to

- use satellite-based and other sensor technologies for early detection and characterization of proliferation activities;
- provide leadership for global nuclear management policies and technologies that will bring deterrence, nonproliferation, and nuclear energy into a constructive synergy for the twenty-first century;
- develop new technologies to protect the United States from chemical and biological threats; and
- expand Sandia's support for and reputation in the local, state, and federal law enforcement, security and response communities.

Descriptions of programmatic work related to this objective are provided in the following sections of chapter 6:

6.1.2 National Nuclear Security Administration's Office of Fissile Materials Disposition

6.1.3 National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation

6.3.4 Laboratory Directed Research and Development Program Results

3.3 Energy and Critical Infrastructure

Sandia will enhance the safety, security, and reliability of energy and other critical infrastructures. Our intermediate goals for this strategic objective are to

- develop models and technologies to support a US unified policy in all things nuclear, and to establish international leadership in nuclear policy and technology;
- develop technology to assure the safety, security, and reliability of the US infrastructure;
- become a global leader in applied repository systems;
- develop technologies that assure safe, secure, and sustainable access to fresh water in the United States and around the world; and
- sustain a core of science that supports energy programs.

Descriptions of programmatic work related to this objective are given in the following sections of chapter 6:

6.1.5 DOE's Assistant Secretary for Environmental Management
6.1.6 DOE's Assistant Secretary for Renewable Energy
6.1.7 DOE's Office of Civilian Radioactive Waste Management
6.1.8 DOE's Office of Nuclear Energy
6.1.9 DOE's Assistant Secretary for Fossil Energy
6.1.10 DOE's Office of Science Programs

3.4 Emerging Threats

Sandia will develop high-impact responses to emerging national security threats. Our intermediate goals for this strategic objective are to

- become by 2005 strategic partners of the DOD community (the DOD, related federal agencies, and their contractors) and jointly develop programs important to the DOD's mission success;
- develop business processes that are world-class in the DOD's eyes and lead to the successful execution of our projects; and
- contribute to Sandia's future excellence by developing business and executing programs that are synergistic with our technical base and add new or improve existing capabilities.

For descriptions of programmatic work related to this objective, see the following sections of chapter 6:

6.2 Work for Non-DOE Entities

To achieve the four strategic objectives above, Sandia will use the following four "how we will do it" strategic objectives that highlight our businesslike approaches. We will focus on internal improvements that integrate internal support with technical effort to meet our customers' needs.

3.5 People

Sandia will ensure a world-class work force. Our intermediate goals for this strategic objective are to

- enable work force planning so that we have the talent required to accomplish business objectives, today and in the future;
- attract and retain people who possess the attributes to be called a Sandian; and
- provide total rewards that are market-based and that are complementary to our unique mission.

3.6 Science and Technology

Sandia will pursue science with the mission in mind, thereby providing solutions and options for the customers of Sandia's current and future business units. Our intermediate goals for this strategic objective are to

- sustain a vibrant, creative research environment that generates breakthroughs that greatly enhance the opportunities for Sandia to serve the nation;
- develop integrated microsystems to provide safe, secure, reliable, and affordable components to enhance national security;
- enhance and integrate our modeling and simulation capabilities for engineering and manufacturing applications;
- discover, develop, and validate new techniques to assure predictable performance of complex systems; and
- ensure Sandia's role in the impending biotechnology revolution, and bring new capabilities to the laboratory for engineering complex systems.

3.7 Infrastructure

Sandia will enable mission work to flourish by providing a great work environment to enhance people's performance each day and by providing a governance system that engenders great work and ensures effective risk management. Our intermediate goals for this strategic objective are to

- develop and deploy a new system of services that is sufficiently agile, business-focused, and worth the cost to enable current and future critical missions; and
- develop and deploy a new Sandia governance system that cost-effectively manages core risks (programmatic, safety, security, environmental protection, reputation, and economic), that employees and stakeholders can believe in, and that increases credibility and self-governance.

3.8 Partnerships

Sandia will maximize our beneficial use of strategic partnerships to support Sandia's strategic business and management units. Our intermediate goals for this strategic objective are to

- establish partnerships with industry, universities, and other nonfederal entities as a "best practice" for all Sandia programs in accomplishing their missions;
- drive major innovations in US industry with mission-essential Sandia technologies;
- enhance mission success with an integrated national, regional, and local industrial partnerships program; and
- use international activities to establish Sandia leadership in the global community.

REPRESENTATIVE MILESTONES FOR FISCAL YEAR 2002

Milestones are a means of measuring Sandia's progress toward our goals in each strategic objective area. Sandia's FY 2002 milestones are based on our eight strategic objectives and their intermediate goals (see chapter 3) and on input from customers and stakeholders. As with the intermediate goals, these FY 2002 milestones are representative of major efforts rather than inclusive of all individual programs.

4.1 Milestones by Strategic Objective

These representative FY 2002 milestones are organized by strategic objective. Areas for which Sandia conducts a self-assessment for the annual DOE Laboratory Appraisal are indicated where applicable.

4.1.1 Nuclear Weapons

Our strategic objective is to ensure that the nuclear weapons stockpile is safe, secure, reliable, affordable, and fully capable of supporting our nation's deterrence policy indefinitely. Representative milestones are given below.

- Complete a pilot analysis of seven capabilities identified by the Program Director Leadership Team (PDLT) and required for the Nuclear Weapons Program, develop an investment strategy required to maintain these capabilities, and establish a process to implement this approach that is formally approved by the PDLT and Nuclear Weapons Leadership Council.
- In conjunction with the Chief Technical Officer, develop and begin implementing a strategy to balance projected increases of Laboratory Directed Research and Development (LDRD) funding with Nuclear Weapons Program funding to optimize the strategic benefit to the Nuclear Weapons Strategic Business Unit (SBU). Annually assess the LDRD program for relevance; develop and deploy a process for strategic investment of the increases in LDRD to benefit the Nuclear Weapons Program, and establish a Nuclear Weapons SBU process to implement this approach. Develop a funding plan for FY 2003 and beyond that is formally approved by the Program Director Leadership Team and the Nuclear Weapons Leadership Council.
- Develop a vision and architecture for the Nuclear Weapons Information Environment and a five-year implementation plan.
- Place a contract in FY 2002 for the Red Storm 20-teraflops computing platform consistent with delivery, installation, and initial support of critical Stockpile Stewardship Program modeling and simulation activities in FY 2003.

- Complete preliminary design activities for the W76-1 portion of the Stockpile Life Extension Program.
- Complete the W80-2,3 Preliminary Weapon Development Report and submit it for DOE/DOD Design Review Acceptance Committee review and approval.
- Establish a systematic approach for a balanced program that supports future changes in US defense policy and demonstrates key concepts, and demonstrate advanced telemetry and system technologies on the IDF-3.
- Provide all materials necessary for the Microsystems and Engineering Sciences Applications (MESA) complex to establish a formal project base line, complete Title II engineering, support the National Nuclear Security Administration in obtaining the critical decision to begin construction, and complete the Microelectronics Development Laboratory systems upgrades and MESA complex utilities.
- Use detailed planning data to stimulate a robust, targeted hiring program that ensures the readiness of talent with the critical skills necessary to support future customer deliverables; track progress against hiring goals, analyze retirement and turnover data for trends, and take appropriate actions to address loss of critical skills.
- Qualify the MC4368 neutron generator subcomponent and achieve a capacity of eighty tubes delivered to inventory per month.

Sandia completed this conceptual design for the Microsystems and Engineering Sciences Applications (MESA) complex. The MESA complex supports Sandia's nuclear weapons strategic objective.

4.1.2 Nonproliferation and Materials Control

Our strategic objective is to reduce the vulnerability of the United States to the proliferation and use of weapons of mass destruction, nuclear incidents, and environmental damage. Representative milestones are given below.

- Demonstrate and test the advanced unmanned aerospace vehicle remote-sensing applications (AURA) light detection and ranging (lidar) sensor in two field test operations at Dugway Proving Ground, Utah.
- Finalize designs and initiate development of the particulate sampling system for the Advanced Atmospheric Research Equipment.
- Establish a Defense Threat Reduction Agency-funded project to begin analysis and implementation of physical protection upgrades at military sites in Russia.
- Complete the initial field trials at Porton Down and in the PROTECT testbed of the Microchemlab™ chemical/biological system.
- Improve and validate our general-purpose computational tools for modeling agent release in public facilities to include heating, ventilating, and air-conditioning and leak-path effects.
- Establish a funded program from the Defense Nuclear Security Office of the National Nuclear Security Administration (NNSA) for Sandia to serve as Security Systems Engineer for the NNSA.
- Deliver the Operation America national-level advanced bomb disablement technology transfer program for local, state, and federal bomb squad personnel throughout the US and select foreign governments.

4.1.3 Energy and Critical Infrastructure

Our strategic objective is to enhance the surety (safety, security, and reliability) of energy and other critical infrastructures. Representative milestones are given below.

- Complete, demonstrate, and validate the Global Nuclear Futures model with key government and university stakeholders.
- Develop an agent-based model of the interdependencies among electric power, telecommunications, and the US economy.
- Increase Sandia revenues from Hanford by 20 percent.

- Receive a minimum of $1 million in funding from at least two US agencies with major responsibilities for water management in the United States and/or international transboundary regions.
- Secure funding in support of Center for Integrated Nanotechnologies construction.

4.1.4 Emerging Threats

Our strategic objective is to develop high-impact responses to emerging national security threats. Representative milestones are given below.

- Develop a comprehensive strategic plan that includes a long-term view of our DOD customers, the Corporate Integrating Initiatives, industrial relationships, staffing, investment, relationships with the other strategic business and management units, and revenue.
- Identify three to five new potential strategic partnerships within the DOD; identify the needed program development, and start it.
- Develop an overarching approach to quality consistent with our DOD customer requirements—as well as those of the National Nuclear Security Administration, the DOE, and Sandia.
- Develop a process for Laboratory Directed Research and Development investment that supports becoming strategic partners of the DOD, related federal agencies, and their contractors—and jointly develops programs important to the DOD's mission success (ET02-1).
- Review "Complementary Work Supporting the National Nuclear Security Administration Mission"[1] and work with Sandia Executive Management toward implementation of key recommendations from the report that support ET02-1.
- Based on the completed strategic plan, develop a multi-year technology roadmap that will be useful in describing Emerging Threats needs to Sandia's science and technology.
- Complete FY 2002 key programmatic deliverables in applications of collectives and intelligent systems, advanced sensors, aerospace and target defeat, chemical/biological decontamination foam, combating terrorism, counterproliferation, and demilitarization.

4.1.5 People

Our strategic objective is to inspire employees to achieve excellence in their contribution to Sandia's mission. Representative milestones are given below.

- Develop and implement web-based tools for the line to use in preparing the FY 2003 staffing plan analysis, including five-year staffing projections.
- By September 2002 implement aggressive and strategic recruiting, campus partnership, and student internship programs that achieve the corporate staffing goals identified in the FY 2002 Staffing Plan.
- Develop and implement changes to the Retirement Income Plan by January 2002.
- Design and implement revisions to our health care plans that manage costs and expand employee options by January 2002.

4.1.6 Science and Technology

Our strategic objective is to pursue science with the mission in mind to provide solutions and options for customers of Sandia's strategic business units. Representative milestones are given below.

- Using a blue-ribbon external advisory committee, review the Science and Technology Strategic Management Unit to evaluate program performance and the quality of Sandia's research and development portfolio, thus augmenting the current set of individual area reviews.
- Use the results of the Advanced Manufacturing Automatic Design of Practical Fixtures project to implement a design review process for neutron generator tooling that includes tolerance stack-up optimization analysis.
- Complete small-scale multiaxial experiments to determine the role of microstructural evolution in solder damage during thermomechanical fatigue.
- Complete high-voltage electrode testing and compare high-voltage electron emission rates from surfaces with electron, ion, and conventional chemical/mechanical treatments.
- Demonstrate ion-beam thin-film processing relevant to neutron tube processing requirements.
- Determine the structure of a test membrane protein using a combined experimental/theoretical approach based on chemical crosslinking, mass spectrometry, and three-dimensional protein structure modeling.

[1] *Complementary Work Supporting the National Nuclear Security Administration Mission: Implementing a Strategy for Maintaining the U.S. Nuclear Weapons Complex Mission-Critical Skills, Core Competencies, and Infrastructure.* Defense Programs Self-Assessment Team. 2001.

4.1.7 Infrastructure

Our strategic objective is to provide necessary infrastructure for Sandia's mission work by enabling individuals and organizations to be optimally successful in conducting business. This effort includes enabling Sandia's missions today and preparing to meet future mission needs, supporting Sandia's superb reputation as a national security laboratory, creating a physical and business environment that empowers our world-class work force, and improving the overall cost effectiveness of mission work. Representative milestones are given below.

- Take appropriate action(s) to implement the August 2001 decision on infrastructure design.
- Implement a new internal governance system by September 30, 2002, aimed at allowing us to achieve consistent and cost-effective integrated risk management, integrated performance management, and business rule.

4.1.8 Partnerships

Our strategic objective is to maximize use of strategic partnerships to support Sandia's strategic business units and strategic management units. Representative milestones are given below.

- Use a Lockheed Martin corporate commitment to double the Lockheed Martin/Sandia Shared Vision Program in FY 2002 in order to develop technologies critical to Sandia and Lockheed Martin missions and to enhance DOE and DOD programs.
- In conjunction with the DOE and National Nuclear Security Administration (NNSA), create a Partnerships vision and strategy, and identify advocates/sponsors in the Secretary of Energy's office and the NNSA Administrator's office.
- Negotiate agreements with two commercialization agents and take equity positions in at least one spin-out company with each, based on Sandia mission-essential technologies.
- Identify strategic partners and establish agent representation in key Pacific Rim markets, leading to an increase of funds-in of more than 33 percent. Support DOE (nuclear waste) and DOD (Singapore naval port) priorities in the Pacific Rim.

4.2 Crosscutting Milestones

The representative milestones given below encompass more than one strategic area.

- Achieve total Sandia FY 2002 operating and capital equipment revenue and FY 2002 construction revenue projected by the strategic business units and the strategic management units.
- Meet or exceed our commitments for orders, sales, earnings before income taxes, cash generated, and total business returns.

4.3 Continuous Improvement

Sandia's strategic objectives and intermediate goals and representative milestones will change if funding or requirements change. The information that appears in chapters 3 and 4 will be modified as necessary on Sandia's internal web.

Every spring Sandia reviews and modifies our planning elements, striving to align more closely with current customers and future national security needs. Every summer we establish milestones for the following fiscal year and use line-of-sight mechanisms to communicate these milestones to all Sandians for their annual performance management. Every quarter we review progress on representative fiscal year milestones and, as requested, report to stakeholders such as Lockheed Martin and the DOE.

We continuously improve our planning process to maximize mission success. A critical part of continuous improvement is the self-assessment of management processes under the annual DOE appraisal agreement.

SANDIA ACCOMPLISHMENTS FOR FISCAL YEAR 2001

The accomplishments described in this chapter were considered completed as of September 30, 2001.

5.1 Nuclear Weapons

Sandia's nuclear weapons program ensures that the nuclear weapons stockpile is safe, secure, reliable, and fully capable of supporting our nation's deterrence policy.

The Nuclear Weapons Strategic Business Unit (SBU) developed and deployed its Quality Management System and Policy for organizations that perform work for the SBU. The management system is based on the International Organization for Standardization set of quality guidelines.

The Nuclear Weapons Leadership Council authorized initiation of the W76 Life Extension Program. This concluded a multi-year effort to assess the warhead state-of-health, develop refurbishment options, and generate management processes and plans to meet aggressive requirements. The conceptual design incorporates new performance options, implements technical innovations, and employs new modeling and simulation tools. Sandia will meticulously follow requirements and design options, reuse selected components, incorporate high-grade commercial electronic parts, streamline production and qualification processes, and rigorously manage risk.

Sandia worked with the Kansas City Plant to design and build two prototype firing sets for the W76 Arming, Fuzing, and Firing Life Extension Program. We used simulation and rapid prototyping to evaluate and solve a variety of design and manufacturing issues while moving from paper designs to hardware in less than a year.

The W76-0/Mark 4 became the first enduring stockpile weapon to complete the DOE Seamless Safety Process for disassembly and inspection operations at the Pantex Plant in Amarillo, Texas. We developed new tooling, new procedures, a weapon safety specification, a hazards analysis, and hazards controls. The Pantex Plant provided essential information about weapon reliability.

For the W76/Mark 4 reentry body, Sandia completed the most detailed structural dynamic model validation experiments ever performed on a nuclear weapon system. These experiments identified modes of vibration as high as 1,000 hertz for the reentry body and each major subassembly. The test series discovered significant unit-to-unit variability for frequencies above 1,000 hertz. Data will be critical to the validation of high-fidelity models that mimic the nonlinear behavior of real weapon structures.

The Stockpile Life Extension Program selection was made for Phase 6.3 of the Navy's W76/Mark 4A. A Sandia independent Weapon Assessment Team reviewed the warhead candidates for quality, reliability, nuclear safety, stockpile surveillance, and security/use control attributes and effectiveness. The Weapon Assessment Team recommended the Mark 4A as a viable design that enhances reliability over the weapon's extended lifetime and provides

nuclear safety and significant use control enhancements to the present W76 design.

The redesigned W76 joint test assembly telemetry system was used in a reentry body launched from a submarine in a successful evaluation test. Advancements in space radiation tolerance were proven, as was the efficacy of the modular telemetry design. This design was the first to use digitization and transmission of neutron and firing system waveforms. This instrumentation system has ten times the data rate of the original, and production costs are significantly less.

We are developing the in situ impregnated gel capacitor for use in firing sets for the Stockpile Life Extension Program. The gel capacitor is less than half the volume of the old capacitor used in most firing sets in the enduring stockpile. The gel capacitor also is about one tenth the cost of the old capacitor.

We completed reliability and data credibility probability analyses for the redesigned W76 Type 2F telemetry and B61-7/11 systems. Both studies used a new methodology for estimating the reliability of commercial parts, as well as software that allowed examination of key contributors to unreliability. A report documenting the results of these studies included a complete description of the general methodology for analyzing instrumentation systems.

The MC4380 Neutron Generator was qualified for the W76-0, meeting a major corporate milestone. This work showed for the first time that Sandia can design and qualify a component to survive strategic radiation environments without underground testing. We also established a new Neutron Generator Production Facility and showed we can reliably produce neutron generators for the stockpile.

Sandia's redesigned W76 telemetry system has ten times the data rate of the original and costs less to produce.

Sandia partnered with Honeywell to purchase neutron generator components, meeting DOE requirements for supplier quality. The rate of parts accepted increased from 80 percent to 96 percent, and the rate of trouble-free accepted parts increased from 62 percent to 86 percent.

Sandia received the DOE Weapons Award of Excellence for support of the Stockpile Stewardship Program. Our Concurrent Design and Manufacturing Program components were delivered within budget, with 100 percent product acceptance and all schedule changes met. We delivered 3,700 components with more than thirty one different classes of designs using seven different technologies.

Sandia contributed to the successful completion of the Phase 6.2/6.2A study for the W80 Life Extension Program. The Nuclear Weapons Council accepted the study team's recommendations and approved Phase 6.3, with a first production unit date of February 2006. The W80 Phase 6.3 is a significant effort for Sandia—requiring new designs for the entire warhead electrical system, neutron generators, gas transfer system, and several new mechanical structural components.

Sandia's Security Matrix Project provided an integrated assessment of weapon security and use control. Team members visited all US sites where weapons are held and analyzed locations, weapon configurations, site infrastructure, and physical and operational security. The study played a significant role in the W80 Life Extension Program and led to changes in Air Force security posture, Navy and Marine Corps security capabilities, and overall DOD security requirements.

Sandia and Los Alamos national laboratories used modern predictive analyses coupled with limited field testing to certify the B61 Alt 349 weapon design for stockpile use. The Design Review and Acceptance Group recommended the design as a standard stockpile item to the Nuclear Weapons Council Standing and Safety Committee in December 2000.

Sandia designed and tested a replacement digital application-specific integrated circuit microcontroller used in a specific B61 configuration. During testing, a problem was discovered with the memory at cold temperatures. A failure analysis team worked for two months to pinpoint the problem. The wafers in process were stopped at the silicide stage (before metal contacts were made) to accommodate a change in metal routing, and new masks were ordered to process the lots on hold. The design fix was proved in November 2000.

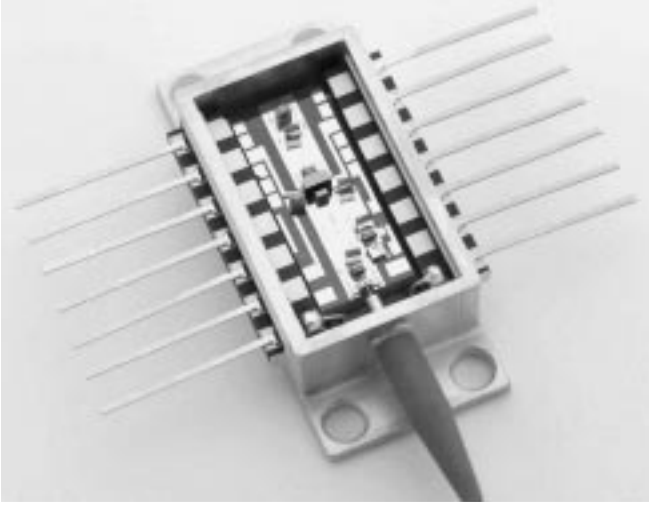
Sandia's Manufacturing Development Engineering Program is a model for manufacturing low-volume, high-reliability parts for the nuclear weapons complex. Since the program's inception in 1992, we have delivered more than 40,000 components for the enduring stockpile. More than 6,400 parts were manufactured by twelve private sector companies that partnered with Sandia in this critical nuclear weapons program. Products manufactured include actuators, thermal batteries, igniters, gas generators, capacitors, frequency devices, and electronic components.

Sandia's Manufacturing Development Engineering Program developed a much more robust high-voltage power transformer for use in firing sets for several weapon systems in the enduring stockpile. The original transformers had relatively low yields due to cracked encapsulation around and in the core and/or separation between the contact assembly and encapsulation. Design improvements included a stress barrier between the core and the epoxy encapsulant and elimination of the contact assembly. More than 250 redesigned War Reserve transformers have been produced.

As the stockpile ages and electronic components degrade, Sandia's Manufacturing Development Engineering Program designs and validates new War Reserve quality components many generations ahead of the old ones. These new technologies are far more reliable and many times lighter and smaller than the old ones. We developed an analog application-specific integrated circuit used in an encryption translator. The chip-sized integrated circuit replaces a much larger printed-wiring board.

We completed the conceptual design for Sandia's Microsystems and Engineering Sciences Applications (MESA) complex. After the final Conceptual Design Report was printed and distributed, funds were authorized to start the next phase (Title I/II Design). The National Nuclear Security Administration's investment in the MESA complex will create Sandia technological capabilities to meet near-term and future mission needs for nuclear weapons.

Sandia's Advanced Firing and Detonation Systems and Microsystems Advanced and Exploratory projects demonstrated a wide range of new technologies for firing system applications in nuclear weapon refurbishment and DOD fuzing options. Technologies included surface micromachine and LIGA (an acronym from the German for lithography, electroplating, and molding) stronglinks; direct optical initiation firing sets and micro-direct-optical-initiation concepts; optical charging and triggering of capacitive discharge units; and technologies necessary for microfiring sets. Several demonstration units were fabricated in partnership with the Kansas City Plant.



Sandia used LIGA microfabrication technology to produce the photonic subsystems in this optical module.

Sandia and the DOD implemented an upgraded reporting system for nuclear weapons, ancillary equipment, and publications. This Workflow Enabled Unsatisfactory Reports System yielded dramatic improvement and the DOE Albuquerque Operations Office recognized this effort with a Performance Excellence Award (Silver Medal).

The DOE National Nuclear Security Administration Office of Transportation Safeguards must meet the highest security standards because its mission is critical to the effective operations of the nuclear weapons complex. Sandia was responsible for four of six milestones required to obtain acceptable security ratings and ensure uninterrupted operation of the transportation fleet. Sandia met all milestones and the Office of Transportation Safeguards security rating was upgraded.

Sandia and Lawrence Livermore national laboratories collaborated with Lockheed Martin to design and flight-test a warhead concept under the Submarine-Launched Warhead Protection Program Pit Reuse Project. Warheads presently deployed by the US Navy were designed and certified prior to cessation of underground nuclear testing and the closure of major DOE weapons component facilities. The Pit Reuse Project investigated potential replacement options, although no stockpile hardware is planned.

Sandia's organic hydrogen getters, which scavenge unwanted hydrogen in nuclear weapons, have been refined, patented, and commercialized via a cooperative research and development agreement with Vacuum Energy Inc. Our hydrogen reduction technologies are now used in consumer and industrial products such as flashlights, refrigerators, and heat exchangers. These advanced getters, created for consumer markets, are being certified for the shipment of radioactive materials within the nuclear weapons complex.

We completed an assessment of Sandia's current and long-term equipment recapitalization needs for facilities that support the National Nuclear Security Administration's mission. We developed a methodology to assess needs based on different levels of future capability for each facility and to estimate associated costs.

5.2 Nonproliferation and Materials Control

Sandia is reducing US vulnerability to threats from proliferation, weapons of mass destruction, nuclear incidents, and environmental damage. Our strategy uses innovative technology and techniques to find practical solutions.

A Sandia-led Chemical Defense Assessment Team was formed at the direction of General Eugene Habiger to study defenses against the use of lethal chemical agents on people guarding special nuclear material (SNM) at DOE sites. This team assessed three of the most critical sites and wrote A Guide to Defending SNM Facilities Against Chemical Attacks.

Russia's Mayak Production Association stores large quantities (approximately 100 metric tons) of plutonium and uranium for weapon and civilian uses. The National Nuclear Security Administration Materials Protection, Control, and Accounting Program provided an initial design for large steel-clad, steel-reinforced concrete blocks to cover canisters of plutonium dioxide, which would increase the time for an enemy to gain access. An agreement was signed that initiates security upgrades at another of Mayak's plants in which extremely large quantities of weapons-grade plutonium and uranium are processed and stored.

US/Russian arms reduction treaties require verification that nuclear materials from dismantled weapons are not returned to weapons use. The Trilateral Initiative of the United States, Russian Federation, and International Atomic Energy Agency is developing a model verification agreement and exploring verification technologies. Sandia provides a senior technical advisor and leads a group of technical experts for the US delegation to develop inventory monitoring and verification approaches acceptable to all parties.

Sandia's Cooperative Monitoring Center is collaborating with nuclear physics institutes in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan on a waterborne radionuclide monitoring experiment for the major rivers in Central Asia. Since the breakup of the Soviet Union, these countries have taken independent courses, so cooperation on any issue has been extremely difficult. These republics contributed greatly to the Soviet nuclear weapons program—from uranium mining and processing to nuclear weapons testing.

Sandia delivered Release 4.0 of the Nuclear Explosion Monitoring Knowledge Base to the US National Data Center. This knowledge base improves the ability of the National Data Center to detect, locate, and identify clandestine nuclear tests by providing detailed information about the earth's structure and signal propagation characteristics.

We designed, fabricated, and demonstrated prototypes of two portable chemical analysis systems to rapidly detect and analyze toxic agents that might be released by terrorists. These prototypes were tested (with chemicals and biotoxins) and detected specific agents in very short times. Furthermore, these systems are not affected by common chemicals that might interfere with detection.

Sandia's newly developed Hound™ is a portable sampling/preconcentration system fitted to a commercial portable detector to improve sampling efficiency. The Hound system is a direct development from the explosives detection portal that Sandia developed for the Federal Aviation Administration. The explosives detection portal and the Hound can detect faint odors (parts per trillion) of explosives and other chemicals.

Representatives from India and Pakistan met at Sandia's Cooperative Monitoring Center (CMC) to discuss issues of common regional concern. Data from a CMC-sponsored water quality project were shared among India, Pakistan, Nepal, Bangladesh, and Sri Lanka. Visiting scholars from India, Pakistan, and the United States published papers on South Asian nuclear doctrines and agreements, the potential for regional naval cooperation, and border security.

The Advanced Modular Tag is a miniature, low-probability-of-detection, low-probability-of-intercept communication and tracking device for use by special operations and other DOD forces. Sandia has teamed with Lockheed Martin to conduct this work, which is funded by the Air Force Space Warfare Center. The Advanced Modular Tag successfully passed a critical series of laboratory and field tests required for full certification and use with US assets.

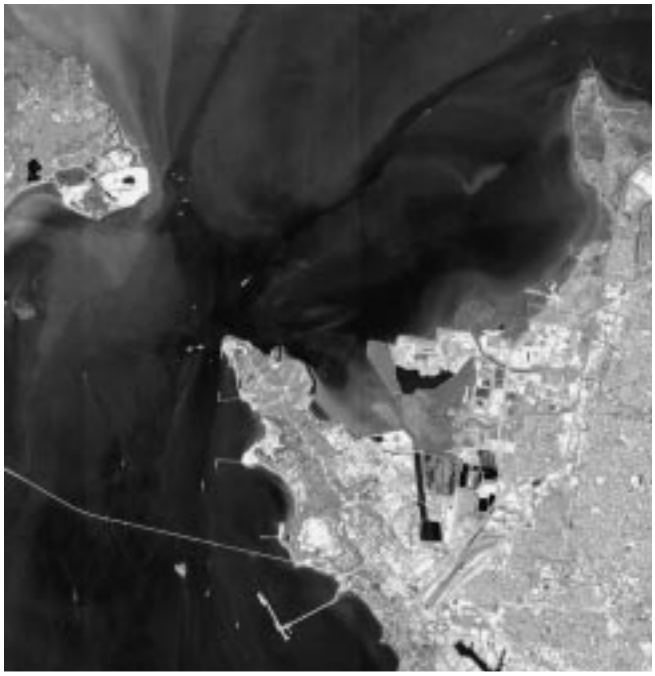
The Operation America Program focuses on advanced technologies to disable complex terrorist devices. Sandians are involved in the series of five-day workshops, each hosted by a different US city and involving bomb technicians from the surrounding region.

Sandia supports the National Nuclear Security Administration's Advanced Ultraviolet Remote-Sensing Applications (AURA) Program, which completed a successful engineering flight test at Dugway Proving Grounds in Utah. The AURA, an advanced ultraviolet laser-induced fluorescence light detecting and ranging (lidar) payload, was installed in the Altus Unmanned Aerospace Vehicle and completed six successful flights. A second flight test in September 2001

Sandia's portable Hound™ sampling/preconcentration system can detect explosives and chemicals at levels of parts per trillion.

demonstrated the detection of effluents from weapons of mass destruction.

The US Air Force launched the Multispectral Thermal Imager (MTI) satellite into polar orbit. The MTI is a Sandia-led, multilaboratory research and development project sponsored by the National Nuclear Security Administration's Office of Nonproliferation and National Security. The MTI will develop, demonstrate, and evaluate multispectral and thermal imaging technologies for a broad range of national security applications.



This image from Sandia's Multispectral Thermal Imager satellite shows the San Rafael bridge north of Oakland and San Francisco, California.

Sandia developed an improved method for evaluating the performance of an inter-satellite communications system used by the constellation of Global Positioning System (GPS) satellites. The method collected large amounts of data without significantly impacting either space or ground operations and provided new insights into possible error sources. This work led to the development of new error-reduction techniques and influenced the design of future GPS satellites.

5.3 Energy and Critical Infrastructure

Sandia supports a number of projects that enhance the surety (safety, security, and reliability) of energy and other critical infrastructures.

5.3.1 Energy

The safety of high-power lithium-ion batteries used in hybrid electric vehicles and the National Aeronautics and Space Administration Space Shuttle is of key importance. If not controlled, thermal runaway in lithium-ion cells can have serious safety implications. Sandia has identified the mechanism of thermal runaway. This improved understanding of the reaction sequence will enable researchers to investigate the chemical mechanisms responsible for thermal abuse intolerance, mitigate these effects, and substantially improve the operational safety of batteries for these applications.

Sandia integrated a fuel cell power system with a robotic vehicle. The fuel cell combines hydrogen and oxygen at a low temperature without combustion to produce high-efficiency electricity. The fuel cell offers a much greater operational range than the batteries presently used.

Sandia overpressurized to failure a quarter-scale model of a Japanese nuclear reactor's prestressed concrete containment vessel. The model, tested for the US Nuclear Regulatory Commission and Japan's Nuclear Power Electric Company, initially leaked at 2.5 times the design pressure. The data from approximately 1,500 sensors will be used by an international team of experts as benchmarks for structural analysis codes and will aid the development of new accident-response models.

Sandia led an extremely aggressive project to develop, integrate, and test a dish/Stirling solar power generation system. We used the best advanced technologies and demonstrated unattended operation of the prototype system. The system met all performance objectives.

Rock compaction resulting from oil extraction can cause severe borehole damage, sometimes resulting in expensive well abandonment and replacement drilling. With funding from the DOE, Chevron, and Aera Energy, Sandia developed a methodology for understanding the failure potential of wells in diatomite reservoirs. The methodology used three-dimensional coupled reservoir flow geomechanical simulations to predict the impact of different well drilling patterns and water flooding on well integrity in weak rock formations. The industry partners incorporated the Sandia technique into their reservoir management practices.

Sandia developed a new way to safely, simply, and effectively connect electricity-producing photovoltaic solar systems to utility company power grids. This Underwriters Laboratories-certified control method automatically diverts or turns off electricity flow from grid-connected photovoltaic systems when an electric distribution line shuts down.

In situ sulfur dioxide measurements are required to address long-standing uncertainties about the influence of fossil fuel combustion emissions on local, regional, and global scales. Sandia recently developed a laser-induced fluorescence detection scheme for sulfur dioxide that has the requisite sensitivity (parts per trillion) for measurements throughout

the atmosphere. A prototype sensor has been used for ambient sulfur dioxide measurements, and a compact ultraviolet laser system is being developed for use in field studies.

Sandia has significantly improved the understanding of soot formation in diesel engines, the most efficient engine option available for transportation. The amount of fuel/air premixing upstream of the initial flame location on a diesel spray plays a pivotal role in the amount of soot formed. This research is providing insight into the ways that parameters such as injection pressure, orifice diameter, turbocharging, and intercooling impact soot formation.

Each year US industries spend enormous sums combating gas leaks. Sandia developed a portable instrument that makes video movies of gas plumes. An infrared laser illuminates the area and the gas becomes visible as it absorbs the laser light. The instrument's small size is a result of newly developed laser materials and a high-power fiber amplifier. The technology is being evaluated by the Environmental Protection Agency.

5.3.2 Critical Infrastructure

Sandia completed a two-year project with Lockheed Martin when a radioactive waste processing facility at the Zvezdochka Shipyard in Severodvinsk, Russia was commissioned. A similar facility will be commissioned at the Zvezda Shipyard in Bolshoi Kamen, Russia. These facilities support Russian submarine dismantlement, funded by the US Defense Threat Reduction Agency. Sandia technical staff led the design, construction, and licensing efforts.

Sandia recently released version 1.8.5 of the MELCOR code, a software developed for the Nuclear Regulatory Agency that incorporates more than twenty years of research into severe accident behavior. The MELCOR code models the progression of a severe accident in a nuclear power plant and the potential release of fission products from the site. MELCOR version 1.8.5, a significant advance over previous versions, was distributed to more than forty foreign and domestic users for plant safety and licensing studies.

Sandia's nuclear power plant fire safety research continues to receive industry and customer praise. Nuclear Regulatory Commission-sponsored programs include assessing the impact of fire-induced cable faults on power, control, and instrument circuits; review of worldwide nuclear plant fires; and plant fire safety inspections. These programs are developing risk-informed regulatory standards and policy designed to maintain high levels of safety while eliminating requirements marginal to risk.

Sandia's Advanced Information Systems Laboratory developed an innovative approach to computer security that uses intelligent agents for a dynamic defense. This work will significantly impact Sandia's national security mission and the multibillion-dollar cyber security industry. We recognized the need for a paradigm shift in information security practices to meet next-generation internet security threats and developed the Standard Agent Architecture II "agent-in-a-box."

Following two years of planning, chemical/biological simulants were released at a major US international airport to characterize the response of the facility to terrorist attacks. The experiments were a major milestone under the Domestic Demonstration and Application Program, which is intended to demonstrate that Sandia technologies can address emerging chemical/biological threats to critical national infrastructure.

Sandians Joe Jones (left) and Joe Saloio (right) are shown with Oleg Pazhukin of the Russian Design Institute at the Zvezdochka Shipyard in Severodvinsk, Russia. The three are standing near sorbent columns at a radioactive waste processing facility that supports Russian submarine dismantlement.

Sandia completed *Reexamination of Spent Fuel Shipment Risk Estimates* (NUREG/CR-6672), which provides much more accurate estimates of risks in transporting spent nuclear fuel. This report is being used to revise the Yucca Mountain Draft Environmental Impact Statement and will become a common reference for regulators, users, and the public. By matching accident statistics and accident conditions, and modeling cask and fuel response to those accident conditions, transportation accident dose risks were shown in NUREG/CR-6672 to be three to four orders of magnitude smaller than those reported in the Nuclear Regulatory Commission's current environmental impact statement for radioactive material transportation (NUREG-0170).

We completed a performance assessment on disposing transuranic waste at the Nevada Test Site. The assessment documents ten years of site studies, system characterization, development of conceptual and mathematical models, ranges of defensible input parameters, and the final demonstration of compliance with Environmental Protection Agency standards. The Greater Confinement Disposal configuration is ideal for isolating radioactive wastes in arid settings.

5.4 Emerging Threats

Sandia's emerging threats technology provides advanced solutions for the DOD and other entities to defend the nation against weapons of mass destruction, defeat hardened and deeply buried targets, combat terrorism, and support related missions. Sandians serve on numerous committees and commissions that support the DOD and related national security entities.

Sandia established major programs in conjunction with other companies in the broad area of maintenance of weapons systems. We partnered with Lockheed Martin on enterprise modeling and health monitoring for the Joint Strike Fighter and the F-16; with Raytheon in service life extension for the advanced Cruise Missile and predictive reliability/maintenance for the Future Combat System; with the Defense Advanced Research Projects Agency in predictive reliability/ maintenance and health monitoring for the Joint Virtual Battlespace; with the Air Force in supply chain management and spares optimization for the F-22; and with the Army in predictive reliability and retrofit optimization for the Apache helicopter.

With funding from the Defense Advanced Research Projects Agency, Sandia developed a hopping machine that may soon give robots unprecedented mobility for gathering war-fighting intelligence, assisting police during standoff or surveillance operations, and exploring other planets. Most mobile robots are presently designed to steer directly to one spot and require expensive and complicated control systems.

Sandia's Rapid Terrain Visualization Interferometric Synthetic Aperture Radar is a terrain-mapping radar that produces elevation maps accurate within 0.5 meter. This system provides the Army with two-hour mapping for battlefield visualization in regions of conflict. Rapid terrain visualization is the first radar to demonstrate these capabilities.

Gathering and transmitting measurements during explosions is difficult. Sandia successfully flight-tested a 33-megabits-per-second, 16-symbol quadrature-amplitude-modulation, high-explosive radio telemetry system that collected and transmitted data during a high-explosive detonation. The primary benefit of quadrature amplitude modulation is bandwidth reduction. To transmit at 33 megabits per second, this system requires a 10-megahertz bandwidth. Conventional telemetry uses more than 35 megabits per second.

The first explosives destruction system designed, fabricated, and quality-tested by Sandia for the US Army Non-Stockpile Chemical Materiél Program closed a campaign of engineering development tests at the Defence Evaluation and Research Agency facility in Porton Down, England. World

Sandia and Lockheed Martin partnered to model and prototype the Joint Strike Fighter, which will be used by the US Air Force, Navy, and Marines.

War I mortar shells and artillery projectiles (seven filled with phosgene gas and twelve with mustard gas) were destroyed, along with a container filled with more than a pound of Sarin nerve agent. The chemical agents were destroyed below detectable limits.

Sandia completed work on two royalty-bearing license agreements to commercialize our decontamination formulation for chemical and biological weapons agents. The formulation can be deployed as a foam, fog, spray, mist, or liquid and is nontoxic to humans. Two separate companies obtained nonexclusive rights under agreements that allow them to supply emergency responders with technology to mitigate the effects of a chemical or biological attack. Part of the royalty and fee revenues will support future Sandia research and development.

We developed the laser dynamic range imager sensor for the National Aeronautics and Space Administration's Johnson Space Center, which provided the funding. The sensor, which captures three-dimensional images at a rate of 7.5 hertz, was delivered to the Kennedy Space Center and installed on the *Endeavor* space shuttle. The sensor was successfully demonstrated during a shuttle mission.

Sandia's Short-Pulse Laser Program secured a DOD funding increase of roughly 50 percent for FY 2001. The program developed the world's first laser techniques to create, sustain, and control 50-femtosecond optical bullets. The program achieved world-record propagation distances and demonstrated new phenomena in laboratory and field trials.

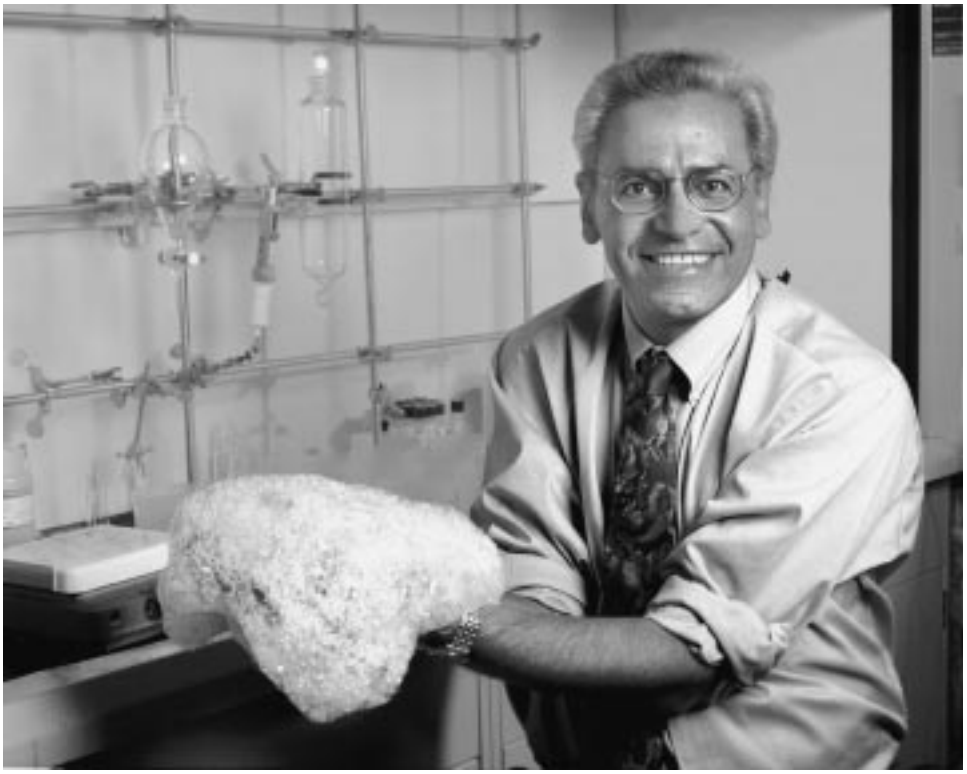
Sandia's Information Design Assurance Red Team continued to analyze advanced information systems for the Defense Advanced Research Projects Agency. Major accomplishments included the definition and characterization of adversary models, which ranged in sophistication from novice to foreign intelligence, and the development of a training curriculum for the Information Design Assurance Red Team.

5.5 People

Sandia hires the "best of the best." We are a flexible organization that develops leaders and managers in an environment that supports daily and long-term operations, creative work, high-performance teams, customer focus, and high-quality work.

Sandia executed a "fee and scope" amendment to our prime contract. The amendment enables a stable flow of fee, which is used to compensate our corporate parent for its many valuable contributions to the Sandia mission. The amendment also will pay for Sandia expenses that are unallowable under our prime contract.

We developed a Congressional Issues Document that contains a set of well-defined, prioritized issues whose resolution is critical to Sandia's success. The document conveys a uniform and effective Washington DC strategy that will ensure Sandia is properly positioned to help resolve issues of importance to national security.



Sandian Maher Tadros is shown with his decontamination foam, which can neutralize both chemical and biological agents without harming humans.

Our Information Technology/Computer Science Retraining Program is a fast-track, Sandia-wide program. The program responds to increasing demands for critical information technology and computer science skills; hiring limitations; a competitive external market; and Sandia's commitment to career development.

Sandia renovated the Building 861 cafeteria in half the normal time required for a project of this magnitude. The upgrade ensured compliance with safety and code requirements, reduced maintenance costs, created a more efficient flow of traffic as requested by customers, improved the ambiance in the dining area, and enhanced the quality of time spent there.

More than one hundred female managers attended a one-day conference on Creating a Woman-Friendly Culture at Sandia. The conference provided a forum to share experiences and make workplace recommendations. Sandia's first Technical Women of the Future luncheon was held for summer and year-round interns. The luncheon encouraged female interns to pursue degrees in science, math, engineering, and technology—and provided an overview of Sandia's philosophy and practices.

Sandia's pension plan benefits were enhanced for retirees and surviving spouses, effective October 1, 2000. Benefits were increased from 3 percent to 18 percent for eligible participants, and minimum pensions were approved.

Sandia implemented an alternative to the rule that had previously limited contract associates' service to a maximum of three years. The alternative enables Sandia to retain the services of more than 425 trained and valued individuals, decreasing overall costs and increasing productivity.

Sandia designed and implemented an online export control training program (EC100). This modular program automatically tailors the depth and breath of the training based on the student's responses to an initial set of eight questions. The DOE and DOD plan to use EC100 as a model for their next-generation training tools.

More than three hundred Sandians, family members, and friends built a Habitat for Humanity house in seven working weeks.

The National Atomic Museum provided 18,569 school children with six educational programs. The museum presented three programs called "Young Women Take Flight" to accompany a Smithsonian exhibition. The Museum has leased six acres for creation of the new National Museum of Nuclear Science and History, scheduled to open in 2004 at the Albuquerque Balloon Fiesta Park.

The Ombuds team intervened on contractor dispute issues, diversity issues, and nearly six hundred cases involving Sandians. These efforts ensure a common understanding of differences and provide a basis for dispute resolution. The team is recognized across the DOE complex as a model program and is repeatedly called on by the DOE to assist in developing approaches for dispute resolution.

The President's Quality Award targets project teams for self-assessment and review of processes and customer relationships. This year's applications increased 40 percent over last year's. The President's Quality Award program received two international awards for its promotional videos. This year's ceremony was aired live and sent electronically to seven hundred participants.

Sandia operates the Trades Training Program in cooperation with the Metal Trades Council, Albuquerque's Technical Vocational Institute, and Albuquerque Public Schools. The Trades Training Program was developed to maximize use of community resources, existing Sandia programs, and a new approach to training that produces fully qualified tradesmen at a greatly reduced cost.

5.6 Science and Technology

Sandia is a national leader in integrated microsystems, integrated model-based engineering and manufacturing, complex systems surety, and key areas of biotechnology. These technologies draw on Sandia's research foundations in materials and process science, computational and information sciences, microelectronics and photonics sciences, engineering sciences, and pulsed power sciences. The following accomplishments are organized by research foundation.

5.6.1 Materials and Process Science

Sandia's new Ion Beam Analysis Facility enables nondestructive measurement of the constituents (including tritium) of neutron tube targets and sources. Improvements of the process will allow backup War Reserve certification of our ion beam analyses.

Sandia used the low-energy electron microscope to learn how certain combinations of atoms spontaneously self-assemble into structures consisting of nanometer-sized dots and stripes. Direct observations of this self-assembly validated existing theories that explain how interatomic forces compete to produce stable, two-dimensional patterns. We use nanoscale patterned surfaces as templates to fabricate nanostructured materials with unique mechanical, optical, or electronic properties for multifunctional, miniaturized actuating or sensing systems.

For more than fifty years, identifying and controlling the sources of residual stress in thin films has been a major problem. We have used extremely sensitive in situ stress measurements to observe the complex evolution of stress during the early stages of film growth in a variety of materials systems—from metals to semiconductors and in both polycrystalline and amorphous films. We have learned to control and tailor stress to enhance film reliability and performance in important applications ranging from neutron tube sources and targets to interconnects for integrated circuits.

In order to isolate key corrosion processes that degrade electrical device performance, Sandia used ion implantation and ion-beam irradiation to determine the influence of solid-state transport processes on the behavior of copper in atmospheric sulfidizing environments. In conjunction with solid-state measurements of sulfidation kinetics and density-functional theory calculations, we obtained several findings. For copper oxide, we predicted and experimentally verified the importance of vacancy trapping on slowing the rate of sulfidation. In addition, solid-state transport of copper from the substrate through the product layer was shown to be the primary mass transport process.

Electrical breakdown of lightweight, microballoon-filled dielectric materials has been a challenge in the design and fabrication of high-voltage electrical components. Sandia has shown that reducing the size of the microballoons substantially increases the electric field required for voltage breakdown, especially in the presence of ionizing radiation. We have developed synthetic chemistry techniques that yield microballoons of 1 to 3 microns (an approximate tenfold reduction in size). These materials and a physical model we developed to predict voltage breakdown in components will enable the design of high-voltage components with improved performance.

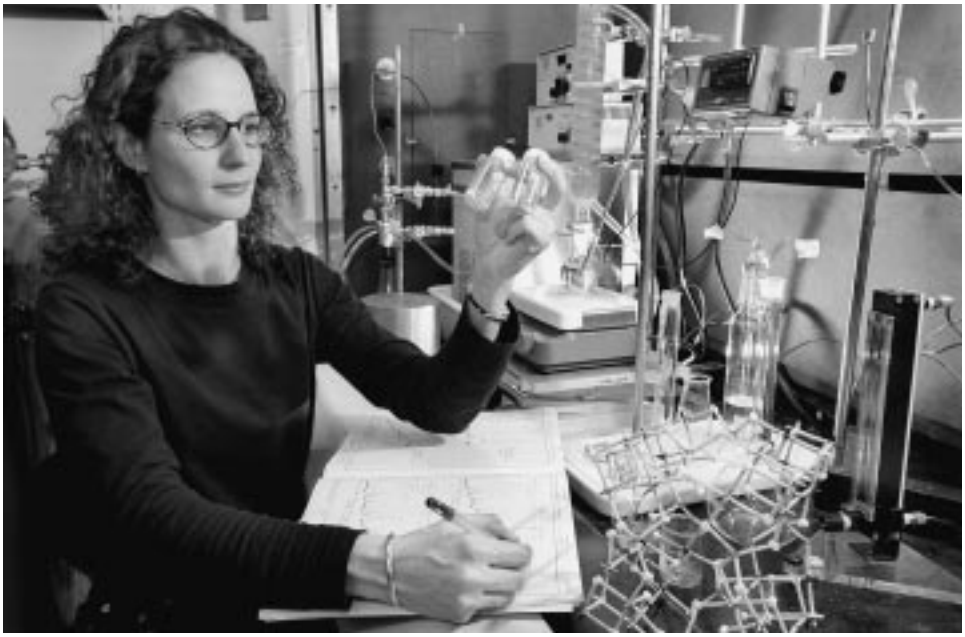
Understanding the physics of sintering and the resulting densification of ceramic materials is key to designing and fabricating high-quality electronics and electrical components. Sandia developed a microstuctural model for grain growth and densification of ceramics. This model (together with other Sandia continuum sintering and deformation models) can guide designers and production engineers in controlling shape, reproducibility, performance, and reliability of devices such as multilayer ceramic substrates and ceramic-sealed electronic interface connections.

LIGA (an acronym from the German for lithography, electroplating, and molding) uses x-ray synchrotron radiation to create nonconducting molds, which are subsequently filled with metal by means of electrodeposition. Sandia is using LIGA technology to fabricate nickel-based microsystems. We are also using LIGA to cast microparts from ceramics, stainless steel alloys, and polymers.

Sandia and an international team of scientists developed a photochemical technique for producing unique nanostructures (hexagonally packed tubes or three-dimensional tetragonal configurations). In the process, silica gels containing photoactivated acids are exposed to ultraviolet light, thereby engineering specific nanostructures. This photoinduced densification modulates the refractive index of the resulting material enough to make a diffraction grating or other optical device.

Sandia discovered a family of tunnel-collapsing materials, named Sandia octahedral molecular sieves (SOMS), to immobilize nuclear waste. When SOMS are submerged in waste solutions, specific metals such as radioactive strontium stick inside the tiny tunnels. Heating the SOMS collapses the tunnels and traps the hazardous contents so they can be safely disposed.

Sandia studied microscopic processes in soldering and brazing to identify a new mechanism for alloying metals on surfaces. We used real-time scans with a unique microscope to show that the copper/tin alloy bronze formed as tin islands swept across a copper surface. This motion occurs because the surface energy is lowered by the bronze alloys left in the island's track. This mechanism is analogous to the "camphor dance" in which camphor particles are similarly propelled by surface-energy reduction on a liquid. This discovery may enable us to use surface alloys to make novel nanoscale devices, including those for generating power.



Sandian Tina Nenoff examines vials of Sandia octahedral molecular sieves (SOMS) powder. Sandia's SOMS can remove radioactive metals from waste solutions.

Liquid/solid contact often forms a near-surface interphase with mechanical properties uniquely different from those of the bulk liquid. The effect creates water's high surface tension as well as the rock-fracture damage in aging sculptures and monuments. Sandia's interfacial force microscopy measurements showed that in water a self-assembled monolayer film terminated by three ethylene glycol units (known to be protein resistant) produced an interphase with an unexpected and presently unexplained thickness. This discovery has potential applications in areas ranging from biology to geology.

5.6.2 Computational and Information Sciences

Sandia's Design Analysis Kit for Optimization (DAKOTA) software package was used to perform sensitivity and optimization analyses on an arming, fuzing, and firing model for the W76 warhead. These analyses were part of a critical milepost simulation of the W76 system response to hostile radiation environments using the massively parallel, finite-element modal analysis (SALINAS) three-dimensional structural dynamics code developed by Sandia's Accelerated Strategic Computing Initiative. An expert external review panel concluded that the Sandia team had greatly surpassed the milepost success criteria and had demonstrated a modeling capability substantially beyond anything commercially available.

A more reliable classified videoconferencing system is now in place at Sandia. The system enables customers to use classified videoconferencing whenever they wish, without the need to schedule through National Nuclear Security Administration or DOE Headquarters. This videoconferencing system uses the SecureNet infrastructure to link video and audio between sites.

Restricted Network outages have interrupted business at inopportune times. A Network Reliability Task Force continued to work toward improved reliability and availability while maintaining advanced systems that support supercomputing users and the Microsystems and Engineering Sciences Applications complex.

The enhanced Sandia Classified Network now provides Sandia engineers and scientists with the functionality and tailored security to accomplish their critical mission work. The enhancement used the flexibility of Web technologies interwoven with unique need-to-know security structures.

Sandia met the need for information management, retention, and collaboration on both the restricted and classified networks by implementing Web Fileshare. Users contributed more than 16,000 files, and 2,800 searches were run each month. This system provides a common set of tools to effectively manage information through its life cycle—from creation to archiving.

The cost of desktop computing support at Sandia reached a new annual low of $2,200 per customer while adding several new services and achieving increased customer satisfaction (8.8 on a scale of 10). This is a 31 percent reduction from the 1994 cost when the computer support units were first formed. The reduction is the result of process and technology improvements.

Sandia developed a high-performance computer graphics rendering system. The large Accelerated Strategic Computing Initiative (ASCI) supercomputers generate data sets exceeding the capability of the largest computer graphics systems. We used inexpensive personal computer graphics cards to build a scalable rendering system. A 64-node graphics cluster recently rendered 225 million polygons per second. This result is one hundred times faster than the best graphics pipe available on the production ASCI visualization servers.

Sandia's Computational Plant (Cplant™) is now the largest Linux cluster in the world, with nearly 2,000 Compaq Alpha nodes. The Cplant team developed a flexible architecture to accommodate additions and a testing strategy to ensure a production quality environment for users. Cplant will be made accessible to sister laboratories and the community.

Sandia extended the Cougar operating system so users could access computer coprocessors on the ASCI Red teraflops supercomputer. This extension met the needs of the teraflops user community for more computational throughput within severe schedule constraints imposed by our support contract with Intel. Sandia's Virtual Node Operating System team developed and delivered the capability in six months while meeting all of Intel's stringent testing and evaluation requirements for the operating system. The Virtual Node Operating System provides the ASCI Red user community with the equivalent of many thousands of hours of additional teraflops computer time, worth tens of millions of dollars over the four years of the machine's remaining life cycle.

5.6.3 Microelectronics and Photonics Sciences

Sandia and Brown University used the results of in situ stress studies to design a distributed Bragg reflector. This reflector enabled the first demonstration of an ultraviolet vertical-cavity surface-emitting laser (VCSEL). Such lasers will allow incandescent lighting to be replaced with solid-state lighting as envisioned in the National Solid State Lighting Initiative. The improved efficiency of solid-state lighting will save energy and reduce pollution.

Sandia is creating a world-class photonics competency. Photonic lattices are optical analogues of semiconductors that enable a high level of control over optical properties. Photonic lattice applications are expected to include surface coatings to tailor optical properties and optical components for photonic integrated circuits. Silicon surface micromachining technology creates well-defined structures showing close agreement with theoretical predictions. Sandia developed the first

three-dimensional infrared photonic crystal and the first three-dimensional photonic crystal at optical wavelengths (1.5 micron). We also produced the first demonstration of thermal emissivity modification using this device, and we received an *R&D* magazine R&D100 award, an *Industry Week* magazine award, and a Lockheed Martin NOVA award.

Aluminum gallium indium nitride devices are being studied for next-generation electronic and optoelectronic applications. Sandia demonstrated the world's first ultraviolet semiconductor laser—a photo-pumped continuous wave indium gallium nitride ultraviolet VCSEL. Potential applications include high-efficiency solid state lighting, absorption and fluorescence-based chemical sensing, and detection of a wide range of biological agents.

Sandia's Microchemlab™ project has developed an autonomous, portable chemical analysis instrument. Dozens of supporting technologies for analysis of both gas and liquid samples have been developed and demonstrated at Sandia. Analysis is rapid (approximately 1 minute) and has high sensitivity (approximately 1 part per billion) and specificity. More than seventy patentable technical advances have resulted from this project. Negotiations are under way to license technologies from this effort for commercial application.

With funding from the Defense Advanced Research Projects Agency, Sandia partnered with Honeywell and the Massachusetts Institute of Technology to produce the polychromator, an optical correlation spectrometer system that uses polysilicon micromachining to produce diffraction gratings with individually programmable elements. Diffraction from designed, multiperiodic grating produces synthetic molecular spectra. Potential applications include remote chemical sensing, mapping chemical distribution in the atmosphere from space, optical processing, and fugitive emission detection. The polychromator received an Industry Week magazine award and a Lockheed Martin NOVA award.

5.6.4 Engineering Sciences

Sandia developed a unified thermodynamic theory of polymer viscoelasticity to model the life-cycle performance of encapsulated weapon components. The theoretic work has been extensively validated and implemented in three-dimensional, finite-element codes to predict a wide range of polymer response—including aging, yielding, and relaxation. This work in turn has enabled new theories dealing with polymer curing, failure, impact/high-strain-rate wave propagation, and mesoscale physics.

Predictive modeling of the dynamics of structures with bolted interfaces is of broad engineering interest. Damping in bolted joints is particularly difficult to model. Sandia initiated a combined experimental and analytic program focused on the damping mechanisms in bolted interfaces that led to the discovery of an underlying power law relationship between the applied force and the energy dissipation per cycle. The reduced-order analytic models developed will be important in modeling weapon system structural performance.

Sandia's microstructure-property material model, which can predict the stress and failure response for component designs and/or manufacturing processes, received an *R&D* magazine R&D100 award. The model was used to decrease the size and weight of automotive components, thereby reducing emissions and conserving fuel. The multiphase aspect of the material model was used in a commercialized heat treatment simulation tool for process design involving carburizing and quenching phase transforming of alloy steels. The model was also used to optimize die design in a weapons component forging process.

Sandia made significant advances in the parallel performance and physical fidelity of our suite of electromagnetics and plasma physics computational tools, collectively named EMPHASIS. EMPHASIS is used to qualify systems in intense electromagnetic and x-ray environments, design high-frequency electronics, and model pulsed power components. We are using these tools to assess the shielding effectiveness of a Lockheed Martin system. One EMPHASIS tool has performed 1 trillion operations per second on Sandia's teraflops computer.

We successfully simulated a section of the radiation-hardened Pentium® microprocessor using the Sandia-developed ChileSPICE™ circuit simulator. Production runs using ChileSPICE have reduced simulation time up to an order of magnitude compared with commercial simulators. The increased performance and enhanced convergence technologies will lead to improved circuit designs on a much larger scale than can be achieved today.

Sandia's GOMA code is a multiphysics, massively parallel, finite-element code with unique features. In an effort to bring a science-based understanding to manufacturing processes, the GOMA software team has worked with manufacturing personnel and material scientists in the areas of welding, brazing, cermet processing, and encapsulation.

5.6.5 Pulsed Power Sciences

Sandia modified the Annular Core Research Reactor for hostile environment testing of weapon components. The reactor was reconfigured for pulsed operation with experiments located in the center of the reactor, enabling completion of programmatic goals for the neutron generator program. General Thomas Gioconda, National Nuclear Security Administration Principal Deputy for Military Applications, praised the reconfiguration effort, which earned a DOE Nuclear Weapons Program Award of Excellence and a Sandia President's Gold Quality Award.

Sandia developed a novel method to study radiation symmetry in inertial confinement fusion hohlraums. The Lightscape™ commercial lighting simulation package, used primarily for architectural design, was adapted to model radiation transport accurately in complex, three-dimensional

Z-pinch hohlraums. We developed codes and algorithms for use with Lightscape to determine the hohlraum geometries that produce optimal radiation symmetry.

Ignition of a capsule within a hohlraum on the National Ignition Facility could fail if shocks cannot be timed accurately or burnthrough of the outer layer (the ablator) cannot be predicted within a few percent. In FY 2001 we made progress in characterizing ablator materials (copper-doped beryllium and polyimide) on the OMEGA laser in collaboration with Lawrence Livermore and Los Alamos national laboratories, using a streaked optical pyrometer and a streaked x-ray imager. We designed a new ultraviolet shield that allows us to obtain rapid and precise alignment of the ablator samples and we did experiments in a wedge geometry. The wedge geometry will allow us to obtain multiple-shock propagation data. Our data will be used to benchmark codes such as LASNEX, to ensure capsule stability and non-burnthrough of the ablator.

The Z Accelerator is presently the only facility that can produce smoothly increasing compressions to megabar pressures over 100- to 200-nanosecond time scales and in which isentropic compression waves can be measured with time-resolved velocity diagnostics. This magnetic-pressure technique, which can assess the response of materials to aging, forms a bridge between lower-pressure gas gun data and higher-pressure underground test data. We have obtained material property data at lower cost and higher accuracy (within a few percent) as compared to a gas gun. Complete equation-of-state curves for up to eight material samples can be diagnosed on a single Z shot, at about one-tenth the cost of using a gas gun. Recently, we used the three-dimensional, particle-in-cell code QUICKSILVER to develop a different hardware design for the end of the Z Accelerator transmission line. The new design should allow us to reach pressures of 2 to 5 megabars.

As a spinoff of the isentropic compression method, we developed a new way to obtain equation-of-state data by launching "cold" flyer plates to high velocities using the intense currents on the Z Accelerator. This work won an employee recognition award. With the magnetic fields generated from these currents, we have accelerated large (9 to 12 millimeters in diameter and 200 to 300 millimeters thick) flyer plates of aluminum, copper, or titanium to 13 kilometers per second (2.5 megabars). At these velocities, the flyer plates are not distorted, melted, or vaporized, as they would be with a gas gun. To model the behavior of the flyer plates, we must have an accurate knowledge of the metal-insulator and solid/liquid/vapor transitions. We have obtained quantum molecular dynamics calculations to improve further the conductivity models in our magnetohydrodynamic simulations—compared to those we developed in 1999 to correct the traditional models, which differed by orders of magnitude from measured data. By using a shaped magnetic pressure pulse, we expect to eliminate the shock that partially melts aluminum flyer plates at 21 kilometers per second. By launching the flyer plates into a deuterium cell, we have reached 300- to 700-kilobar pressures in liquid deuterium. Our data for liquid deuterium agree with ab initio theories, but disagree with data from Lawrence Livermore National Laboratory's Nova laser and with the Naval Research Laboratory's Nike laser. The laser data have larger error bars and suggest that liquid deuterium may be 50 percent more compressible than most models assume.

During FY 2001 we completed construction of the Z-Beamlet laser diagnostic, which will be used as a bright x-ray source to image (backlight) plasma produced during a Z-pinch implosion within a hohlraum. We began the effort to install, modify, and activate the laser in the fall of 1998. We used

Sandian Mark Knudson holds flyer plates (left) and launcher chambers (right). The Z Accelerator (background) uses magnetic fields to accelerate flyer plates to 13 kilometers per second.

components of the Lawrence Livermore National Laboratory Beamlet glass laser, which was constructed in 1994 as a one-beamline prototype of the National Ignition Facility. Modifying and activating the Z-Beamlet laser was an international collaboration that included Lawrence Livermore National Laboratory, the Atomic Weapons Establishment in Aldermaston, England, and the Gesellschaft für Schwerionenforschung in Darmstadt, Germany. The first backlit images of an imploding capsule inside a hohlraum were obtained on June 25 and 29, 2001. Obtaining these images marks the completion of the Z-Beamlet laser construction project.

Sandia's segmented rail phased induction motor (SERAPHIM) development project received funding in the FY 2001 Transportation Appropriations Bill to design and test a full-scale prototype of the motor. SERAPHIM was invented as a spinoff of the Sandia coil gun, an electromagnetic launcher to accelerate large projectiles to several kilometers per second. The SERAPHIM motor sequentially powers a series of electromagnetic coils mounted on the vehicle. The powered coils induce surface currents and opposing magnetic fields in passive coils mounted on the rail. Sequential firing of the powered coils produces either acceleration or braking. Because the main limitation of high-speed trains is air resistance SERAPHIM will probably rely on wheels rather than magnetic levitation. With electromagnetic propulsion and passive wheels, the rail will be subject to less wear, the vehicle will have good grade climbing capability, and the wheels and suspension can be designed to provide a high-quality, quiet ride.

In another transportation application of pulsed power, we received funding to evaluate the use of electron beams to heat gases in a hypersonic wind tunnel. The program will develop a ground-based wind tunnel facility to test aircraft engines at Mach 10-15 for several seconds at a simulated altitude of 30,000 meters. We are teaming with Princeton University, Lawrence Livermore National Laboratory, MSE Technology Applications in Butte, Montana, and the Air Force's Arnold Engineering Development Center.

We significantly improved our suite of electromagnetics and plasma physics computational tools, called EMPHASIS. EMPHASIS is used to assess the shielding of electronic systems in electromagnetic and x-ray environments, to design high-frequency electronics, and to model pulsed-power components. One of the EMPHASIS codes has been demonstrated at 1 trillion operations per second on Sandia's teraflop computer.

The Advanced Radiography Program provides a compact, inexpensive, high-quality, high-brightness radiographic source for subcritical hydrodynamic radiography experiments at the Nevada Test Site as part of the National Nuclear Security Administration's Directed Stockpile Work. In FY 2001 we used a rod-pinch diode to develop a 2.25-megaelectronvolt x-ray radiography source for Los Alamos National Laboratory (LANL). This source is four times brighter than originally specified. Radiographs of a static replica of a subcritical object were obtained in a collaborative experiment with LANL. The experiment combined the rod-pinch source, the static object, and an electro-optical camera to validate the use of radiography for LANL's upcoming subcritical experiments. We successfully tested the first stage of a new three-stage pulsed-power radiographic accelerator named the Radiographic Integrated Test Stand (RITS). When completed, RITS will be the first pulsed-power accelerator at Sandia designed specifically for the development of radiographic sources.

5.7 Infrastructure

Sandia's new Security Police Facility Command Center was established in a modernized area in Building 956. The new Command Center has state-of-the-art phone and radio systems, caller identification, and a 911 tie-in. The new strategic location saves officers time and transportation costs. Our old Command Center in Building 802 (unstaffed, but fully functional) now serves as a backup facility.

All Security audits and surveys received satisfactory ratings (the DOE's highest ranking). Sandia has made significant progress in improving and strengthening the overall performance of the Safeguards and Security Program. We implemented enhanced security procedures for vaults and vault-type-rooms. We replaced unapproved space-savers with General Services Administration-approved safes. Nonstandard storage locations are either manned or alarmed.

More than 10,000 Sandia employees and contractors and 4,000 visitors received the newly designed DOE/Sandia standard badge. All limited area entrances at Sandia/New Mexico were changed to require use of both an employee's badge and personal identification number.

Sandia packaged and shipped enriched uranium to the Y-12 Plant in Oak Ridge, Tennessee. This multifaceted project presented a broad range of new challenges, and the corporate knowledge gained will facilitate continued initiatives to dispose Sandia's legacy nuclear material in the future.

Sandia teamed with Kirtland Air Force Base to implement a base-wide residential recycling center. The center achieved DOD recycling goals and national recognition by winning the Air Force's Ronald Yates Award for Team Excellence.

The In-Ground Storage Vault was designed and constructed to provide high-security, temporary (two-year) storage for Sandia Pulsed Reactor fuel materials. This facility is the first step in a comprehensive plan to ensure that the Sandia Pulsed Reactor is available at a reasonable cost to meet nuclear weapons testing requirements. The plan will culminate in construction of a high-security Sandia Underground Reactor Facility to house future Sandia Pulsed Reactor operations.

Sandia's Facilities Management and Operations Center obtained Nuclear Weapons Strategic Business Unit funding to demolish five buildings at the New Mexico site. These demolitions eliminated more than 67,000 square feet of substandard

space. The demolition program reduced operations and maintenance costs and allowed building sites to be reused for new mission requirements. During this same period, vacant space was reduced by approximately 7,000 square feet.

Our Processing and Environmental Technology Laboratory received the DOE Program and Project Management Award 2000 from DOE's Office of Engineering and Construction Management. The state-of-the-art building is a materials science chemistry laboratory that provides a safe, energy efficient, and attractive work environment.

Sandia earned two New Mexico State Environment Department Green Zia awards for reducing energy and water use at the Central Steam Plant and for incorporating sustainable resource conservation and pollution prevention designs into new buildings. We also saved 22 million gallons of groundwater by reusing microelectronics wastewater for other operations at Building 858.

We established a swing shift of five mechanical tradesmen to perform preventive maintenance. This shift minimized disruptions to building residents, reduced equipment failures, and reduced overtime costs.

Sandia/California demolished the 85,000-square-foot Building 913 to provide a site for the new Distributed Information Systems Laboratory. This was the largest demolition project in the history of Sandia. Approximately twenty functions were relocated to ten other facilities. Because of known contamination, Building 913 required extensive characterization and cleanup prior to demolition. The project recycled 6,500 tons of concrete and approximately two million pounds of metals (steel, copper, aluminum, and brass).

5.8 Partnerships

5.8.1 Established Partnerships

Sandia, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and a consortium of semiconductor companies called the Extreme Ultraviolet Limited Liability Company (EUV LLC) completed the first full-scale prototype machine for making computer chips using extreme ultraviolet light, a breakthrough that will lead to microprocessors tens of times faster than today's most powerful chips and create memory chips with similar increases in storage capacity. The prototype machine, called the Engineering Test Stand, was assembled at Sandia/California and will be used by EUV LLC partners and lithography tool suppliers during the next year to refine the technology and prepare it to create a prototype commercial machine that meets industry requirements for high-volume chip production. The consortium includes Intel Corporation, Motorola Inc., Advanced Micro Devices Inc., Micron Technology Inc., Infineon Technologies, and International Business Machines.

Technology developed by Sandia and a Russian weapons laboratory and adapted by Stolar Horizon Inc. (Raton, New Mexico) attracted a $20 million investment by Credit Suisse First Boston, a global investment banking firm. The technology refined at Stolar Horizon will provide better maps of oil and gas deposits for exploration companies, improve mining techniques for coal miners, and facilitate military detection of land mines. The company expects to increase its staff from

Two Sandians adjust the Engineering Test Stand, a prototype Extreme Ultraviolet Lithography (EUVL) machine developed by Sandia, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and a consortium of semiconductor companies.

aseventeen to fifty by the end of FY 2001. The partnership will create nearly 350 jobs in New Mexico and twice that many in Russia as the technology is commercialized.

Sandia provided integrated sensing, cutting, and contour-generating technologies to fabricate an automated meat cutting system for Iowa Beef Packers. Sandia successfully completed all technical tasks a year and a half ahead of schedule and under budget. Sandia and Iowa Beef Packers have filed a number of technical disclosures and patent applications as a result of this work.

Sandia and PPG Industries Inc. (Pittsburgh, Pennsylvania) developed nonlinear viscoelastic modeling software that can be used to design paint with improved chip resistance. The current method for paint design and certification relies heavily on experience and experimentation. The software should decrease costs through reduced testing and a shortened development cycle and should improve chip resistance by optimizing design. The software also benefits the National Nuclear Security Administration by helping develop new tools to analyze encapsulated components (e.g., neutron generators) from manufacture through the product's operational service life.

Sandia and Vacuum Energy Inc. (Cleveland, Ohio) developed a novel hydrogen getter that safely removes unwanted hydrogen from heat exchangers used in coal-fired electric power generating plants and petrochemical refineries. Hydrogen, formed as a byproduct of water reacting with steel pipe, blocks efficient heat transfer and has caused catastrophic failure of heat exchangers in the past. A licensed product has already been sold commercially. The getters will increase the energy efficiency of heat exchangers and reduce the energy loss of the insulating vacuum in a wide range of appliances.

Sandia and The Goodyear Tire and Rubber Company improved the accuracy and expanded the frequency range of structural dynamics models for the noise, vibration, and harshness response of passenger vehicle tires. The improved models have been experimentally validated and have improved Goodyear's relationship with vehicle manufacturers. Goodyear stated that this effort reached technical achievements "previously thought unattainable by industry experts." The experimental and analytic techniques developed within this partnership are directly applicable to model validation for National Nuclear Security Administration Defense Programs.

Less than two years after initial discussions of technical collaborations with Sandia, Bird Technologies Group (Solon, Ohio) announced the opening of Bird Electronic Research Center in Albuquerque, New Mexico. The Bird Electronic Research Center has been established as a nucleus to meet the company's microwave system research needs. The center is located at the Inhalation Toxicology Laboratory, which serves as an incubator for new high-technology companies in New Mexico. Representatives from Bird Technologies selected Albuquerque because of the readily available skills and technology available from Sandia, the University of New Mexico, and other research facilities at Kirtland Air Force Base.

5.8.2 Cooperative Research and Development Agreements

Sandia and Celera Genomics have a cooperative research and development agreement (CRADA) to develop software and computer hardware specifically designed for the demands of computational biology as well as a full range of life sciences applications. Compaq Computer Corporation will provide the project technology. Celera, Sandia, and Compaq will work together to increase computing capability to 100 trillion operations per second. By sharing some Sandia-developed computing technology, Celera and Compaq may ultimately reach the "petacruncher" (1,000 trillion operations per second) level.

Alcoa, ASB Industries, DaimlerChrysler, Ford Motor Company, the Jacobs Chuck Manufacturing Company, Johnson Manufacturing, Ktech Corporation, Pratt and Whitney, Praxair, and Siemens Westinghouse Power Corporation are working with Sandia under a CRADA to accelerate the development and commercialization of the near-room-temperature metal-coating technology known as Cold Spray. In the Cold Spray process, metal or composite powders are accelerated to high velocities in a compressed gas jet and then bond to a target surface by a process similar to explosive welding—but on the microscale.

Sandia is collaborating with AlliedSignal Federal Manufacturing and Technologies and Rockwell Collins Inc. (Cedar Rapids, Iowa) to explore the commercial manufacture of complex electronic assemblies for weapons. This CRADA has delivered prototype assemblies produced on automated manufacturing lines using commercial off-the-shelf components at a fraction of the cost traditionally incurred for similar products. The CRADA may significantly reduce the cost of radio frequency assemblies for future weapons needs.

Sandian Mark Smith uses a laser velocimeter to measure the speed of tiny metal particles shooting toward a work surface during Cold Spray deposition.

Sandia and Goodyear Chemical (a division of the Goodyear Tire and Rubber Company) are collaborating to discover more energy-efficient processes that could dramatically reduce US petrochemical industry dependence on foreign oil. Sandia and Goodyear will analyze chemical process technologies that may reduce energy consumption, waste generation, and environmental emissions. This is the sixth CRADA between Goodyear and Sandia since 1993—and the first with Goodyear's chemical business.

Sandia and Eclipse Aviation signed a CRADA to develop simulation technologies that will better join aluminum parts during civil aircraft construction. Eclipse representatives visited Albuquerque to investigate potential headquarters for its operations. The City of Albuquerque asked Sandia to present technical capabilities related to the aircraft industry and provide information on its small business technical assistance and technology transfer activities. As a result of this visit and other city and state-sponsored presentations, Eclipse decided to establish its headquarters in Albuquerque.

5.8.3 Funds-in Agreements

Lucent Technologies signed a funds-in agreement with Sandia to characterize neutron-induced single-event upset in advanced Lucent memory and logic technologies.

Sandia signed a finds-in agreement with British Nuclear Fuels Limited Fuel Solutions (Scotts Valley, California) to verify representation of the impact limiters in the structural analyses used to calculate impact limiter deformations and deceleration loads on the TS125 transportation cask during drop conditions.

EMCORE Corporation's Albuquerque-based Micro Optical Devices Division requested a new amendment to their current funds-in agreement, the vertical cavity surface-emitting laser optical transceiver engineering study. The amendment allows completion of certain elements of prototype production transfer and follow-on support. Sandia will complete transfer of assembly processes and enhance yield with process engineering, production screening, reliability test engineering, and failure analysis.

EMCORE Corporation (Somerset, New Jersey) is also working with Sandia to better understand the issues associated with heterojunction bipolar transistors (HBTs). The increasing demand for portable phones has led to the need for HBTs with higher performance and lower power consumption. EMCORE has developed materials that address these applications. Sandia will fabricate HBTs using EMCORE's material and will provide performance and reliability feedback. This work is aligned with National Nuclear Security Administration Defense Programs objectives in photonics and compound semiconductor research.

Under a funds-in agreement with the American Water Works Association Research Foundation, Sandia will develop a vulnerability assessment methodology of the water infrastructure and propose upgrades to provide better protection.

Sandia signed a funds-in agreement with Taisei Corporation (Tokyo, Japan) to guide site-selection and characterization for high-level radioactive waste disposal in Japan. We will then model the methodology using data collected from the area around Horonobe to develop site-specific characterization guidance for the Horonobe Underground Research Laboratory. Results will be submitted to the Japan Nuclear Cycle Development Institute. The work is consistent with the DOE's Office of Science and Technology/Environmental Management program supporting all restoration and waste management activities. Project results can also be used in the high-level waste program administered by the DOE Office of Civilian Radioactive Waste Management.

The National Institute for Aviation Research at Wichita State University signed a funds-in agreement with Sandia to investigate the effects of several variables for the bonded repair of composite honeycomb aircraft structures. Sandia will characterize the strength of the repairs using various experimental methods. We will use Commercial Aircraft Composite Repair Committee methods and repair procedures and provide input to the Federal Aviation Administration, which can develop general guidelines for bonded repair. This agreement supports Sandia's weapons programs in the area of nondestructive inspection techniques.

5.8.4 Licenses

Sandia's surface micromachining technology that produces microelectromechanical systems (MEMS) devices continues to generate interest. MEMX Inc., a Sandia spin-off company, will commercialize a MEMS-based optical switch for the telecommunications industry. The license grants Sandia equity in the company in exchange for rights to develop business based on Sandia intellectual property. This first-of-a-kind (for Sandia) equity license offers an opportunity to share in the company's technical developments and financial successes while also aiding Sandia's national security missions with a regional supplier base.

Ardesta (Ann Arbor, Michigan), a company dedicated to the development of the microsystems industry, signed an agreement with Sandia to transfer MEMS and microsystems technologies to startup companies in the commercial sector. This agreement gives Ardesta a nonexclusive license to make and sell products using Sandia Ultraplanar Multilevel MEMS Technology (SUMMiT), opening the door to future collaborative work among Sandia, Ardesta, and companies that Ardesta may form in commercializing MEMS and microsystems. The agreement specifies that within one year Ardesta will develop a design and training center in Albuquerque based on the Sandia Agile MEMS Prototyping, Layout Tools, Education, and Services (SAMPLES™) model.

Sandia issued a license to Novint Inc. to use SUMMiT to produce MEMS devices and is launching products based on haptics, a technology that adds the sense of touch to three-dimensional computer interfaces.

Electro Scientific Industries Inc. (Portland, Oregon) signed an exclusive three-year license agreement for Sandia's patented beam shaping technology. Electro Scientific is targeting advanced packaging drilling applications down to 25 microns. This imaging and beam shaping technology allows the company to deliver 25 percent higher throughput by efficient delivery of the laser energy to the work surface. Electro Scientific also is interested in collaborative technology developments with Sandia to enhance the way laser energy is delivered to the work surface.

Sandia licensed Intel to use our advanced failure analysis techniques for integrated circuits. The license is for thermally induced voltage alteration for use in developing future microprocessors.

OptoMetrix Inc., an optical instrumentation company specializing in failure analysis techniques for integrated circuits, was licensed to use Sandia's advanced failure analysis techniques. The license allows OptoMetrix to market equipment that performs light-induced and thermally induced voltage alteration. Although several end users have obtained licenses for these techniques, this is the first time an equipment manufacturer has been licensed to sell the techniques.

Sandia licensed our foam for the rapid decontamination of chemical and biological warfare agents to Modec Inc. (Denver, Colorado) and Envirofoam Technologies Inc. (Huntsville, Alabama). The licensees have already produced commercial products and sales.

Baker Hughes Oilfield Operations (Houston, Texas) obtained a license to use Sandia's downhole communications acoustic telemetry technology to create a set of tools for taking measurements while drilling oil and gas wells.

5.8.5 Memoranda of Understanding

Sandia and the Navajo Nation signed a historic memorandum of understanding to create technology partnerships. The agreement covers several potential areas of collaboration and cooperation. These include developing strategies to promote regional economic development and high-quality education; offering broad services from Sandia's Corporate Business Development and Partnerships Center; identifying mutual interests and concerns; and using Sandia's expertise and resources to help address technical issues on the reservation.

The Sandia Science and Technology Park program office created a memorandum of understanding that binds public and private parties to develop the 219-acre park just outside the Eubank gate of Kirtland Air Force Base. Signatories include the Albuquerque Public Schools; the New Mexico State Land Office; Shaw, Mitchell, and Mallory Limited Partnership; the City of Albuquerque; Sandia; and the Science and Technology Park Development Corporation.

5.8.6 Other

The New Mexico Legislature passed legislation that allows Sandia to earn a tax credit up to $1.8 million in return for assisting small businesses in the state. Sandia is using the New Mexico Small Business Assistance Program to help small businesses resolve technological problems or business issues. The program will meet its goal of completing two hundred business assistances in FY 2001.

Sandia partnered with the University of New Mexico Cancer Center to obtain a $1 million grant from the Keck Foundation to support development of new tools for research in functional genomics. Sandia combined optical imaging devices developed as part of our satellite program, chemometrics data analysis routines developed for materials characterization, and data mining and visualization software (VxInsight™) to obtain funding for a next-generation gene scanner.

MAJOR PROGRAMMATIC ACTIVITIES

6.1 Programs for the United States Department of Energy

6.1.1 National Nuclear Security Administration's Office of the Deputy Administrator for Defense Programs

Project Trinity, part of the Manhattan Project, brought the best available scientific minds to Los Alamos, New Mexico to design, build, and test the world's first nuclear explosive device. Meanwhile, Project Alberta brought an equally impressive array of military and engineering talent to develop those first nuclear explosive devices into feasible nuclear weapons. After World War II, Project Alberta coalesced in Albuquerque into Sandia Laboratory.

Today, Sandia is one of three US National Nuclear Security Administration (NNSA) Defense Programs laboratories that design, produce, and maintain the US nuclear weapons stockpile. Los Alamos National Laboratory and Lawrence Livermore National Laboratory design the nuclear explosive packages for the stockpile. Sandia integrates these nuclear explosive subsystems with the many nonnuclear components needed to ensure a safe, secure, reliable, and deployable nuclear weapons stockpile.

Sandia designs, develops, tests, certifies, produces, maintains, and retires the principal subsystems for safing, arming, fuzing, and firing; for external neutron initiation; for gas transfer; for use control; and for other aerodynamic and structural components. We also are responsible for most limited-life components within weapons systems. Limited-life components have service lives based on the constant, relatively rapid, and precisely predictable degradation of their constituent materials, and these components must be replaced before the materials degrade. Sandia produces many of these components and is responsible for more than 90 percent of the individual parts of a typical nuclear weapon, which often contains more than six thousand parts representing over one hundred classes of component types and requiring approximately two hundred distinct process streams for fabrication and assembly.

Sandia provides field support to the military throughout the service life of every nuclear weapon for safe and secure use control, handling, shipping, storage, and maintenance. We develop capabilities for the safe and secure transportation and storage of nuclear weapons, we design the ancillary equipment that enables military personnel to handle and maintain nuclear weapons safely and securely, and we support the dismantlement of weapons retired from the stockpile. Sandia also conducts the stockpile sampling and

surveillance program for the NNSA, and specific surveillance activities associated with Sandia components and subsystems. We support retrofits to improve the safety or use control of stockpiled weapons or correct defects that may be discovered through stockpile surveillance.

Sandia is the central interface with the DOD for weapon requirements, system design and interface, logistics, surveillance, training, and dismantlement. This responsibility is increasingly important in a global environment characterized by the spread of military technologies, including weapons of mass destruction. Nuclear deterrence remains a cornerstone of our national defense.

Nuclear weapons with the advanced safety, security, use control, and performance characteristics of the weapons in the modern US arsenal represent an extraordinary technical achievement. Sandia's cradle-to-grave responsibilities demand a broad knowledge base, a science-based engineering approach, and a fundamental understanding of existing and future technologies. Thus, we must remain perpetually vigilant in two related areas of stewardship. First, we must ensure the present reliability of the stockpile. Stockpile surety is annually assessed, certified, and reported to the President. Second, we must assure the viability of the stockpile in the future, a more subtle and complex task.

We are now in a new phase of our institutional history. In accordance with established national policy, the NNSA funds scientific initiatives to computationally design and certify nuclear weapons without the need for nuclear testing. These initiatives form the foundation of science-based stockpile stewardship and at Sandia have yielded advanced capabilities derived either directly from work conducted under these initiatives or from secondary technologies. However, the shift toward these initiatives has had a subtle impact on both the resources available for our ongoing core stockpile surveillance and support mission. This impact has increasingly strained our core stockpile surveillance and support readiness.

The weapons remaining in the stockpile are well past their original design lives. The US nuclear weapons stockpile is now the oldest ever to remain in service, and we have little experience to guide us in predicting age-caused deterioration. Moreover, reductions in stockpile size have made each of these aging weapons more important as parts of a smaller deterrent. In the past, the stockpile consisted of many weapons and many different weapon types, providing both a substantial base from which to gather data on the condition of the weapons and a substantial inventory of options in the event of a problem with any single weapon type. However, reductions in stockpile size also have reduced the number of different weapon types, thus reducing the diversity of the stockpile and raising the possibility that a single repeated flaw (a common mode failure) could compromise a significant portion of the remaining deterrent. At the same time, our smaller production complex has less capacity to rapidly correct any large unanticipated problem in the stockpile. All these factors have narrowed the margin of error that can be tolerated in the remaining weapons.

We traditionally have monitored the stockpile by randomly selecting and testing weapons at different points in their service lives. As problems are discovered in weapon components, systems, or subsystems, Sandia investigates their cause, assesses their potential impact on the stockpile, and develops options for their correction. This sampling process consumes a number of weapons and components over the service life of any particular weapon type. In the past, greater production capacity and shorter weapon service lives allowed prebuilding of sufficient replacement parts to establish a protected period for each weapon type. During this protected period, a desirable rate of stockpile sampling could be maintained without reducing weapons below intended stockpile levels. Today, with reduced weapon numbers and longer service lives, the weapons in the stockpile are outliving their original protected periods, which raises the issue of choosing a less than optimal rate of stockpile sampling, an erosion of stockpile numbers, or both. The cessation of underground nuclear and radiation effects testing combined with increasing constraints on nonnuclear testing exacerbates this situation.

During the Cold War, the safety, security, and reliability of the entire stockpile was consistently improved by the technological and engineering advances and the constant research, testing, review, and assessment associated with each new weapon developed. Thus, the entire stockpile benefited from a continuous process of material and design review and modernization. Today, with no new complete replacement weapons developed for many years, the synergistic link between ongoing weapons development/replacement and the maintenance and modernization of the stockpile has been weakened.

Over the past decade, these changes have affected Sandia's ability to maintain core stockpile surveillance and support readiness. For example, this readiness resides in the intellectual, scientific, and technological capabilities of our staff, in their vigilance over the stockpile, and in their ability to apply technological leverage toward national security objectives. Yet Sandia's staff is aging, and in the absence of new weapons development we have lost many staff members who had direct experience with the full new weapon development process. Our critical core stockpile surveillance and support responsibilities are increasingly being discharged by individuals with no personal experience of complete weapon design and integration.

Also, more and more of our core personnel continue to work in substandard, obsolete, and deteriorating structures. Much of Sandia's critically important site and physical infrastructure dates from the early years of the Cold War, is

approaching a half century in age, and can no longer be rejuvenated through maintenance, patchwork repair, or incremental renovation. These structures need more extensive and intensive redevelopment or disposition actions.

To address these problems, the NNSA is building on previous efforts of the DOE in formulating a new nuclear weapons program structure that can refocus resources. This new program structure organizes the efforts of the nuclear weapons complex into six elements of Directed Stockpile Work, seventeen scientific and technological Campaigns, and seven aspects of Readiness in Technical Base and Facilities (see table that follows).

For the period covered by this plan, Sandia anticipates receiving significant funding and completing significant work in all six elements under Directed Stockpile Work, in twelve of the seventeen scientific and technological Campaigns, and in at least four of the seven aspects of Readiness in Technical Base and Facilities. The following sections of this document are structured in accordance with that work breakdown.

6.1.1.1 Directed Stockpile Work

Directed Stockpile Work encompasses all activities that directly support specific weapons in the nuclear stockpile and their ancillary equipment (containers, handling gear, use control equipment, etc.). These activities include current maintenance and day-to-day care as well as planned alterations, modifications, and refurbishments outlined by the Stockpile Life Extension Program. Additionally, this work includes research, development, engineering, surveillance, and certification activities in direct support of each weapon, both in the present and the future. Directed Stockpile Work represents a robust program that will ensure the future viability of the stockpile by maintaining a balanced effort of both near-term weapon activities and long-term future research and development. For the period covered by this plan, Sandia anticipates completing significant work in all six elements under Directed Stockpile Work: Stockpile Research and Development; Stockpile Maintenance; Stockpile Evaluation; Production Support; Dismantlement and Disposal; and Field Engineering, Training, and Manuals.

6.1.1.1.1 Stockpile Research and Development

Stockpile research and development includes the scientific understanding and engineering development necessary to support near- and long-term requirements of the nuclear stockpile. This work includes development of all new weapon designs (when needed); preproduction design and engineering activities; design and development of weapon and use control code management system upgrades; enhanced fidelity instrumentation for the surveillance flight test program; systems analysis studies; and the baselining of systems. Sandia's efforts will focus on the continuing development of advanced tools and hardware to be used to further our mission responsibilities in stockpile assessment and certification, maintenance, surveillance, and refurbishment in accordance with the schedule, as well as a limited amount of general supporting research and development.

Specific focal areas anticipated for the next two fiscal years include support for system studies, mutual defense agreements, and US/foreign weapon cooperative safety exchanges; development of specific components and subsystems in accordance with the schedule (e.g., a small neutron generator, switch tubes, and Microsystems and Engineering Sciences Applications support); development of improved and modernized engineering business practices and information systems; development of advanced, improved, and modernized flight test assemblies and instrumentation; refurbishment required for several enduring stockpile systems; and continued vigilance through exploration of potential future system concepts and technologies.

6.1.1.1.2 Stockpile Maintenance

Stockpile maintenance includes continuing maintenance and annual certification of the enduring stockpile, as well as final development stages and Sandia production support of alterations, modifications, limited-life component exchanges, and life extension activities on various weapon types to maintain a safe and reliable weapons stockpile. Sandia's efforts focus on Phase 4 support for necessary life extension operations and repairs associated with the Stockpile Life Extension Program, limited-life component exchange, and required development and engineering activities that directly support the Stockpile Life Extension Program and limited-life component exchange.

Specific focal areas that have been identified for the next two fiscal years include support for enduring stockpile systems engineering, significant-finding investigations and unsatisfactory reports associated with potential anomalies in the stockpile and annual certification requirements; support for independent safety, use control, reliability, security, and quality assessments related to the overall surety of the stockpile; field support related to use control, maintenance and handling equipment, containers, and aircraft compatibility; field support and coordination related to the development, production, certification, and execution of limited-life component exchanges, stockpile modifications, refurbishments, and safety and security improvements; support and coordination activities associated with the development of advanced flight test assemblies; implementation of improved and modernized engineering business practices and information systems; and production support for manufacturing, development, engineering, and neutron generators for the stockpile.

Work Breakdown Structure

6.1.1.1 Directed Stockpile Work	
Funded at Sandia	**Not Funded at Sandia**
1) Stockpile Research and Development	
2) Stockpile Maintenance	
3) Stockpile Evaluation	
4) Production Support	
5) Dismantlement and Disposal	
6) Field Engineering, Training, and Manuals	

6.1.1.2 Campaigns	
Funded at Sandia	**Not Funded at Sandia**
1) Primary Certification	
2) Dynamic Materials Properties	
	3) Advanced Radiography
4) Secondary Certification and Nuclear Systems Margins	
5) Inertial Confinement Fusion Ignition and High Yield	
6) Nuclear Survivability	
7) Defense Applications and Modeling	
8) Weapon System Engineering Certification	
9) Enhanced Surety	
10) Enhanced Surveillance	
11) Advanced Design and Production Technologies	
	12) Pit Manufacturing Readiness
	13) Secondary Readiness
	14) High Explosive/Assembly Readiness
15) Nonnuclear Readiness	
16) Materials Readiness	
	17) Tritium Readiness

6.1.1.3 Readiness in Technical Base and Facilities	
Funded at Sandia	**Not Funded at Sandia**
1) Operations of Facilities	
2) Program Readiness	
3) Special Projects	
	4) Material Recycle and Recovery
	5) Containers
	6) Storage
7) Weapon Incident Response	

6.1.1.1.3 Stockpile Evaluation

Stockpile evaluation includes new material laboratory tests, new material flight tests, stockpile laboratory tests, stockpile flight tests, quality evaluations, special testing, and surveillance of weapon systems to assess the safety and reliability of the nuclear weapons stockpile as a basis for the Annual Certification to the President. Sandia's efforts focus on continuous monitoring and evaluation of the enduring stockpile through stockpile sampling and testing. Stockpile evaluation is a perpetual obligation with a relatively stable set of basic requirements: stockpile evaluation laboratory tests, stockpile evaluation flight tests, and general surveillance support for nonnuclear components.

Two concerns for the core stockpile support mission during the next five years will be replacement of aging test equipment in Sandia's Weapons Evaluation Test Laboratory at the National Nuclear Security Administration's Pantex Plant in Texas and revamping of the stockpile evaluation program consistent with the 150-day surveillance study.

6.1.1.1.4 Production Support

In the area of production support Sandia's Concurrent Design and Manufacturing Program provides efficient, advanced manufacturing of components to War Reserve specifications.

Since it began in 1992, the Concurrent Design and Manufacturing Program has delivered more than 40,000 custom components—including actuators, thermal and special batteries, igniters, gas generators, capacitors, magnetics, frequency devices, and electronic components. These components are concurrently designed and manufactured in a partnership that includes Sandia, manufacturers across the nation, and the remaining production agencies at the Kansas City Plant in Missouri, the Pantex Plant in Texas, the Savannah River Site, and Los Alamos National Laboratory. Delivery quality was at 100 percent lot acceptance with no returns from the field.

During FY 2001, we supplied components for the B61, B61 Life Extension Program, B83, W78, W87, W62, W76 Life Extension Program, and W80 Life Extension Program. We delivered several critical components to the US Air Force for the B61 Type 3E Trainer, including the first War Reserve delivery from Sandia's Microelectronics Development Laboratory. We also delivered a redesigned actuator with an integral glass header for the B83.

6.1.1.1.5 Dismantlement and Disposal

Dismantlement and disposal covers all activities, including safety analysis, associated with the retirement, disassembly, component characterization, and disposal and reclamation of weapon materials and components; the engineering, development, testing, certification, procurement, and refurbishment of containers required for interim storage; and the staging and storage of weapons, components, and materials awaiting dismantlement. Sandia's efforts focus on safe disassembly, staging and storage, and component processing and characterization—all with the goal of supporting the safe and secure dismantlement of retired nuclear weapon systems in accordance with Strategic Arms Reduction Treaty agreements.

6.1.1.1.6 Field Engineering, Training, and Manuals

As the US nuclear ordnance engineering center, Sandia has unique and extensive responsibilities for the proper training of National Nuclear Security Administration and DOD personnel, including explosive ordnance disposal teams and their contractors. Training covers the proper handling, storage, maintenance, and potential use of the nuclear deterrent. Our efforts in these areas focus on proper military liaison and support to the field, proper training of personnel, and proper maintenance of weapons manuals and reference materials.

6.1.1.2 Campaigns

Campaigns are technically challenging, multiyear, multifunctional efforts across the DOE Defense Programs laboratories, the production plants, and the Nevada Test Site—which constitute an integrated weapon science and technology program designed to develop and maintain critical capabilities needed for weapons stockpile certification. The goal of these campaigns is to address current and future issues by employing the best scientists and engineers and using the most advanced sciences and technologies. Campaigns have milestones and specific end dates, effectively focusing research and development activities on clearly defined deliverables. For the period covered by this plan, Sandia anticipates receiving significant funding and completing significant work under twelve of the seventeen campaigns: Primary Certification, Dynamic Materials Properties, Secondary Certification and Nuclear Systems Margins, Inertial Confinement Fusion Ignition and High Yield, Nuclear Survivability, Defense Applications and Modeling, Weapon System Engineering Certification, Enhanced Surety, Enhanced Surveillance, Advanced Design and Production Technologies, Nonnuclear Readiness, and Materials Readiness.

6.1.1.2.1 Primary Certification

This campaign includes experimental activities that will develop and implement the ability to certify rebuilt and aged primaries to within a stated yield level without nuclear testing. Activities will include hydrodynamic experiments (e.g., those conducted at the Dual-Axis Radiographic Hydrotest Facility); subcritical experiments at the Nevada Test Site U1a Experimental Facility needed to validate simulation and modeling capabilities; other aboveground experiments, including those

at the National Ignition Facility; and reanalysis of past underground test results. Sandia's efforts in this area focus on the development and implementation of advanced compact flash radiographic sources for use on subcritical experiments.

A number of specific focal areas are anticipated for the next few fiscal years. We will

- complete installation of an operational prototype 2-megavolt radiographic source at Los Alamos in FY 2001;
- complete installation of twin 2-megavolt radiographic sources at the Nevada Test Site U1a Experimental Facility complex in FY 2002/2003; and
- demonstrate a 4-megavolt radiographic source by FY 2004.

6.1.1.2.2 Dynamic Materials Properties

This campaign includes efforts to develop physics-based, experimentally validated data and models of all stockpile materials under a broad range of dynamic conditions found in nuclear explosions. In the past, dynamic materials properties were often inferred from and normalized to integral test data on a descriptive and empirical basis. Without the availability of such integral tests, the materials models to be developed by this campaign are essential to establish predictive relationships between materials properties and stockpile performance, safety, and reliability. Initially, this campaign will focus on stockpile materials with the highest leverage and greatest uncertainties, including actinides, surrogate metals, high explosives, organics, and foams. Sandia's efforts will focus on equations of state, melt and phase transitions for stockpile materials, the constitutive properties of metals (including strength, spall, and ejecta), and materials processing and its influence on properties and performance.

We will support the development of experimentally validated multiphase equations of state, melt and phase transformation, and validated multiscale constitutive models of dynamic response, including strength and performance parameters for relevant materials. This work includes special nuclear materials and surrogates as the basis for high-fidelity weapons performance simulations and inertial confinement fusion.

We will obtain a precise understanding of the effect of preparation conditions, composition, and microstructure on materials performance and reliability. This effort will enable us to tailor materials for essential weapons applications.

We will obtain performance and process data on materials required to support stockpile refurbishment options or materials that can serve as direct replacements for those in use whose availability is curtailed, including organic dielectric films, filled encapsulants, removable epoxy resins, and encapsulant foams.

We will develop the knowledge base needed to understand, characterize, model, and ultimately control the advanced materials processing technologies critical to weapon component production and performance.

We will develop models of the effects of hydrogen isotopes and helium decay on the mechanical behavior of metals and polymers.

We will characterize material and process response models for newer processes such as LIGA (an acronym from the German for lithography, electroplating, and molding) and cold spray. This work will have application to future stockpile-refurbishment options and to current processes that remain critical to the stockpile but that are historically prone to defects, such as welding, brazing, and ceramic compaction.

We will also develop and demonstrate new enabling characterization methods and improved processes for stockpile-critical materials.

The Dynamic Materials Properties Campaign is associated with two areas of concern for the core stockpile support mission during the next five years. One concern involves insufficient funding to allow proper utilization of Sandia's Z Accelerator and other pulsed power techniques needed to support specific equations of state and materials shock response testing. A second concern involves the lack of funding to take full advantage of opportunities for development of engineered nanomaterials for microsystems and to enable lightweight, inert, robust packaging materials and integrated microsensors.

6.1.1.2.3 Secondary Certification and Nuclear Systems Margins

This campaign includes experimental and computational activities that will determine the minimum essential factors needed to produce an effective weapon. In the past, our incomplete understanding of secondary physics required underground nuclear tests to establish weapon performance margins. In the absence of underground nuclear testing, aging and remanufacturing issues require predictive capability. The activities in this campaign will develop a validated predictive computational capability for each system in the stockpile. Sandia's efforts in this area will improve the theoretic and computational capabilities and support the development of computational models required to predict the performance of nominal, aged, and rebuilt secondaries and thus certify the stockpile in the absence of nuclear testing. A specific Sandia activity in this campaign is the development and characterization of radiation environments that

are required for the campaign's major technical efforts. We will perform collaborative experiments with the other national laboratories in the areas of initial radiation case dynamics, radiation flow, and secondary performance.

The lack of funding to fully utilize Sandia's Z Accelerator and other pulsed power capabilities is also an area of concern for this campaign. The completion of Stockpile Life Extension Program elements and the resolution of significant finding investigations for several weapons systems require the development and validation of computational and materials models that can be achieved only through experimental and theoretic capabilities and by performing experiments using Sandia's pulsed power facilities. There are many more requests for experiments on our Z Accelerator than current funding supports. Additional funding and utilization of the Z Accelerator will be required to meet established milestones.

6.1.1.2.4 Inertial Confinement Fusion Ignition and High Yield

This campaign includes activities to support ignition implosions on the National Ignition Facility and to enhance experimental capabilities for stockpile stewardship on our pulsed power facilities. A fusion yield of 200 to 1000 megajoules in the laboratory is a long-term goal. We are providing intense x-ray sources for weapon physics and weapon effects testing, evaluating high-yield inertial confinement fusion concepts in the laboratory using Z pinches, and developing sophisticated diagnostics for the National Ignition Facility and Z Accelerator to support the nation's Nuclear Weapons Program. Our experiments and analysis will lay the foundation for a future high-yield facility. With 1-gigajoule yields, we can understand the margins of failure for ignition and burn in a nuclear weapon.

We are focusing our near-term efforts on

- diagnosing and modeling radiation transport, mix, and hydrodynamics in inertial confinement fusion implosions;
- providing an environment to evaluate radiation flow and secondary performance for the Secondary Certification and Nuclear Systems Margins Campaign;
- operating the Z-Beamlet (an x-ray backlighting diagnostic on the Z Accelerator) for the Secondary Certification, Dynamic Materials Properties, and Nuclear Survivability campaigns;
- validating models and scaling for inertial confinement fusion energetics and capsule radiation symmetry with Z pinches;
- developing the capability to make accurate measurements of the properties of deuterium and other materials of interest to inertial confinement fusion and weapons for the Dynamic Materials Properties Campaign;
- operating and maintaining Sandia's pulsed power facilities for the Readiness in Technical Base and Facilities program; and
- improve the reliability and reduce the operational costs of the seventeen-year-old facility while increasing x-ray energy and magnetic pressures and enhancing the precision of the data.

6.1.1.2.5 Nuclear Survivability

This campaign will develop microelectronics technologies and certification tools required in the absence of nuclear testing to ensure that refurbished stockpile weapon systems and components satisfy their radiation-based performance requirements as defined in each weapon's military characteristics and stockpile-to-target sequence. This campaign will reevaluate nuclear weapon radiation environments, develop validated computational tools to support radiation-hardened design and qualification, and develop key radiation-hardening technologies. These capabilities are being developed for application to the W76 Life Extension Program, which is critically dependent on their timely development and validation.

Sandia's goals during the next several fiscal years include demonstrating the maturity of next-generation, radiation-hardening microelectronics technology by designing and fabricating representative test devices and circuits and characterizing their performance in radiation environments. In addition, we will conduct experiments to validate mechanical response models, mature our understanding of radiation-induced damage mechanisms in semiconductors and other critical weapon materials, improve the testing and diagnostic capabilities to support model validation and improved material characterizations, and investigate radiation-hardening phenomena in microelectromechanical systems.

Nuclear weapons must be able to survive and/or operate in severe radiation environments that can disrupt the operation of electronic and nonelectronic nonnuclear components. Radiation can produce thermal and mechanical stresses that may impact the reliability of these components. Although radiation is generally perceived as resulting from hostile attacks, disruptive levels of radiation can result from naturally occurring space environments. Also, periodic weapon diagnostics and exposure to radioactive decay from the nuclear explosive package can produce lower radiation levels. Radiation can deform, spall, or degrade materials;

change the conductivity of electronic components; generate and transmit shocks in materials; and release trapped gases. Microelectronic components are especially vulnerable. One of Sandia's primary missions within the Nuclear Survivability Campaign is providing technology to ensure that weapons systems and components will survive and perform reliably in the presence of these stressing environments—without the benefit of underground radiation—effects testing. Sandia conducts this mission by integrating laboratory experiments with modeling and computation in support of radiation-effects testing, radiation transport, diagnostics, and analysis. With increased reliance on the simulation of complex system response, aboveground experimental programs are required to validate computer simulations that depend on material properties and device characteristics. As part of the code validation process, preserving and applying data from past underground experiments are also important.

Sandia operates a number of facilities that provide intense x-ray, gamma-ray, neutron, electron, and mechanical environments to support the qualification of weapon systems and components and to validate simulation codes. These facilities include the Sandia Pulsed Reactor Facility, the Annular Core Research Reactor, the Gamma Irradiation Facility, the Saturn x-ray source, the High-Energy Radiation Megavolt Electron Source (HERMES) III, the Sphinx Accelerator, and the Z Accelerator. The proposed refurbishment of the Z Accelerator to produce 26 to 28 megaamperes will improve our ability to simulate hostile environments in the laboratory. In addition, Sandia maintains in standby mode key facilities that could be reactivated to support critical missions if the need arises and if comparable facilities at other locations are no longer be available.

6.1.1.2.6 Defense Applications and Modeling

In support of the Defense Applications and Modeling Campaign, Sandia designers are spending more time computing and less time and fewer resources on physical prototyping and expensive performance testing.

In the past, Sandia relied heavily on large-scale empirical testing of iterative prototypes to validate and certify the safety and reliability of the entire stockpile. In response to continuing budget constraints, a smaller stockpile that offers reduced opportunities for sampling, the moratorium on nuclear testing, and increasing constraints on all forms of empirical testing, Sandia now relies on modeling and simulation to support weapon qualification. However, to meet our stockpile stewardship needs, we need higher-resolution, full-system simulation tools. To achieve simulations with the required complexity and detail, we must advance current computational speeds tremendously. The Accelerated Strategic Computing Initiative (ASCI) is hastening these advances to facilitate the shift from test-based methods to reliable computation-based methods.

Sandia is using the ASCI to develop advanced applications computing hardware and computational infrastructure. Advanced applications include verification, validation, and materials and physics models. The applications effort is developing high-performance, full-system, full-physics predictive codes to support weapons performance assessments, manufacturing process analyses, accident analyses, and certification. We are developing new mathematical methods, algorithms, and software to solve large-scale problems on the ASCI's massively parallel, distributed systems.

Our verification and validation efforts systematically measure, document, and demonstrate the predictive capability of the simulation models. We use verification to evaluate current software engineering practices, establish requirements for software projects, and ensure that our computer models provide the analytically correct answers. The validation program determines the accuracy of our computer models. With laboratory experiments and high-performance simulations providing the basis for predictive models and validated materials properties data, we have developed a powerful synergy between high-performance scientific computing and advanced experimental facilities to provide a rigorous scientific basis for weapons qualification. Concurrent with these efforts, we work to determine the physical properties of materials. Areas of importance include shock physics, chemically reacting flows, electromagnetics, and the computational analysis and design of materials.

Sandia's hardware support includes work to develop more powerful computing platforms to produce high-performance simulation and virtual prototyping using the advanced applications being developed in the program. ASCI Red is a 3-trillion-operations-per-second (teraflop) machine currently running at Sandia.

Sandia's ASCI computational infrastructure is required to support work in applications and modeling and to make computing platforms readily available to researchers. The problem-solving environment allows applications to be executed efficiently on ASCI computer platforms and provides accessibility to the platforms for weapons scientists and engineers from their desktops. This environment includes software development tools, libraries, frameworks, solvers, archival storage, and high-speed interconnects. Distance and distributed computing extend the environments required for high-end computing to different sites. Such computing develops the high-speed encryptors required to interconnect the laboratories securely and takes advantage of commodity computing systems that complement ASCI supercomputing platforms. To fully understand the results of multi-teraops simulations and to compare results of simulations and experiments, Sandia is developing a visual, interactive environment that allows data to be shared, explored, and easily accessed for collaboration among researchers.

6.1.1.2.7 Weapon System Engineering Certification

Supporting both certification and Directed Stockpile Work, the Weapon System Engineering Certification Campaign will establish science-based engineering methods to increase future certification confidence in weapons systems through validated simulation models and high-fidelity experimental test data. This campaign will develop validated engineering computational models and a suite of tools to allow science-based certification of the B61, W76, and W80 Life Extension programs. Sandia will establish the experimental infrastructure required to develop and validate the mathematic models utilized by the next generation of computational tools and needed to accurately predict the response of weapons systems to abnormal thermal environments and hostile impulse and blast loads.

Sandia will work on the following tasks during the next few fiscal years:

- planning that assesses the experimental modeling and simulation requirements of the W76 and W80 refurbishments;
- characterizing abnormal thermal environments for improved assessment and validation of phenomena and transport mechanisms that occur at interfaces;
- validating material constitutive relationships over a broader range of environments;
- benchmarking the interdependencies of phenomena coupling; and
- revitalizing the large-scale experimental capabilities needed to accredit computational tools.

6.1.1.2.8 Enhanced Surety

This campaign will develop enhanced surety options that can be considered for incorporation in scheduled stockpile refurbishments. This campaign will develop surety options and technologies for the B61, W76, and W80 weapon systems in time to support Blocks 1 and 2 refurbishment schedules. It will also develop new surety assessment methodologies and support integration of microsystems components into surety components, subsystems, and architectures. This campaign is needed to provide the most modern surety possible for nuclear weapons during the replacement, refurbishment, and/or upgrade of weapon components. Sandia's mission is to ensure the safety, security, and use control of the stockpile through use of the most modern, effective, and reliable capabilities, technologies, and performance available.

Over the next few fiscal years, Sandia intends to demonstrate advanced surety concepts and technologies.

6.1.1.2.9 Enhanced Surveillance

This campaign will provide a basis to determine if or when components must be replaced. To certify aged systems, National Nuclear Security Administration Defense Programs must be able to provide life estimates of components to give high confidence that refurbished systems can remain in the field for another twenty to thirty years. This campaign will develop tools, techniques, and models to measure, qualify, calculate, and predict the effects of aging on weapon materials and components and to understand how aging impacts weapon safety and reliability. We will augment weapon surveillance with new diagnostics for early detection of potential defects. The campaign will provide valuable information for long-term capability development, such as when new manufacturing facilities (e.g., pit production) will be needed. Sandia is protecting the credibility of the deterrent by warning of manufacturing and aging defects before performance is impaired. Work will proceed in this campaign during FY 2001. However, the cost of pending refurbishments to the W76 and W80 has placed this campaign under severe financial pressure for FY 2002 within current budget guidance.

This lack of funds for FY 2002 is a serious concern. Lack of funding will constrain our ability to predict the future readiness of the stockpile and will force reactive maintenance, in which problems are addressed after they affect system performance, rather than when precursors to failure are identified. Stockpile Life Extension Program planning will be impacted because enhanced surveillance is important for identifying components needing prompt replacement.

The Enhanced Surveillance Campaign also oversees the technology developed to predict component and materials performance in Sandia's nuclear weapon components. Lack of sufficient funds will delay development of a component surveillance program that links materials aging to component performance. In addition, resource limitations will severely delay the development of advanced, high-fidelity joint test assemblies, impacting our ability to maximize data collection during flight tests.

6.1.1.2.10 Advanced Design and Production Technologies

The Advanced Design and Production Technologies (ADAPT) Campaign develops capabilities to deliver qualified refurbishments on demand. Its modeling and simulation tools and information management technologies enable full-scale development with minimal prototyping and totally paperless processes. ADAPT accomplishes this rapid response with multiple, fast-turnaround engineering options, virtual prototypes, and modern product data management and

collaboration tools. Our world-class, concurrent, and highly integrated design and manufacturing technologies provide tools for enhancing design and manufacturing operations both within the nuclear weapons complex and across our domestic strategic industrial base.

Using our present status as a base line, our goal is to provide stockpile refurbishment products at reduced cost, in less time, and with minimum defects by FY 2006. Near-term goals are to

- deploy an enhanced framework for integrating and accessing software tools;
- provide collaboration capabilities for design and manufacture;
- develop LIGA (an acronym from the German for lithography, electroplating, and molding) and Acorn (a component in the W76 warhead) technologies for weapon Stockpile Life Extension Program options; and
- develop additional advanced robotic and intelligent machine options for manufacturing.

However, current budget constraints will force reductions in funding for ADAPT during FY 2002. Activities associated with the above near-term goals will be affected and if halted may be difficult to restart, with negative effects on Stockpile Life Extension Program schedules. Full-scale efforts will be resumed if resources become available.

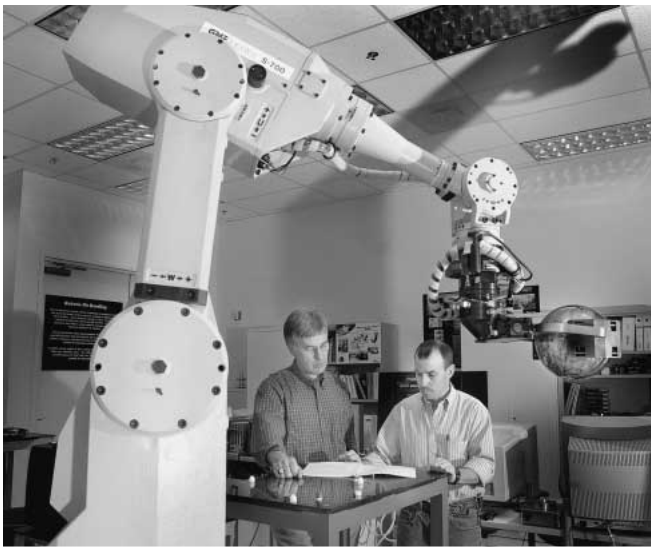
6.1.1.2.11 Nonnuclear Readiness

This campaign will ensure future manufacturing capabilities for nonnuclear production. Some capabilities in this area have been lost because of changing environmental requirements, resource constraints, or downsizing. These capabilities must be reestablished to support emerging Stockpile Life Extension Program requirements and to provide manufacturing capabilities that have lower costs and faster response times. This effort requires the reestablishment of special processes and materials, replacement of sunset technologies, development of technical work force competencies, development of component certification and recertification techniques, implementation of science-based manufacturing, modernization of manufacturing-related business practices, and incorporation of production realization techniques. Sandia is the design, engineering, and production liaison for more than 90 percent of the components in a typical modern nuclear weapon and for manufacturing an essential category of limited-life components. Our goal is to deliver by FY 2006 defect-free components to the military within nineteen months of final design and at 50 percent of their FY 1998 cost. Although work continues in FY 2001 and activities are planned for FY 2002, current budget constraints may jeopardize this campaign at Sandia in FY 2002.

6.1.1.2.12 Materials Readiness

This campaign assures that the critical nuclear and special nonnuclear materials needed for research, development, and production within the nuclear weapons complex will be available in the right form, at the right place, and at the right time. This campaign provides technologies and processes for modern materials management and inventory information systems.

The numbers of weapons components in storage, as well as those requiring packaging and shipping, have increased significantly over the past ten years as a result of dismantlement and stockpile modernization. Current distributed storage and inventory management is limited, inefficient, and not properly integrated. This campaign supports the new highly enriched uranium storage facility at the Y-12 Plant in Oak Ridge, Tennessee and also includes planning activities for storage, processing, and allocation of materials throughout the National Nuclear Security Administration (NNSA) complex. Sandia shares the goal of implementing an integrated nuclear materials stewardship plan by FY 2005 to address production agency and disposition program interfaces, packaging issues, material handling, and facility issues—including safety, security, and accountability. Sandia's role is to create processes, technologies, and analytic tools to support development of an integrated materials management system by FY 2005. In addition, Sandia will act as the system integrator for the NNSA Nuclear Materials Stewardship plan. Through FY 2001, work continued on the integrated inventory information management system, robotics handling at the Pantex Plant



Sandians Bill Drotning and Howard Kimberly are shown with a prototype pit-handling system similar to one already in use at the Pantex Plant in Texas. The robot arm is grasping a bowling ball.

in Texas, and remote monitoring technology at the Pantex and Y-12 plants. However, the cost of pending stockpile refurbishments and the reallocation of funding to other campaigns will jeopardize this campaign at Sandia in FY 2002 under the current budget. Efforts for this campaign will be resumed in FY 2003 at previously established levels if resources are available.

Elimination of the Materials Readiness Campaign at Sandia would hinder efforts to develop and implement a comprehensive materials stewardship plan. If funding is cut, we will defer installation of the NNSA enterprise-wide materials inventory information management system. We will postpone full-scale implementation of materials monitoring systems that enhance safety and security. Sandia-designed equipment has already been installed for evaluation at some sites in the complex. Eliminating funding for this campaign would impact our ability to support those installations.

6.1.1.3 Readiness in Technical Base and Facilities

Readiness in Technical Base and Facilities provides physical infrastructure and operational readiness at the national laboratories, the Nevada Test Site, production sites, and other National Nuclear Security Administration (NNSA) sites required to conduct the scientific, technical, and manufacturing activities for stockpile stewardship. For the period covered by this plan, Sandia anticipates receiving significant funding and completing significant work in Operations of Facilities, Program Readiness, Special Projects, and Weapon Incident Response.

6.1.1.3.1 Operations of Facilities

Operations of Facilities includes NNSA Defense Programs' share of the cost to operate and maintain programmatic facilities in a state of readiness at which each facility is prepared to execute programmatic tasks identified under Directed Stockpile Work and the Campaigns. This category includes Defense Programs' share of the cost of all structures, equipment, materials, procedures, and personnel necessary to provide program sponsors with a facility that is safe, secure, reliable, and ready for operations. Sandia has a number of facilities covered by this Readiness in Technical Base and Facilities subcategory. Additionally, this category contains Defense Programs-funded infrastructure projects, including waste management, general plant projects, and decommissioning and demolition.

The Microelectronics Development Laboratory in Albuquerque maintains radiation-hardening integrated circuit technologies as a contingency source for stockpile, research, test assembly, and other needs. The laboratory also provides custom circuits to weapons development programs for future Stockpile Life Extension Program activities and to integrate emerging radiation-hardening technologies with commercial sources as a means of sustaining capabilities for national defense. The Microelectronics Development Laboratory delivers prototype surface-micromachined silicon microelectromechanical systems to development organizations within Sandia for Stockpile Life Extension Program activities. The laboratory also migrates microelectromechanical systems technology to meet component requirements identified by Sandia weapons designers for future Stockpile Life Extension Program options.

The Compound Semiconductor Research Laboratory generates new technology options in semiconductor materials, processes, and device technologies to support Directed Stockpile Work; provides a flexible clean-room facility for prototyping, demonstrating, and validating advanced microsystem weapon component concepts; and serves as a contingency source for photonics-based and other microsystems that require integration of diverse technologies. The Compound Semiconductor Research Laboratory, which originally was designed for five years of operation, is now entering its second decade of operation. A replacement facility is needed now and is programmed as part of the Microsystems and Engineering Sciences Applications complex. The operational capacity of the existing laboratory will become an issue during FY 2002.

The Tonopah Test Range in western Nevada provides Sandia with essential system test capabilities (including those for joint test assemblies) as part of the stockpile sampling effort.

The Albuquerque Full-Scale Experimental Complex includes Sandia's Technical Area III experimental facilities and provides much of our capability for systems tests in controlled normal and abnormal environments, as required by NNSA Defense Programs and other customers. Simulations use mechanical environments, shock and vibration environments, and thermal environments that support a full spectrum of testing needs—from system engineering to model validation and certification. These facilities and most of the test equipment they house range from thirty to fifty years in age. A planned line item construction project (Test Capability Renovation) will renovate and refurbish these facilities to fully meet today's testing needs.

The High-Energy Radiation Megavolt Electron Source (HERMES) III and Saturn accelerators are unique, large-volume, high-fidelity, gamma- and x-ray radiation sources that generate environments for radiation-effects testing to support stockpile stewardship in all Directed Stockpile Work and in the Dynamic Materials Properties, Inertial Confinement Fusion Ignition and High Yield, Nuclear Survivability, and Weapon System Engineering Certification campaigns.

The Sphinx Accelerator is an adaptable, small-volume, rapid-turnaround x-ray radiation source.

NNSA Defense Programs nuclear facilities in Area V that support neutron and long- pulse gamma effects testing include the Sandia Pulsed Reactor (SPR) Facility, Annular Core Research Reactor (ACRR), Gamma Irradiation Facility (GIF), and Radiation Metrology Laboratory (RML). The SPR fast burst reactor is operated in support of neutron and long-pulse gamma effects testing on weapons systems and components. The ACRR supports stockpile stewardship activities concerning terminal-phase, hostile, and fratricide effects. The ACRR provides neutron and long-pulse gamma radiation for system qualification, modeling and simulation validation, and phenomenological investigations. The GIF cobalt 60 irradiator supports extended gamma effects testing on electronics components. The RML supports radiation environment characterization and dosimetry measurements for both Area V reactor test facilities and Area IV x-ray effects testing. We conduct radiation transport, radiation effects modeling, experimental design, and safety analyses to support testing and analysis activities.

Sandian Don Berry operates the Gamma Irradiation Facility (GIF) door. The GIF uses various types of radiation to test everything from microchips to satellites.

Sandia's Z Accelerator is the world's most powerful laboratory x-ray source. The Z Accelerator supports all Directed Stockpile Work and the Dynamic Materials Properties, Secondary Certification and Nuclear Systems Margins, Inertial Confinement Fusion Ignition and High Yield, and Nuclear Survivability campaigns.

The Neutron Generator Production Facility produces neutron generators, a limited-life component required by all nuclear weapon systems.

Sandia's Primary Standards Laboratory provides metrology oversight, certification of standards, development of new standards, and proficiency testing to assure the quality of all measurements involving nuclear weapons. The laboratory is part of the infrastructure required for the development, maintenance, and refurbishment of nuclear weapons and supports all Sandia Directed Stockpile Work and Campaigns associated with the actual manufacturing of weapon components.

The goal of the Legacy Waste Management Project is to treat and dispose of historical or legacy waste that was in Sandia's inventory prior to FY 2000. This project will safely (and in compliance with applicable regulations) store primarily radioactive waste until it can be disposed at approved facilities. The project includes all costs for analysis, treatment, packaging, transportation, and disposal of the waste. The project does not include additional waste created after FY 1999.

The Current Waste Management Project supports the timely collection, treatment, and disposal of newly generated waste to prevent the long-term accumulation and storage of waste on site. Activities include maintaining waste facilities; obtaining regulatory permits; reporting; collecting, treating, repackaging, and transporting all chemical and radiological waste; and operating all waste handling and disposal activities to fully meet existing local, state, federal, and DOE guidance. This project provides a comprehensive set of measurable results to demonstrate our commitment to incorporating pollution-prevention practices in all aspects of Sandia's work.

Emergency response teams handle incidents involving the malevolent use of special nuclear materials and serve as part of the overall NNSA emergency response programs.

6.1.1.3.2 Program Readiness

Program Readiness includes activities that support more than one Directed Stockpile Work activity, Campaign, or facility and that are essential to achieving all objectives. Sandia has numerous projects and programs covered by this subcategory of Readiness in Technical Base and Facilities.

The Defense Nuclear Materials Stewardship project conducts research, develops, tests, and evaluates advanced technologies and modern material management systems to enhance the safety, security, and accountability of nuclear weapons, nuclear materials, and weapon components during storage, handling, and transportation. This project includes sensor development and data management technologies for warhead monitoring, pit container monitoring, and other

support in modern technologies and processes, storage facilities, material accountability, and information systems.

The Knowledge Management Program maintains scientific and engineering skills to sustain the life-cycle of the stockpile; to provide integrated access to nuclear weapons data and information for the use of authorized personnel; and to coordinate and monitor the university research portfolio, including the University Collaborations Program. This program develops work force stewardship strategies to recruit and retain staff with needed skills; enhance career development, and improve access to retirees and other specialized knowledge resources for active weapon professionals.

Nevada Test Site operations include instrumentation, arming, and firing support for fielding experiments.

The Microsystems Infrastructure Readiness Project enables, exercises, and sustains Sandia's microsystems capabilities, with a secondary goal of developing capabilities to support fabrication of war-reserve microsystems components. Project activities integrate with preconceptual and conceptual work on the Microsystems and Engineering Sciences Applications complex and Microsystems Processing Laboratory facilities.

The Pulsed Power Technology Project maintains our capability for designing a wide variety of pulsed power drivers, ranging from high-impedance accelerators for gamma rays and radiography to high-power drivers for z-pinches for electromagnetic code validation. Sandia's Pulsed Power Technology Project is making significant contributions to the campaigns in Dynamic Materials Properties, Advanced Radiography, Secondary Certification and Nuclear Systems Margins, Certification in Hostile Environments, and Defense Applications and Modeling.

6.1.1.3.3 Special Projects

Because many employees in the nuclear weapons complex are reaching retirement age, a new generation of workers must be hired and trained. Sandia's technical work force averages more than 46 years of age; only 10 percent is age 35 or less. One quarter of our technical work force will be eligible for retirement by 2005, and nonretirement separations are trending upward. Moreover, Sandia is having greater difficulty competing with industry for scientists and engineers.

In 1999, the Chiles Commission recommended that national weapons laboratories "establish and implement plans . . . for replenishing essential personnel. These plans should have long-term as well as short-term focus and should provide for hiring scientific, engineering, and technical talent in anticipation of recognized needs."[1]

Sandia is using National Nuclear Security Administration funding for Special Projects to establish a suite of education programs that targets the Chiles Commission's recommendation. These programs are intended to attract a broad range of talent, ranging from PhD engineers and scientists through technologists with associate degrees. Some of these programs are described below.

The Engineering Sciences Summer Institute provides graduate students and university faculty members a summer research experience in applied mechanics. Participants are mentored by top scientists and engineers and attend a series of presentations on related topics, including finite-element analysis, materials modeling, and other computational analysis topics related to the behavior of materials. The program culminates with a one-week symposium of technical staff, students, and faculty members from around the nation.

The Rio Grande Corridor Initiative is a research internship program for students and faculty at universities located near the New Mexico site. The program promotes long-term collaborations and targets critical skills needs that can be filled within the region. Participants include New Mexico Highlands University, the University of New Mexico, New Mexico State University, the New Mexico Institute of Mining and Technology, and the University of Texas at El Paso. The initiative focuses on National Nuclear Security Administration research. Student and faculty research has improved microelectromechanical systems fabrication, supported urgent materials evaluation tests, enhanced surveillance programs, provided component support for lightning arrestor components, and developed lead zirconate titanate parts for weapons components.

The Accelerated Strategic Computing Initiative Research Internship Program provides college upper-division computer science and graduate students with experience in advanced computations and three-dimensional modeling and simulation. Research opportunities focus on projects related to the Accelerated Strategic Computing Initiative, a program to ensure the safety, security, and reliability of the nation's nuclear arsenal in the absence of nuclear testing. Students are mentored by Sandia scientists in the areas of networking and security, distributed and parallel computing, scientific graphics, computational mathematics, object technologies for parallel computing, and scientific data handling.

The Microsystems Summer Internship Program provides undergraduate and graduate engineering students opportunities to work in Sandia's Microsystems and Engineering Sciences Applications complex. Sandia scientists and engineers guide student work in disciplines critical to this program (microsystems technology development, computational and engineering sciences and analysis, and system integration and certification).

The College Cyber Defenders Program provides undergraduate and graduate students with hands-on experience in information protection, computer security, networking, and distributed systems. This program has attracted a sizable number of computer science students to work on cyber security at Sandia. Of the twenty-eight students who participated during

[1] The Report of the Commission on Maintaining United States Nuclear Weapons Expertise. March 1, 1999. p. 29. (electronic version available at http://www.anrc-research.org/chiles.html).

FY 2000, Sandia has hired three and is considering three more. In the future we expect a significant portion of our computer science hires to come through Cyber Defenders. This program has received positive media attention that benefits Sandia and the National Nuclear Security Administration. A press clipping service reported that 12.6 million readers received news of the College Cyber Defenders Program and a 60 Minutes broadcast reached an estimated 17 to 28 million viewers. Such positive press can pique job seekers' interest in working at Sandia.

The Radiation Sensors Technology project is designed to expand undergraduate and graduate research opportunities for students to work on cadmium zinc telluride radiation sensor technology. Applications exist in a number of new National Nuclear Security Administration areas and in medical, industrial, environmental, nonproliferation, and national security areas. Thesis work is available on this project for graduate students.

The National Security Engineering Program offers outstanding college electrical engineering students systems engineering work on applications for the National Nuclear Security Administration. Areas include process development and fabrication of micromachines for a variety of applications, processing methodologies and electronic data collection and reporting, programmable logic, fail-safe microprocessor architectures, and use-control equipment.

The Advanced Manufacturing for Education Program offers a four-year high-school curriculum that prepares students to continue their education or move directly into the work force. Sandia works with the Center for Occupational Research and Development, Albuquerque Public Schools, and the Albuquerque Technical-Vocational Institute (TVI) to create a hands-on curriculum that encompasses math, science, and computer technology. Students are encouraged to continue their education at TVI and to interview at Sandia for a position in the Mutual Education of Skilled Technologists Intern program, hosted by the Advanced Technologies Center.

Go Figure is an annual contest to identify and acknowledge mathematically talented students, whether or not they have participated in advanced mathematics activities. The contest measures a student's ability to think mathematically and to apply past experience to a new situation. Complex problems are broken into smaller steps, and the students must find and use clues to solve the problems. Problems are designed to test student ingenuity and ability to apply new information. Results are used to identify talented students who are then invited (along with their parents and teachers) to a recognition banquet. This contest can increase interest in a mathematics career.

6.1.1.3.4 Weapon Incident Response

Weapon Incident Response manages National Nuclear Security Administration (NNSA) offsite radiological emergency response programs, including the Accident Response Group, Nuclear Emergency Search Team/Joint Technical Operations Team, and the Radiological Assistance Program. Sandia ensures that emergency response operations, training, and technical integration activities are consistent with NNSA-directed goals and objectives. Sandia teams respond to incidents involving the malevolent use of special nuclear materials and serve as part of the overall DOE emergency response programs.

6.1.2 National Nuclear Security Administration's Office of Fissile Materials Disposition

The Office of Fissile Materials Disposition is chartered to develop strategies and to direct activities that ensure the safe, secure, cost-effective, and verifiable long-term storage and eventual disposition of surplus US weapons-grade fissile materials in a manner that encourages reciprocal actions abroad. Sandia continues to provide support to this office in three main areas: technical integration of program elements, logistic and administrative oversight for the US/Russian Plutonium Disposition Development Program, and technical expertise in the areas of robotics and automation.

Technical integration involves monitoring national laboratory technical support activities, facilitating communication to support technical objectives, and ensuring that required data and analyses are fully integrated with programmatic and technical requirements.

Funding for the US/Russian work comes primarily from legislation intended to reduce the proliferation of Russian weapons materials. A series of test and experimental activities has been established by US scientists and their Russian counterparts to demonstrate verifiable conversion of plutonium from weapons. Sandia has assisted the US/Russian Steering Committee and Working Group in defining joint US/Russian research and development projects, scheduling their activities, establishing the reporting format, and writing applicable portions of the joint reports. A major adjunct to this work includes assisting the National Nuclear Security Administration (NNSA) in working with the Department of State on international agreements compatible with technical progress and programmatic decisions.

The Plutonium Management and Disposition Agreement, signed during the fall of CY 2000, is a government-to-government US agreement with the Russian Federation regarding the disposition of 34 metric tons of weapons-grade plutonium. The agreement has provisions for monitoring and inspections. The exact nature of the verification regime has not been determined and some areas are problematic both for the United States and Russia. Sandia is the lead laboratory supporting NNSA determination of the verification regime. Sandia is also leading the development of a draft verification scenario for the disposition regime to be used by the US negotiating team.

Many of the disposition processes will require robotics and automated handling equipment to reduce the exposure of workers to radiation hazards and to limit opportunities for proliferation. Sandia's Intelligent Systems and Robotics Center has contributed significantly to the establishment of such processes.

6.1.3 National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation

Sandia's support for the Office of Defense Nuclear Nonproliferation includes research and development for a variety of systems that detect proliferation of weapons of mass destruction; develop technologies to minimize the consequences of potential use of chemical and biological weapons; develop technologies and systems to verify international agreements; apply technologies to prevent the spread of nuclear materials, technology, and expertise; and support the elimination of surplus fissile material inventories usable for nuclear weapons. Two important aspects of these systems are information management and support for enhanced control of special nuclear material in the former Soviet Union. Because these program elements are implemented within a political framework of openness and cooperation, Sandia's technology must balance adequate protection of sensitive and classified information with national goals of openness and transparency.

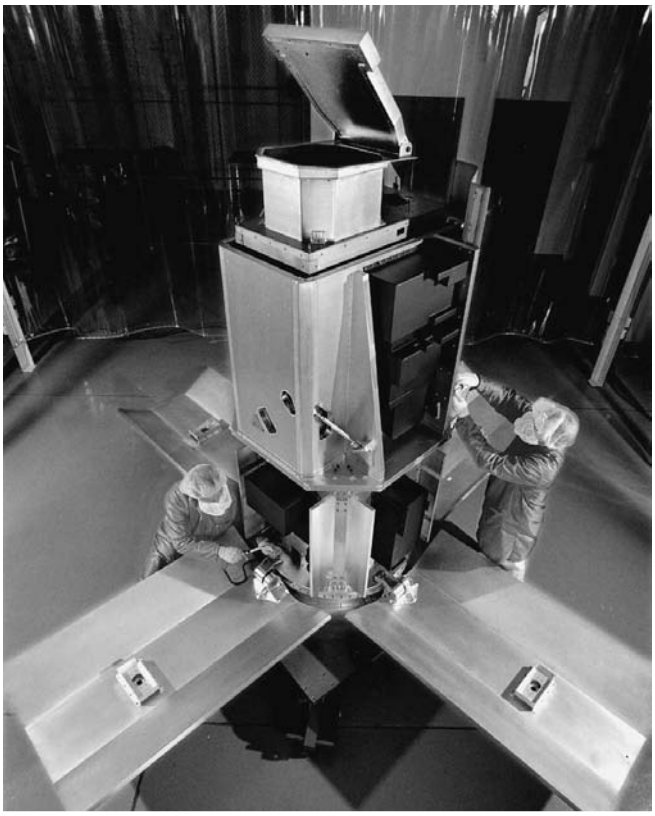
6.1.3.1 Nonproliferation and Verification Research and Development

Sandia is developing new sensors to detect low-yield nuclear explosions in the atmosphere. Instrumentation installed on Global Positioning System satellites now provides continuous worldwide coverage. We also are developing seismic-data processing technology to enhance detection of underground nuclear explosions. In response to the evolving geopolitical climate, the emphasis of this program has shifted from monitoring bilateral agreements to monitoring for covert nuclear testing and supporting a comprehensive test ban. In addition, Sandia is developing models of verification technologies for system performance evaluation. Our activities are part of a multilaboratory effort focused on affordable, deployable, and flexible sensors for seismic, hydroacoustic, radionuclide, and infrasound data acquisition and data processing. These activities are being coordinated and in many cases cofunded by the DOD, which has the operational nuclear test monitoring responsibility within the US government.

We are developing airborne and satellite-based systems and technology for detecting and characterizing proliferation-related activities, including detection of chemical weapons, biological weapons, and missiles. In conjunction with Los Alamos National Laboratory, we developed and deployed a satellite-based, multispectral thermal imaging system. With other national laboratories, we are developing laser-based techniques for remote detection and identification of chemical species in effluent plumes. In addition, Sandia is developing specialized chemical microsensors, bioinformation systems, and decontamination technology for detecting nuclear, biological, and chemical weapons and for detecting nuclear materials smuggling.

Sandia develops synthetic aperture radar systems and processing algorithms for national security applications that may require all-weather, day-and-night capabilities. We also are 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.

Sandia conducts advanced research and development of technologies expected to be applicable to nonproliferation and verification. Current projects are focused on microtechnologies, nuclear materials analyses, and radiation detection. Work in microtechnologies focuses on detecting chemicals associated with nuclear weapons programs. Nuclear materials analyses characterize environmental samples collected from the environs of nuclear facilities. Radiation detection investigates means of detecting and



Sandia's Multispectral Thermal Imager satellite collects information based on light and heat patterns in fifteen spectrum bands.

recognizing unique radiation signatures emitted by nuclear processes in operating production reactors.

6.1.3.2 Arms Control and Nonproliferation

Sandia helps evaluate export licenses in weapon technology using our considerable experience in engineering nuclear weapons. We also help develop technology for ongoing International Atomic Energy Agency remote monitoring and inspections. Sandia's Cooperative Monitoring Center is used by a number of countries and agencies to evaluate the applicability of monitoring technologies and procedures to arms control and regional security. Prototype monitoring equipment allows representatives of regional parties (from areas such as south Asia, the Middle East, the Balkans, and the Korean peninsula) to perform hands-on evaluation of various technologies and to use models to simulate the applications of technical solutions to specific regional problems. Our support of the National Nuclear Security Administration (NNSA) includes treaty implementation analysis, staff support, nuclear testing analysis, and dismantlement analysis. We have supported the NNSA's (formerly the DOE's) onsite evaluation program since 1983 and continue to evaluate the impact of onsite inspections on sensitive industrial facilities and on other issues related to implementation of various treaties. Policy support includes both sides of the policy/technology interface. The Cooperative Monitoring Center supports technical analysis of policy options for the NNSA and provides national security policy insight to other Sandia organizations. We also provide technical advice to the NNSA and various negotiating delegations.

We are reducing the risk of nuclear weapons proliferation (including threats such as theft, diversion, and unauthorized possession of nuclear material) by supporting numerous projects in the former Soviet Union that help protect nuclear weapons, materials, and facilities. Additionally, our cooperative interactions with scientists and engineers in various institutes in the former Soviet Union encourage dismantling of weapons of mass destruction, promote nonproliferation activities, assist former Soviet states in converting their defense-oriented capabilities to civilian market-driven enterprises, and provide Western nations with better access to the science and technology that exist within the former Soviet Union.

Sandia develops remotely accessed, unattended cooperative monitoring systems and technologies for applications and evaluation in foreign states without nuclear weapons that are party to the Treaty on the Non-Proliferation of Nuclear Weapons. These activities typically support the International Atomic Energy Agency and bilateral safeguards agreements between the United States and foreign states with nuclear materials of US origin. Other work is conducted for the physical protection of nuclear materials in the Baltic and newly independent states of the former Soviet Union and in states that are party to the Convention on the Physical Protection of Nuclear Material. These activities include the International Atomic Energy Agency International Physical Protection Advisory Service, training classes, and physical security upgrades.

6.1.3.3 Materials Protection, Control, and Accounting

The dissolution of the Soviet Union in 1991 weakened the effectiveness of their nuclear security measures. Recognizing the threat to global safety if these materials were stolen, Russia and the United States (as well as other countries) began cooperative efforts to safeguard Russian nuclear materials. Russia's fifty years of nuclear weapons and nuclear power programs produced up to a thousand metric tons of fissile material. This material is dispersed in approximately 250 buildings at forty different sites across ten time zones.

The National Nuclear Security Administration's (NNSA's) Materials Protection, Control, and Accounting (MPC&A) Program reduces the threat to US national security posed by unsecured Russian fissile material by providing the first line of defense in preventing nuclear proliferation and nuclear terrorism. The program employs a three-part approach. First, the material is secured by physical and accountancy upgrades appropriate for its level and the threat of theft. Second, the number of targets for theft is reduced by consolidating material in fewer buildings at fewer sites and by converting excess highly enriched uranium to low-enriched uranium. Finally, we encourage Russia to develop capabilities and commitments to operate, maintain, and regulate these security improvements for the long term.

Sandia's participation in the MPC&A Program, in cooperation with NNSA and other national laboratories, has included work at the Ministry for Atomic Energy of the Russian Federation (Minatom) defense and civilian facilities, at Russian Federation Navy sites, and also in national infrastructure (transportation, communication, training, and sustainability) projects. The General Accounting Office's February 2001 report identifies four sites where US MPC&A work in Russia had been demonstrably successful in reducing the risk of the proliferation of nuclear materials: the Mayak Production Association; the Institute of Physics and Power Engineering (Obninsk); and Navy Fuel Storage Sites 49 (Murmansk) and 34 (Vladivostok). Sandia provided the project leadership for all of the work cited in this report for those four sites.

6.1.3.4 Initiatives for Proliferation Prevention

Sandia has been an active participant in the multilaboratory Initiatives for Proliferation Prevention Program, which engages scientists, engineers, and technicians from the former Soviet Union in nonmilitary projects. This program focuses on individuals and organizations that have worked on weapons development programs (including nuclear, chemical, biological, and associated delivery systems). The Initiatives for Proliferation Prevention program

provides seed money for research activities and provides links with US industry to commercialize such new activities. Sandia has an active portfolio at several sites with projects in areas as diverse as lower limb prosthetics, oil field exploration, and advanced radiation sensors.

6.1.3.5 Nuclear Cities Initiative

The Nuclear Cities Initiative, begun in 1999 as a companion program to the Initiatives for Proliferation Prevention Program, focuses on the closed cities in the Russian Ministry of Atomic Energy complex. The initiative's objective is to significantly downsize the Ministry of Atomic Energy complex and to provide alternative employment for scientists in these closed cities. The Nuclear Cities Initiative provides seed money for conversion projects and research initiatives that directly benefit the United States. Currently, the Nuclear Cities Initiative is focused on three closed cities: Sarov (formerly known as Arzamas-16), Snezhinsk (formerly known as Chelyabinsk-70), and Zheleznogorsk (formerly known as Krasnoyarsk-26). Sandia has active projects at all three sites and is the lead laboratory for coordinating projects at Zheleznogorsk.

6.1.3.6 Highly Enriched Uranium Transparency Program

In February 1993, the United States and Russia signed an agreement to convert highly enriched uranium from the dismantlement of Russian nuclear weapons into low-enriched uranium for fuel to be used in commercial nuclear reactors. The United States agreed to purchase 500 tons of low-enriched uranium for use in the nation's reactors. The agreement also established measures to fulfill nonproliferation, physical security, material accounting and control, and environmental requirements for highly enriched uranium and low-enriched uranium. The Highly Enriched Uranium Transparency Program will develop confidence that certain US/Russian nonproliferation objectives are being met (i.e., that highly enriched uranium is being taken from Russian nuclear weapons, blended into low-enriched uranium, shipped to the United States, and fabricated into commercial reactor fuel). Sandia provides technical, administrative, and management support for the program in several areas including: onsite monitoring; data authentication and tamper indication for special monitoring equipment; vulnerability assessments; and advanced technology development to support the transparency regime.

6.1.3.7 Chemical and Biological National Security Program

Sandia supports the Chemical and Biological National Security Program (CBNP) with a range of different activities. These include threat and response analysis, which assesses the nature of the threat posed by terrorists with chemical or biological agents and evaluate potential civil response options in both technology development/deployment and in organizational response. We also are developing a variety of specific key technologies, often in collaboration with other laboratories. These range from detector development (using our Microchemlab technologies), to development of special formulations of aqueous foams for decontamination, to modeling and simulation of the initial release and dispersion of chemical/biological agents. We are also conducting the Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT) to evaluate and demonstrate technologies and systems for protection of people in public facilities. This project includes work on subway systems and airports, work that requires close collaboration with the public agencies with whom we partner.

Sandia's Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT) evaluates technologies that can counter such weapons of mass destruction. Here, simulated chemical/biological agents are being released to help characterize dispersal of chemical/biological agents in public facilities.

6.1.3.8 Office Defense Nuclear Security

Sandia provides engineering support to National Nuclear Security Administration facilities and brings a common element to the design of security systems. A team of security experts is available to assist with vulnerability analyses, to validate response force tactics, and to serve as a source of information on security technologies. We provide independent reviews and help develop systematic approaches to key issues such as the graded approach to security.

Sandia is the lead laboratory for physical security research and development. We serve as the central resource for information on the performance of physical security technologies used to protect DOE facilities. We have laboratories dedicated to the study of intrusion detection, video assessment, entry control (including contraband and biometrics), passive and activated delay, alarm communication and display, and simulation of response force tactics.

6.1.4 National Nuclear Security Administration's Office of Transportation Safeguards

The Office of Transportation Safeguards (OTS) provides safe, secure, and cost-effective transportation within the continental United States for all National Nuclear Security Administration (NNSA) nuclear weapons, explosives, special nuclear materials, and nuclear test devices, as well as for certain nonnuclear and limited-life weapon components.

Sandia provides design, engineering, production, operational engineering, and emergency response support for major elements of the Transportation Safeguards System. Sandia is responsible for the complete life cycle of all engineered systems from concept development and prototyping to subsequent production, system upgrades, and retirement. Sandia supports the OTS with long-range planning, vulnerability analysis and security, risk assessments and safety authorization basis, fleet maintenance, and small-quantity production runs. Research and development funding is used to identify and advance emerging technologies that will support the OTS, the Global Nuclear Materials Management Initiative, and other government agencies.

We are planning major upgrades for all aspects of the Transportation Safeguards System during the next five years. We will continue to support production of the Safeguards Transporter into FY 2007 and production of the next-generation tractors through FY 2004. We will also support the development and production of escort vehicles, including at least one new special vehicle to meet emerging mission needs. A multiphased replacement of the communication equipment will ensure continued robust and secure communication with enhanced tactical capabilities. The command center will undergo major scheduled renovation, resulting in an information management system infrastructure that can sustain the increased OTS workload and new mission requirements. Analysis of security and safety issues will focus Transportation Safeguards System resources on developing new technologies to address emerging requirements.

Sandia supports the National Nuclear Security Administration's Office of Transportation Safeguards in a number of areas, including fleet maintenance.

6.1.5 DOE's Assistant Secretary for Environmental Management

Work for the Assistant Secretary for Environmental Management includes support for Sandia's onsite operations and development of solutions for national environmental problems. Onsite operations include restoration of Sandia environmental sites and management of waste from continuing operations. National operations include development of solutions for a full range of research and development activities, and demonstration of the resulting innovative technologies.

6.1.5.1 Waste Management Operations

Sandia's Waste Management Program is responsible for the treatment, storage, and offsite disposal of hazardous, low-level, mixed, and solid wastes. These wastes are generated by decommissioning activities and routine operations at Sandia sites..

Sandia's Waste Management Program treats, stores, and disposes waste via a six-step process:

- generators formally request collection service;
- waste management personnel review the requests and certify that the waste meets Resource Conservation and Recovery Act acceptance criteria;
- the waste is collected, segregated according to Department of Transportation hazard classes, and delivered to the appropriate Sandia interim-storage facility;
- the waste is stored pending final disposition;
- waste management staff prepare manifests to identify the quantity, composition, origin, routing, and destination of waste; and
- the waste is sent to a commercial or government facility for treatment, recycling, or disposal.

Sandia's Generator Interface Program is the technical interface between waste generators and waste management operations. The program helps waste generators develop and implement waste management procedures, ensures that these procedures are followed, inspects and evaluates waste generators, recommends actions to reduce waste quantity

or hazard level, defines radioactive-material management areas, and provides training for waste generators. We also maintain the sections of Sandia's Environment, Safety, and Health Manual dealing with management of chemical, radioactive, and mixed waste; provide technical consultation and liaison services; and serve as the interface between Sandia's Waste Management and Environmental Restoration programs.

To reduce risk and cost within the Waste Management Program, Sandia developed a waste-minimization and pollution-prevention program to decrease waste generation by source-reduction techniques; identify recycling options for waste materials that cannot be eliminated or minimized; and specify treatment options to reduce volume, toxicity, or waste mobility prior to storage or disposal. Waste-minimization activities include assessments to identify viable pollution-reduction alternatives; a system to track the purchase and use of all chemicals; a team to enhance employee awareness, source reduction, and recycling initiatives; and a chargeback system that taxes waste generators to fund pollution-prevention initiatives.

Sandia's California and New Mexico sites have a Resource Conservation and Recovery Act permit for operation of our hazardous-waste management facility. Hazardous wastes are disposed at various commercial facilities. Compatible waste streams are consolidated at the hazardous-waste management facility to decrease costs. These consolidated streams are analyzed before disposal in accordance with the facility permit approved by both the federal and California environmental protection agencies. Low-level waste is disposed at the Nevada Test Site in compliance with DOE orders, Environmental Protection Agency requirements, and Nevada Test Site criteria.

Hazardous materials generated at the Tonopah Test Range in Nevada are shipped to commercial facilities for disposal within ninety days of generation. Several drums of legacy radioactive materials are stored on site, pending shipment to the Nevada Test Site. No radioactive wastes are currently generated by Sandia operations at Tonopah. The Kauai Test Facility generates small quantities of hazardous wastes, which are handled through the Navy Pacific Missile Range waste management program or by commercial treatment and disposal facilities. No radioactive or mixed wastes are generated at the Kauai site.

6.1.5.2 Environmental Restoration Operations

The Environmental Restoration Project addresses legacy contamination resulting from past releases of hazardous, mixed, and radioactive contaminants at approximately two hundred Sandia/New Mexico sites. The project has also had responsibility for about twenty sites at Sandia/California and for sites at Kauai (Hawaii), Tonopah (Nevada), and other locations.

We assess the known and potential release sites and take remedial action if necessary. Assessment and remediation are conducted in full compliance with all applicable laws, regulations, and DOE orders. The primary regulatory driver for the Sandia/New Mexico Environmental Restoration Project is the Resource Conservation and Recovery Act Hazardous and Solid Waste Amendments. Activities at Sandia's Chemical Waste Landfill are regulated under applicable Resource Conservation and Recovery Act closure requirements. The primary regulatory drivers for Sandia/California are laws and regulations governing groundwater quality. Remedial actions at Sandia/California have been completed. Groundwater monitoring requirements to ensure that cleanup was completed have been established with the California Environmental Protection Agency. Remedial actions at Sandia/New Mexico are scheduled to be completed by the end of FY 2005. However, the impacts of proposed budget cuts by the new administration have not yet been fully assessed. In addition to completing the required remedial actions, Sandia is planning long-term environmental stewardship activities to ensure that public health and the environment continue to be protected after environmental restoration operations are completed.

Sandians Cliff Ho and Henry Bryant deploy an electronic "sniffer" at the Chemical Waste Landfill. The sniffer can detect toxic chemicals in the field.

6.1.5.3 Environmental Technology Development

Sandia's Environmental Technology Development Program encompasses a range of customer needs. We develop technology for waste management and environmental restoration, supply information management and decision support, and provide monitoring/sensor systems for environmental applications.

Sandia's research and development supports the destruction or separation of hazardous materials and waste. Our

technology in combustion research and chemical sciences is the basis for much of this work. Sandia's Combustion Research Facility is developing a fundamental understanding of both thermal and nonthermal waste-destruction technologies. We provided significant systems-level development of supercritical water oxidation systems, steam reforming, and incineration processes. For contaminant removal and isolation, we developed inorganic ion-exchange material for radioisotopes, regenerative mercury filters for mixed-waste treatment, and supercritical carbon dioxide systems for extracting organics from waste. We also contribute solutions for major waste management problems such as the cleanup of Hanford waste tanks, including development of nonradioactive simulated wastes for test purposes and monitoring contaminant movement beneath leaking tanks.

We focus Sandia's environmental restoration technology on developing better ways to clean up the DOE's contaminated sites. We develop technologies and systems for quicker, safer, and more efficient site remediation. Sandia has development, demonstration, and evaluation roles in landfill covers, permeable reactive barriers, impermeable containment barriers, verification and monitoring systems, and in situ destruction of contaminants technologies. We contribute to the science base for significant issues such as contamination of groundwater and vadose zone water. In addition, Sandia's Innovative Treatment and Remediation Demonstration Program applies technology to problems while providing test and evaluation data. Sandia established the Subsurface Flow and Transport Laboratory to increase understanding of the fundamental processes involved in fluid flow and contaminant transport through rocks and soils. This experimental laboratory includes state-of-the-art quantitative flow and transport visualization using high-resolution image acquisition and analysis. Sandia involves academic and industrial users in the transport laboratory to create a research center of excellence serving the needs of geoscience programs within the DOE.

Sandia's large robotics program applies advanced controls to standard industrial robotics hardware for nonstandard applications. For example, hazardous waste cleanup requires affordable systems to retrieve the waste, monitor its condition, ensure environmental and human safety, and meet changing legal and regulatory requirements. Sandia developed the control system for the robot arm projects that assist in the cleanup of underground storage tanks and the field use of a telerobotic vehicle for retrieval of hazardous materials from buried waste sites.

Risk assessment, decision support, and information management have been a vital part of many programs at Sandia for decades. We now apply this expertise to a wide range of environmental projects. Our tools and techniques allow us to identify the hazards associated with a technical system, find solutions, determine the risks of identified hazards, and reduce risks to acceptable levels through appropriate design, control, and decision methods. The techniques have particular applicability in the environmental arena, where information may be limited and the cost to acquire additional data may be high. These tools enable users to perform risk- and cost-related analyses of site-remediation activities. Such analyses are used to optimize the data-collection process for groundwater monitoring, well placement and sampling, characterization studies prioritization, radionuclide and hazardous-materials risk assessment, and site ranking.

Sandia has decades of experience in the development and use of methods for sensing and interpreting environmental information. Sandia's sensor development program extends the state of the art in sensor technologies for defense systems, commercial manufacturing, and environmental monitoring. We develop complete systems for monitoring multiple media (air, water, and soils) and systems for characterizing conditions during manufacturing or waste-treatment processes. Sandia technologies include contaminant monitors such as portable acoustic wave sensors for volatile organic compounds, chromatographic separation/laser detection systems for monitoring low-volatility organics at molar concentrations, miniature fiberoptic chemical sensors for volatile organic compounds and metals, tunable diode lasers for ammonia, metal-emissions monitors based on laser spark spectroscopy, and mercury monitors. We also provide

- radiation detectors for elemental and radionuclide detection (ambient-temperature x- and gamma-ray detectors and volume-integrating and imaging systems);
- remote optical monitoring systems (multispectral ultraviolet-light detecting and ranging [lidar] technology and ultraviolet dual-infrared absorption lidar for ozone and water-vapor detection);
- geophysical imaging and characterization systems (two- and three-dimensional high-frequency seismic and electromagnetic imaging, borehole radar, and ground-penetrating radar);
- in situ permeable-flow sensors; and
- time-domain reflectometry sensors for cone penetrometers.

We develop methods for emplacing sensors and complete systems for compiling and interpreting the resulting information. Initiatives are under way to develop revolutionary systems for the nation's environmental monitoring needs to support the DOE's long-term environmental stewardship responsibilities.

6.1.5.4 Nuclear Waste Repositories

6.1.5.4.1 The Waste Isolation Pilot Plant

Sandia is responsible for scientific studies and performance modeling to demonstrate the Waste Isolation Pilot Plant's suitability for long-term disposal of the DOE's transuranic waste. Sandia has provided a detailed geotechnical understanding of the Waste Isolation Pilot Plant site (located near Carlsbad, New Mexico) and scientific research on issues related to the disposal of transuranic waste. Sandia has served as the scientific advisor for the project since its beginning in the 1970s, and we will continue to provide scientific assistance for the recertification phase to meet the requirements of the 1992 Waste Isolation Pilot Plant Land Withdrawal Act and applicable long-term regulations. Sandia will provide scientific assistance at levels required by our DOE customer throughout the thirty-five-year operational phase of the facility, particularly in support of modifications to the certified basis and the five-year recertification applications required by regulation.

Performance Assessment

Sandia proposed to the DOE Carlsbad Field Office that a Performance Assessment Institute be developed in Carlsbad, New Mexico. The institute will consist of a high-performance computing center affiliated with a consortium of universities and national laboratories. Sandia's National Transuranic Program will be the primary customer for the institute, which will also develop broad capabilities applicable to relevant global technical areas.

Performance assessment of environmental issues includes analyses of processes and events relevant to the issues and comparison of proposed management options to a specified performance measure. A performance assessment can range from deterministic analyses (using simplified models) through discrete process modeling and decision analysis to large-scale simulation of complex models within a probabilistic framework. Analysis of inherent risks to health and safety will be embodied in all approaches. The institute will provide a scientific basis for performance-based regulatory approaches to environmental issues. The Performance Assessment Institute's capabilities will include

- analyses of Waste Isolation Pilot Plant compliance with Volume 40 of the Code of Federal Regulations: Part 191-Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Part 194-Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; and Part 262-Standards Applicable to Generators of Hazardous Waste;
- removal, remediation, or containment of hazardous contaminants in storage facilities, surface soils, surface water, and subsurface environments at sites across the DOE complex;
- transportation and permanent surface or deep geologic disposal of hazardous and radioactive wastes; and
- risk assessments for pollution and cleanup along the US/Mexico border.

The Performance Assessment Institute will develop innovative performance assessment technologies, train professionals in the public and private sectors, and ensure rapid deployment of new technologies. The institute will foster recognition of the DOE Carlsbad Field Office and all participants as experts in hazardous and radioactive waste management. An educational program at the College of the Southwest, the Carlsbad Environmental Monitoring and Research Center, waste characterization and experimental facilities operated by Sandia and Los Alamos national laboratories, and a proposed International Center for Excellence in Regulatory Science will complement the institute.

Interpretation of Monitoring Data

Sandia's interprets data collected within the regulated monitoring program (hydrologic, geomechanical, human, and air) and recommends strategies that improve the overall monitoring objectives of the program. Contrary to the performance assessment conceptual model, water levels are rising in the Dolomite above the repository, so Sandia is evaluating the cause and the effect on performance.

Also, parameters monitored in the underground do not correlate well with those implemented in performance assessment. An experimental program is under way to improve this correlation and find viable monitoring methods.

We are also developing a repository air monitoring program that will eliminate the need for head space gas sampling of waste drums. The new program will almost certainly use new technologies developed by Sandia (e.g., the Microchemlab).

Performance-Based Requirements for Waste Acceptance

A proposal has been made to better understand repository performance to reduce uncertainty in the waste inventory. This work was recommended by the National Academy of Sciences at the time of certification. The performance assessment will be required to develop a more detailed understanding of both the near and far fields.

6.1.5.4.2 National Transuranic Waste Program

Sandia supports the DOE Carlsbad Field Office in US transuranic waste management efforts. After the Waste Isolation Pilot Plant (WIPP) opened in March 1999, we focused on meeting the DOE's disposal goals and optimizing the transuranic waste system. This system consists of twenty-three sites across the country that supported the nation's production and testing of nuclear weapons. Transuranic waste was generated and is stored at these sites. Additional transuranic waste will be generated as a result of cleanup and decommissioning efforts. The transuranic waste system includes the WIPP disposal site near Carlsbad, New Mexico and associated transportation elements.

Sandia's transuranic waste program supports the DOE's effort to progress from the current level of waste disposition to a full system capability, to remove obstacles associated with waste disposition, and to make the system more efficient.

Sandia has competencies in systems engineering, operation analysis, and discrete-event simulation modeling. A discrete-event simulation model for the transuranic waste system developed prior to the opening of the WIPP is now being revised, based on actual system performance data. Analyses performed with the system model are used to support decisions affecting operations across the transuranic waste system.

6.1.5.5 Nuclear Materials Management

6.1.5.5.1 Nonactinide Isotopes and Sealed Sources Management Group

Sandia is the lead laboratory for the Office of Environmental Management's Nonactinide Isotopes and Sealed Sources Management Group, one of five nuclear materials management groups created to ensure nuclear materials integration across the DOE nuclear materials complex. This group provides a structure for integrated cradle-to-grave management of nonactinide isotopes and sealed sources (NISS). A complex-wide program provides consistent use, reuse, recycle, and disposal options to sites with excess NISS.

6.1.5.5.2 Nuclear Materials Focus Area

Sandia is one of three co-managers of the Office of Environmental Management's (EM's) Nuclear Material Focus Area (NMFA). The NMFA is one of five strategic focus areas created to address environmental consequences from the production of nuclear weapons. Specifically, the NMFA is chartered to develop and deploy new technologies for nuclear materials stabilization and disposition, enable progress toward meeting the Accelerated Paths to Closure objective, develop integrated solutions to obtain both multisite and multiprogram benefits, and provide research and development support for DOE responses to Defense Nuclear Facilities Safety Board recommendations.

The NMFA is addressing the legacy from five decades of Cold War nuclear weapons production that includes nuclear materials owned by EM and nuclear materials belonging to other DOE programs stored in EM facilities. The NMFA is organized under the Office of Science and Technology (EM-50) into five management and technology development product lines: Material Processing, Long-term Storage, Packaging, Transportation and Storage, Spent Nuclear Fuel, and Nuclear Materials Stabilization.

6.1.6 DOE's Assistant Secretary for Renewable Energy

Sandia supports the DOE's National Energy Strategy goal of providing secure, affordable, and environmentally acceptable energy supplies by improving energy infrastructure surety and energy production, conversion, and use. We have more than twenty-five years of experience in energy research and technology development. Our programs include energy storage systems, hydrogen storage, geothermal energy systems, solar electric technologies, wind energy, and industrial and transportation applications. These programs are closely coordinated with industry, allowing Sandia to develop strong technology partnerships and to focus research and development efforts on major national needs. We also provide support for DOE's energy transmission reliability and distributed energy resources programs.

We are studying the reliability of the electric power grid using modeling, simulation, and risk assessment methods. We are also developing a highly secure Supervisory Control and Data Acquisition system to reduce the vulnerability of the power grid to cyber threats.

We are analyzing the portfolio of the DOE's energy research and development projects. At the request of the Under Secretary of Energy, we modeled the carbon emissions and environmental impact of using different sources to generate electricity.

We cooperate with the DOE and with industry in demonstration projects that strengthen the competitive position of US industry. Our efforts are international and support the DOE's global policy. We use Sandia's research foundations to assist industry in improving the manufacturability and cost competitiveness of renewable energy systems.

6.1.6.1 Energy Storage Systems

Sandia is collaborating with industry, academe, and international groups to develop advanced stationary energy storage components and systems for the DOE Office of Power Technologies. These systems are critical to the success of the nation's energy future. We use cost-shared, competitive contracts with industry partners to develop both advanced technologies and highly integrated components and systems. We use our technical expertise to manage these contracts,

analyze the benefits of storage in utility and renewable energy systems, evaluate prototype storage components, and conduct applied research. Successful development of cost-effective energy storage systems will increase the energy security of the nation, increase use of renewable resources, and improve the power quality and reliability of the electricity supply-estimated to be worth about $150 billion annually.

6.1.6.2 Hydrogen Storage and Utilization

The public is concerned about the environmental impact of hydrocarbon use and especially about the increasing national dependence on foreign petroleum supplies. Hydrogen offers significant advantages over other alternative fuels, including the potential for generating no harmful pollutants. Hydrogen can be produced domestically from hydrocarbon energy sources. When combined with carbon dioxide sequestration, this represents a carbon-free energy resource. Also, hydrogen can be produced domestically from renewable energy sources to create a sustainable, environmentally benign energy system.

Sandia is advancing the use of hydrogen with programs that span most of the DOE's hydrogen research. These programs include basic and applied hydride material research, hydrogen storage systems engineering, basic and applied hydrogen combustion research for stationary and mobile applications, and applied fuel cell systems for distributed utility applications.

We are investigating hydride storage materials to develop and demonstrate storage systems that fully use the volume density and safety advantages of hydrides. This effort focuses on magnesium alloy hydrides because of their relatively low cost and potential weight advantage over other hydride systems. Sandia also is collaborating with the University of Hawaii to investigate catalyzed hydride materials. These newer materials can increase hydrogen storage capacity without significantly increasing weight.

Sandia also is developing a fundamental understanding of hydrogen-enriched combustion of hydrocarbon flames for stationary power turbines. Such lean, premixed systems address carbon management issues within our existing hydrocarbon infrastructure.

We provide the technical and management lead for the hydrogen program in areas involving infrastructure, combustion end-use, hydrogen storage, systems integration, and hydrogen power parks. We are also developing methods for producing clean hydrogen using dehydrogenation catalysts and advanced separation membranes.

Sandia analyzes complex problems in the hydrogen energy field. We use engineering systems analysis to investigate phenomena ranging from the detailed chemical and physical behavior of solar-thermal hydrogen production to the use of hydrogen in renewable distributed energy systems.

6.1.6.3 Geothermal Systems

Much of the cost of generating electricity from geothermal sources is associated with drilling and completing wells. Consequently, we focus on new drilling and completion technologies to help expand the commercial use of US geothermal resources.

Sandia develops technology to increase the rate of penetration and extend drill-bit life in hard, abrasive formations; to better detect and control lost circulation; to better characterize wellbore and reservoir conditions with high-temperature instrumentation derived in part from National Nuclear Security Administration Defense Programs work; and to transmit data from the wellbore to the surface using wireless telemetry. We also are developing a new drilling system to sense conditions underground at the bit, enabling the driller to avoid conditions now impossible to predict or perceive from the top of the well. This system combines the latest in information and communication technology with advanced sensors and drilling tools to dramatically improve drilling performance for the geothermal, oil, and gas industries.

6.1.6.4 Solar Energy

6.1.6.4.1 Concentrating Solar Power

Sandia's Concentrating Solar Power Program teams with manufacturers to improve reliability, decrease costs, and increase acceptance of generating electricity using parabolic trough systems, dish/engine systems, and central receiver systems. We are the organizational headquarters of SunLab, a collaboration with the National Renewable Energy Laboratory that works to achieve the goals of the DOE's Concentrating Solar Power Program. Sandia helps develop commercial dish/Stirling systems; develops advanced components (dishes, heliostats, and receivers for dish, trough, and power tower systems); designs, analyzes, and tests components and systems at industry sites and at the National Solar Thermal Test Facility; and supports industries that promote the use of solar power concentration technologies.

6.1.6.4.2 Photovoltaics

Sandia is reducing both initial and life-cycle costs of photovoltaic energy systems produced by US industry and used worldwide. We team with others to accelerate development and acceptance of the technology at home and abroad.

Within the DOE complex, Sandia is the lead laboratory for balance-of-system and systems engineering. Through the National Center for Photovoltaics partnership, we work on all aspects of photovoltaic technology with the National Renewable Energy Laboratory. We are increasing reliability and thus reducing the life-cycle cost of photovoltaic systems. In particular, we assisted industry in developing and testing

a control methodology that enables multiple photovoltaic systems to interact with the electric grid safely and reliably. We also assist with high-value, off-grid applications in the United States and in partnership with the US Agency of International Development in Mexico and Central America.

6.1.6.4.3 Wind Energy Technology

Wind energy is the world's fastest-growing energy source, expanding at annual rates ranging from 25 percent to 35 percent during the 1990s. In CY 2000, about 3,500 megawatts of new wind energy-generating capacity were installed around the world, but only 53 megawatts of that total (a little more than 1 percent) were installed in the United States. However, the American Wind Energy Association expects as much as 2,000 megawatts of new US wind capacity to be installed during CY 2001. Sandia continues to apply engineering sciences to reduce the cost of wind-generated electricity to a competitive 2.5 cents per kilowatt-hour by early in the twenty-first century. Our research focuses on the wind turbine, including how it can be designed and manufactured to be both cost effective and highly reliable. We specialize in structural materials, manufacturing processes, and inspection techniques—using both analyses and experiments to increase US industry's knowledge base. Our work is conducted under the auspices of the DOE's Office of Energy Efficiency and Renewable Energy. We team directly with other government laboratories and work closely with wind turbine designers and manufacturers and their component suppliers.

Sandia's wind turbine generator produces 660 kilowatts of electricity from winds blowing between eight and thirty-five miles per hour.

6.1.6.5 Industrial Sector

6.1.6.5.1 Combustion Technology

Sandia's Combustion Research Facility, a DOE Office of Science user facility,[2] is used for experimental, theoretical, and computational investigations to reduce energy consumption and environmental impacts while broadening our science and engineering foundations. This work uses unique laser diagnostic capabilities.

Sandia collaborates with industry on its combustion projects. We are reducing emissions without compromising fuel efficiency, developing improved technologies for internal combustion engines and industrial processes, and improving systems for the destruction of hazardous wastes.

6.1.6.5.2 Materials Processing by Design

Sandia's materials processing programs work to improve existing processes and to develop new commercially and environmentally acceptable methods for the glass, chemical, petroleum, steel, metal casting, aluminum, 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. Our present focus is on development of predictive models of high-temperature chemicals and materials synthesis processes.

6.1.6.5.3 Advanced Industrial Materials Research

Sandia's materials research work for the DOE Office of Industrial Technologies provides computer-aided design, synthesis, characterization, and testing of new materials with the potential for energy savings and waste reduction in industrial applications. This work addresses key strategic needs identified by industry and typically is performed with industrial cooperation and cost sharing. Our focus is on using selective inorganic thin films for energy savings by improving performance of light gas membranes and catalysts, synthesizing novel metal matrix composites by reactive metal infiltration, and optimizing composites manufacturing processes with model-based controls.

[2] See section 8.2.2 for a complete list of Sandia user facilities.

6.1.6.5.4 Catalysis and Separations Science and Engineering

Catalysis and separations underlie nearly all processes for producing fuels and chemicals. These processes also protect the environment by separating and converting waste to less harmful forms. Catalysis is involved in more than 20 percent of the US national gross domestic product (approximately $1 trillion annually) and new separation technologies offer the potential for multibillion-dollar savings when used in energy-intensive industries and for the cleanup of industrial and radioactive waste sites.

6.1.6.6 Transportation Sector

Sandia is developing the technology base to improve efficiency and reduce the environmental impact of automobile and truck engines. This work supports automobile manufacturers and heavy-duty diesel engine manufacturers.

Sandia has capabilities in instrumentation, sensing, analysis and control of manufacturing processes, development and application of lightweight materials, supercomputing, structural analysis, fluid dynamics, combustion, mesh generation, and visualization. These capabilities are supported by the DOE Office of Energy Efficiency and Renewable Energy and the Office of Science. We have developed numerous cooperative research and development projects with US vehicle and engine manufacturers.

Sandia has cooperative research and development agreements with the Low Emission Partnership of the Partnership for a New Generation of Vehicles. These agreements develop the research and technology base for improved after-treatment devices, sensors, and advanced direct-injection gasoline engines.

Sandia also works closely with the US Advanced Battery Consortium to develop electric vehicle battery technologies. This work will produce cost-effective electric vehicles.

6.1.7 DOE's Office of Civilian Radioactive Waste Management

Sandia's main activities for the Office of Civilian Radioactive Waste Management address the geologic disposal of spent fuel and high-level radioactive waste.

The Yucca Mountain Site Characterization Project[3] is investigating the feasibility of isolating high-level radioactive waste in unsaturated volcanic tuff. The potential site is at Yucca Mountain in southern Nevada, adjacent to the Nevada Test Site. As a member of the management and operating contractor 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 compliance with regulatory standards. Sandia's specific responsibilities in this multifaceted project include:

- scenario screening and analyses;
- saturated zone and unsaturated zone flow and transport analyses;
- waste form, waste package, and drip shield degradation analyses;
- drift-scale thermal tests;
- coupled processes analyses;
- data and software verification;
- uncertainty and sensitivity calculations; and
- international peer review support.

In mid-November 2001, Sandia will assist the DOE in preparing and submitting to the Secretary of Energy the site recommendation decision materials, including performance assessment calculations and site characterization studies. The Secretary of Energy will decide whether to recommend to the President that he designate Yucca Mountain as the repository site.

6.1.8 DOE's Office of Nuclear Energy

6.1.8.1 Nuclear Energy Research and Development

The nation is increasingly aware that we need a robust nuclear energy program to ensure a reliable and secure supply of electricity. Nuclear power plants generate about 20 percent of US electricity, and the DOE sponsors several research and development programs to extend existing plant life and develop future plant designs. Sandia actively participates in these programs using our broad base of modeling, experimental, and analytic capabilities:

The joint DOE/Electric Power Research Institute-sponsored Nuclear Energy Plant Optimization Program conducts research to ensure that existing nuclear plants can continue to deliver adequate and affordable energy supplies beyond their initial forty-year license period by resolving open issues related to plant aging and by applying new technologies to improve plant reliability, availability, and productivity. Sandia's broad knowledge of reactor safety concepts enables us to help the DOE and industry identify and prioritize research necessary to maintain safe operation until the end of plant life. Also, we use our extensive materials science capabilities to understand plant aging processes and to develop practical monitoring techniques.

The DOE's Nuclear Energy Research Initiative encourages the development of innovative nuclear power concepts by cooperation among the national laboratories, academe,

[1] The Yucca Mountain Site Characterization Project is funded via an inter-DOE work order. Funding is included in chapter 9 under the entry for All Other Federal Entities.

Sandia is developing a new generation of safe and efficient nuclear reactors. This structure is the largest containment ever tested to failure.

and industry. Reactors that are inherently safe, proliferation-resistant, modular, and low cost are highly desired for next-generation plants. Sandia is active in seven projects that include direct energy conversion, high-temperature gas-cooled reactors, smart sensors, lower cost construction, and understanding reactor pressure vessel lower head failure.

The Nuclear Energy Technologies program is developing a next-generation technology roadmap detailing the research required to develop the most promising concepts of the Generation IV Nuclear Energy Systems Initiative. Generation IV nuclear energy systems will offer significant advances in sustainability, safety, reliability, and economics. Sandia is an active contributor to roadmapping and strategic planning events. We are focused on very high temperature, very high efficiency plant concepts with coproduction of hydrogen for use as transportation fuel.

We coordinate our nuclear energy research and development through our interdisciplinary nuclear initiative team, which contributes a range of technologies to the design, reliability, safety, and security of existing and future nuclear power plants.

6.1.8.2 Isotope Production and Distribution Program

Sandia's role in medical isotope production ended during FY 2001 when our commercial partner ceased distributing iodine 125. In prior years, attempts by DOE to attract a commercial partner to use Sandia production facilities to produce molybdenum 99 (from which technetium 99m is extracted for use as a medical isotope) were unsuccessful. Meanwhile, international sources for medical isotopes have become more diversified, decreasing need for Sandia to provide backup production. The Hot Cell Facility has been mothballed, and the Annular Core Research Reactor is configured in the pulsed mode for testing weapons components.

6.1.8.3 Space Nuclear Power

Sandia provides leadership in systems and technology integration for the near-term space fission system concept team as part of the DOE's special purpose fission technology effort. As more advanced space exploration missions are planned, spacecraft propulsion requirements exceed the power available from solar and chemical systems. Therefore, the need exists to investigate space nuclear reactor concepts.

6.1.9 DOE's Assistant Secretary for Fossil Energy

Sandia's Fossil Energy Program supports DOE Fossil Energy research and development programs. These programs seek to reduce emissions from power plants, develop both miniature and multimegawatt fuel cells, enhance natural gas production by a trillion cubic feet per year, and add a million barrels a day to domestic oil production. In addition to the Office of Fossil Energy at DOE, primary customers include major and independent oil companies, drilling companies, and industry associations such as the Gas Technology Institute.

6.1.9.1 Downstream Processing

Downstream processing develops catalysts for separation needs and conducts combustion research. We continue to investigate carbon-sequestration methods and the feasibility of process optimization techniques for separating petroleum products.

We develop materials, catalysis and separation technology, sensors, and controls for combustion applications. We also develop fuel cell technology that can be fabricated on microchips for powering Sandia's Microchemlab.

Sandia is studying the combustion of coal and biomass fuels using bench, pilot, and full-scale experiments. We are developing in situ sensors to monitor combustion of these fuels and investigating predictive models of combustion behavior for use by US industry. This work is conducted in the coal combustion laboratory and the multifuels combustor at our Combustion Research Facility.

6.1.9.2 Upstream Exploration, Production, and Storage

6.1.9.2.1 Diagnostics and Imaging Technology

In partnership with Lawrence Berkeley National Laboratory and the Idaho National Engineering and Environmental Laboratory, Sandia is developing improved methods for seismic imaging of petroleum reservoirs. Advanced imaging and computer modeling also hold great promise for enabling the economic extraction of the nation's remaining known oil and gas reserves. Consequently, the United States may have better and more cost-effective access to existing domestic oil and gas fields.

6.1.9.2.2 Drilling, Completion, and Stimulation Technology

Sandia is taking a new approach to oil and natural gas extraction. We are extending our high-temperature drilling technology (developed under the geothermal drilling program) to exploring for deep reservoirs. This work involves improvements in bit design, downhole electronics, and information systems. Smart drilling and diagnostics-while-drilling technologies optimize the drilling process.

6.1.9.2.3 Oil and Gas Recovery Technology

We are using high-performance computing to analyze petroleum reservoirs in an attempt to achieve real-time reservoir management. Usually, only three-dimensional seismic data are analyzed to visualize the subsurface environment.

Sandia is developing better ways to pump oil from reservoirs through applied production technology and improved measurement of pump performance. This technology will aid independent oil and gas producers, who provide a major portion of domestic production.

As the geotechnical contractor for the DOE Strategic Petroleum Reserve, Sandia has extensive experience in developing safe underground oil and gas storage systems for commercial storage companies. The Strategic Petroleum Reserve stores nearly 600 million barrels of oil in more than sixty salt caverns and has just signed agreements to begin receiving additional royalty-in-kind oil and commercial oil. We are addressing technical issues concerning abandonment of the Weeks Island site, the long-term intrusion of gas into stored oil, and surface subsidence that results from closure of underground caverns.

The deregulation of natural gas and mandated access to gas pipelines have encouraged new commercial salt cavern gas storage development. We are supplying technology for the commercial development of gas storage salt caverns, which can accommodate short-term increases in consumer demand for natural gas.

6.1.9.2.4 Environmental Technology

Sandia has demonstrated methods for continuously monitoring particulate matter from engines and power plants used in oil- and gas-field production. These methods can be used to help meet clear air standards.

6.1.10 DOE's Office of Science Programs

Sandia is an important contributor to the DOE's mission of maintaining the nation's excellence in science to support energy, national security, and related technologies. Areas of research include fusion energy sciences, scientific computing, basic energy sciences, and biological and environmental sciences. In all these areas, we stress three important themes:

- excellence in scientific research;
- integration of research and development with DOE technologies; and
- collaboration with universities, industry, and other national laboratories.

Our programs support the DOE's objective of strength through science. Every phase of Sandia's research and development cycle integrates science and technology, including areas such as geoscience, combustion science, and scientifically tailored materials with new and unusual properties. In each case, basic research generates new knowledge, and our new understanding is integrated directly into DOE technology programs. We also have numerous interactions with other national laboratories, universities, and US industry.

We are determined to maintain the excellence of our basic research, which depends on our outstanding research staff.

6.1.10.1 Fusion Energy Sciences Program

Sandia's Fusion Energy Sciences Program is developing a technology base for the design of in-vessel components that will perform satisfactorily in fusion plasma environments. 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. The process 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, which uses high-power electron beams to generate high-heat fluxes that simulate fusion reactor environments. Materials and components are also exposed to tritium plasmas in Sandia's Tritium Plasma Experiment, located at Los Alamos National Laboratory. Materials from these tests and fusion devices are characterized using Sandia's accelerator facilities for ion beam

analysis. Experimental devices at Sandia/California are used to study plasma/materials interactions.

Sandia directly supports US and international fusion machines. This support includes tritium removal inventory support and materials postmortem analysis for the recently closed Princeton tokamak fusion test reactor; materials analysis and diagnostic development for the General Atomics DIII-D Advanced Divertor Project; and measurements of plasma/wall interaction in the C-Mod tokamak at the Massachusetts Institute of Technology and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory. We participate in collaborative experiments on the Joint European Torus in the United Kingdom, the JT-60U tokamak and the Large Helical Device in Japan, and the superconducting tokamak advanced research device in Korea.

In all these experiments, Sandia provides specialized diagnostics and data analysis for evaluating plasma/material interactions, boundary layer plasma control, and plasma-facing components. We also collaborate on plasma/material interaction and high-heat-flux issues with colleagues in Europe and Japan. At the DOE's direction, Sandia has entered into cooperative exchanges on plasma-facing component development with several laboratories in Russia. We completed a successful six-year collaboration on the design of the international thermonuclear experimental reactor as part of the US team collaborating with Europe, Japan, and Russia.

In 1999, the DOE started two new projects to find innovative solutions for plasma-facing components: the advanced limiter/divertor plasma-facing surfaces program and the advanced power extraction study. These projects use liquid surfaces facing the plasma (examples of liquids being studied are lithium, tin/lithium alloy, and lithium/beryllium fluoride). These studies are a joint effort of Argonne National Laboratory, General Atomics, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, Sandia, the University of Illinois, the University of California at Los Angeles, and the University of California at San Diego. We are using Sandia's unique test facilities and analytic capabilities to determine the heat-flux capability, particle pumping and retention characteristics, erosion rates, and design features of liquid walls in a fusion device. We are developing the diagnostics to measure steady-state heat flux on a flowing liquid and the effect of extremely intense, short-duration heat pulses on a liquid surface. We are working with other institutions to design and construct a variety of proof-of-principle liquid surface devices that can be tested in US fusion machines in the next three to five years.

Because of the increased focus in US fusion energy sciences on more compact, alternative concepts to the conventional tokamak, the issues of plasma/material interactions will be of greater importance in the future. Sandia is acting as a central resource for developing plasma-facing components to optimize the performance of alternative concepts. We also have started discussions with the inertial fusion energy community on future projects related to reactor chamber technology development. Our liquid wall research is directly related to many concepts for inertial fusion reactors.

6.1.10.2 Scientific Computing: Massively Parallel Computation

Sandia's computational sciences program creates modeling and simulation technologies for all Sandia strategic business units. The program develops numerical algorithms for solving scientific and engineering problems, a software and hardware infrastructure for parallel computing, and techniques for distributed computing. The work in numerical algorithms focuses on massively parallel computing-the scaling to tens of thousands of processors and to multiphysics problems with billions of degrees of freedom. Software infrastructure research includes work in parallel operating systems, mesh generation, static and dynamic load balancing, visualization, and user interfaces.

Sandia has played a leading role in massively parallel computing for more than a decade. During the past five years, Sandia and Intel have set many world records for computational speed. Sandia is the only institution in the world that has twice won the Gordon Bell Prize, given annually for the most significant achievement in parallel computing. Sandia has won numerous other national awards and has received patents for associated inventions. Our software is licensed and distributed worldwide.

Computational technologies are playing an important role in a wide range of Sandia programs. Examples include simulating the performance of weapons, analyzing weapons safety issues, computation-based design and manufacturing, and modeling and simulation of biological systems. An important goal is the creation of an easy-to-use design and analysis environment that seamlessly integrates model development, analysis, and postprocessing.

Distributed computing technologies are critical to our future computing requirements. Sandia continues to develop the next generation of massively parallel processing computers and is pioneering new techniques that will leverage commercial off-the-shelf hardware and software to create a rich computing infrastructure for simulation and visualization. The Computational Plant Project is creating many of the needed technologies and Cplant™ software is being developed. Sandia is also developing scalable rendering technology to deliver performance exceeding the highest commercial rendering systems.

6.1.10.3 Basic Energy Sciences

Sandia supports DOE Basic Energy Sciences with several research efforts. Larger projects include scientifically tailored materials and combustion research. Smaller projects include geoscience and engineering research.

6.1.10.3.1 Chemical Sciences

Sandia's largest project in chemical sciences is housed at the Combustion Research Facility, a DOE user facility. In

this facility, Sandia staff and visiting scientists study fundamental combustion processes.

The long-range objective of the Combustion Research Facility is to maximize energy efficiency, fuel utilization, environmental protection, industrial productivity, and equipment design. Studies supported by the DOE Office of Science include combustion chemistry, combustion diagnostics, reacting flows, and combustion modeling.

Work in combustion chemistry improves our understanding of the complex chemical processes involved when fuels burn. We determine the rates and mechanisms of elementary chemical processes with emphasis on the close coupling of experiment, theory, and modeling. Computer 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 the modeling of processes important to energy-producing technologies. We focus on the formation and destruction of nitrogen-containing pollutants, the oxidation of hydrocarbons, and the chemical paths leading to soot precursors in rich flames.

A primary thrust of this research is the development of advanced combustion diagnostic techniques. Because of their nonintrusive nature and improved versatility, we use laser-based optical techniques. Laser-induced fluorescence, quantitative imaging, cavity-ringdown absorption spectroscopy, and nonlinear optical wave mixing are among the diagnostic methods we are developing. These methods are used to measure temperatures, species concentrations, and other parameters important to understanding combustion phenomena.

A multidisciplinary program in reacting flows is an important link between studies of combustion chemistry and the world of practical combustion. This program increases our understanding of the fundamental interactions between chemistry and fluid dynamics in combustion. Results are used to improve predictive capabilities for turbulent combustion of hydrocarbon fuels. Research includes investigation of primary turbulent transport in flows involving complex fluid mechanics but simplified chemistry.

Sandia's combustion modeling program develops numerical methods to predict the mutual influences of chemical reactions and fluid transport. 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. Distributed and massively parallel computer architectures are enabling rapid advances in the realistic representation of the coupling between turbulence and fully detailed chemistry.

Major users of the Combustion Research Facility include those supported by the Assistant Secretary for Energy Efficiency and Renewable Energy and the Assistant Secretary for Fossil Energy. Users conduct industry-oriented research in transient and continuous combustion (including coal and biomass processes) and in advanced materials synthesis.

The DOE sponsors a vigorous 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 conduct basic and applied combustion research and publish their findings. Their participation helps transfer 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 combustion science and technology. Facility staff represent the United States in International Energy Agency programs in combustion energy conservation. International Energy Agency activities involve collaboration with foreign scientists in engine studies and coal research through an informal exchange program. The Combustion Research Facility remains the US focal point for generating and disseminating new knowledge that advances clean and efficient combustion.

6.1.10.3.2 Materials Sciences

Our Materials Sciences Program focuses on scientifically tailored materials. Research is ongoing in artificially structured materials, nanoscale sciences, defects and impurities in solids, and advanced techniques in the synthesis and processing of materials.

Scientifically Tailored Materials

Sandia's research in scientifically tailored materials combines theory and experiments in solid-state sciences, computational materials sciences, atomic-level diagnostics, and materials synthesis and processing to produce new classes of materials for the advancement of science, energy applications, defense needs, and industrial applications.

Scientifically tailored materials research uses capabilities developed in various projects to establish the state of the art in materials science and technology. 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 originated from research in this area.

We continue research in the physics and chemistry of ceramics; the use of energetic particle beams for the synthesis and study of materials; field-structured nanocomposites; tailored surfaces and interfaces for materials applications; chemical vapor deposition sciences; artificially structured semiconductors; advanced growth techniques and the science of epitaxy; transport in unconventional solids; atomic-level science of interfacial adhesion; synthesis and processing of nanometer-sized clusters for energy applications; wetting and flow of liquid metals and amorphous ceramics at solid interfaces; the science of localized corrosion; and the physics of nanostructured semiconductors. This last activity includes

composition-modulated semiconductor structures for photovoltaic and optical technologies, a joint effort with the National Renewable Energy Laboratory. Three new projects in the program deal with cooperative phenomena in molecular nanostructures, the science of dipolar nanocomposites, and plasma crystals. Considerable synergy exists among these program elements. Common themes are synthesis and processing, nanostructured materials, epitaxial materials growth, surfaces and interfaces, and the uses of energetic particle beams.

Research on compound-semiconductor strained-layer superlattices, quantum well structures, and other artificial structures is pioneering 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 group III to V semiconductors. The multiple thin layers behave macroscopically as 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 in other programs to develop new high-speed quantum 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 reduced-friction surfaces, coatings resistant to corrosion and wear, high-temperature superconductors, and optical materials.

Our 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 understand the atomic and molecular processes that govern their structure and properties. The goal is to improve ceramics processing and applications by gaining a better understanding of the underlying chemical and physical principles. We also are creating ordered organic/inorganic composites using self-assembly from surfactant-laced solutions.

Our research continues on atomic-level interfacial adhesion in order to understand the nature of the physical and chemical interactions that both bind solid surfaces and aid in lubrication. Although adhesion problems are pervasive in materials science and engineering, solutions usually are found through trial and error. Identifying a scientific basis to select material combinations for specific interfacial characteristics will bring significant technological and economic gains. This work is expected to have a significant impact on the development of micro- and nanotechnologies where issues of stiction, friction, wear, and lubrication are crucial.

The scientifically tailored materials program is investigating atomic-level processes that control the growth and properties of thin-surface layers. This program also is 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. We are also examining the properties of boron-rich solids and related materials, which have unique bonding, electronic, and transport properties. These refractory materials, which appear promising because of their distinctive properties as high-temperature semiconductors or in high-flux radiation environments, may have applications in high-efficiency thermoelectric energy generators and as neutron detectors.

We are using Sandia's patented technique for producing novel nanometer-sized clusters with potential applications in energy technologies. These clusters are aggregates of a few hundred 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. Our research emphasizes inexpensive metal and semiconductor clusters as alternatives to precious metal catalysts for coal liquefaction, environmental remediation, and solar photocatalysis.

In more recent efforts, we are examining the mechanisms of localized corrosion in passive metals by using nanofabrication techniques to create controlled defects and advanced characterization tools to understand their role in pit initiation; using compound semiconductor surfaces to capitalize on their light-emitting characteristics for probing biological systems; creating novel ceramic/polymer and metal/polymer electric or magnetic field-structured nanocomposites with tailorable one- or two-dimensional anistropic properties; developing energy-efficient nitrogen-based semiconductors with unusual optical and electronic properties; investigating the physics of electronic transport in quantum confined semiconductor structures; and establishing the scientific principles needed for the design of molecular nanocomposite architectures that yield responsive materials with desired functions and performance.

Defects and Impurities in Solids/ Computational Materials Science

Crystalline defects and impurities often determine the properties of solids. This program seeks to understand and control such imperfections, which are crucial to technological applications of solid materials.

We combine unique experimental and theoretical tools developed in this program 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 instruments, video low-energy electron diffraction, surface analysis, scanning tunneling microscopy, and low-energy electron microscopy. Theoretical tools developed and employed include local density approximation/pseudopotential methods, the embedded atom method, and cluster functional methods for large-scale atomic-level computer simulations.

These tools are used to study the structural and dynamic properties of 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. We investigate the growth of metal layers on substrates 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 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. Results are disseminated to materials science programs at universities and industrial research and development laboratories via Sandia's visiting scientist program in computational materials science. Collaborations with industry are also established through cooperative research and development agreements.

Synthesis and Processing Center

Sandia coordinates activities within the DOE Center of Excellence in Synthesis and Processing of Advanced Materials. This center is a cooperative venture that involves Sandia and eleven other national and university laboratories. The center brings together elements of the existing basic energy sciences core programs at these laboratories and also includes appropriate university grant research funded by DOE Basic Energy Sciences. The center enhances the science and engineering of materials synthesis and processing to meet the 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 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.

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. In application, synthesis and processing translate scientific results into useful materials by developing processes capable of producing high-quality, low-cost products. A technology steering group guides the research and development agenda of the center.

The center has developed a number of multilaboratory projects. The selection criteria are outstanding science with a clear relation to technology, existing or potential connections to DOE-funded programs, and existing or potential in-kind partnerships with industry. At present, the center emphasizes eight multilaboratory projects:

- nanoscale phenomena in perovskite thin films,
- isolated and collective phenomena in nanocomposite magnets,
- science of localized corrosion,
- smart structures based on electroactive polymers,
- high-efficiency photovoltaics,
- design and synthesis of ultrahigh-temperature intermetallics,
- controlled defect structures in rare-earth superconductors, and
- interfacial adhesion related to protective oxides grown on metallic substrates.

Nanoscience Integration Center/ Computational Materials

Nanoscience is exploiting novel properties and phenomena that result from nanometer-scale control of materials and structures. We are bringing together tools to synthesize, experimentally measure, model, and integrate nanoscale materials into structures and devices. We focus on multidisciplinary research in materials science, chemistry, physics, biology, and microfabrication.

Sandia participated in planning two new networks of cooperative research teams at DOE laboratories, at universities, in other government laboratories, and in industry. The Computational Materials Science Network is modeled after the DOE's Center of Excellence in Synthesis and Processing of Advanced Materials and is sponsored by the Division of Materials Sciences, Office of Basic Energy Sciences. The network is advancing computational materials science to solve materials problems that require cooperation across organizations and disciplines. Sandia contributes expertise in first principles and continuum modeling.

A new nanoscience network has been recently formed between DOE Basic Energy Sciences and National Nuclear Security Administration Defense Programs to link advances

in nanoscience and technology to national security needs. We played a key role in the planning of this activity, which was also modeled after the Synthesis and Processing Center. Again, various national laboratories, universities, and industrial partners are involved in these collaborative efforts based on existing program directions.

Center for Integrated Nanotechnologies

Sandia, Los Alamos National Laboratory, and the University of New Mexico are developing plans for a Nanoscience Research Center (NSRC) in New Mexico. This will be one of five regional NSRCs sponsored by the Office of Basic Energy Sciences. The New Mexico Center will be named the Center for Integrated Nanotechnologies (CINT).

The CINT will determine the scientific principles that govern the performance and integration of nanoscale materials and will educate a new generation of scientists, thereby building the foundation for future nanotechnologies. We expect the CINT to play key roles in

- advancing understanding and control of materials at the nanoscale;
- providing nanofabrication, characterization, theory, and integration capabilities that leverage existing facilities and expertise;
- providing a broad interdisciplinary research environment that stimulates new collaborations among national laboratories, academe, and industry; and
- educating a nanoscience work force and developing future technologies.

The CINT's technical focus will be on the following four thrusts: nanophotonics and nanoelectronics, complex functional materials, nanomechanics, and nano/bio/micro interfaces.

6.1.10.3.3 Geosciences

Sandia's basic geoscience research provides an improved scientific basis for advanced energy and environmental technologies. The mix of DOE Basic Energy Sciences projects changes every year in response to evolving initiatives and new research efforts. Sandia's geoscience research includes applications to nuclear waste repository design, fossil energy exploration and production, environmental and nuclear waste remediation, global climate change, geologic sequestration of carbon dioxide, battery development, and geothermal energy exploration. Our geoscience research has four fundamental thrusts: geochemistry, geohydrology, geomechanics, and geophysics.

Geochemistry research projects emphasize a mechanistic and atomistic understanding of interfacial and bulk mineral processes using a combination of techniques. Research utilizes empirical and ab initio molecular modeling codes to simulate clay and carbonate mineral bulk structures, relaxed surface structures, and fluid/mineral contaminant sorption interactions. This work provides a better understanding of contaminant sorption, weathering, and materials science processes.

Geohydrology research focuses on detailed physical experiments and high-resolution numerical modeling of fluid flow and mass transport in porous and fractured media. Projects include defining capillary, gravitational, and viscous forces controlling fracture flow and transport of multiphase fluids; understanding gas/liquid interfacial processes in soils or rocks; characterizing and understanding geomedia properties that govern permeability upscaling; exploring mass and heat transport of dissolved and suspended particles in porous media and fractured rocks; and determining the role of fracture intersections on flow and transport. We will use these projects to improve models and computer codes to better understand and predict fluid flow through complex geologic media.

Geomechanics research combines experimental, analytic, and numerical studies of inelastic deformation of geomaterials with confining pressure and pore fluids, and microscale flow modeling and brittle failure processes in porous media. Projects include an evaluation of fluid flow on inelastic deformation, failure during dilation and compaction of rocks, and the characterization and prediction of flow in porous media under compressive stress. This research provides a better understanding of the mechanics affecting underground structures and oil reservoirs.

Geophysics research develops computer algorithms to improve subsurface imaging of complex geologic structures and fluid flow. Projects include development of three-dimensional inversion techniques to interpret field and synthetic seismic and electromagnetic data, numeric waveform inversion algorithms to accommodate three-dimensional heterogeneity, and massively parallel computational approaches and algorithms for terabyte-scale, three-dimensional data sets. This work will provide a methodology to better interpret geophysical signals from subsurface geologic and manmade structures.

6.1.10.4 Biological and Environmental Research

During the past several years, global climate change has become an important component of national and international science and policy agendas. Although most scientists agree that human-made, energy-related emissions may cause a greenhouse warming effect, uncertainty exists about the magnitude, timing, and distribution of this phenomenon. To better understand such issues, the US government is conducting a global climate change research program and the DOE is a major participant. To support the DOE, Sandia uses expertise in remote sensing, field testing, and systems engineering to assist both the Atmospheric Radiation Measurement

Program and its airborne adjunct, the Atmospheric Radiation Measurement Unmanned Aerospace Vehicle Program.

The DOE's Atmospheric Radiation Measurement Program seeks to better understand earth radiation field/cloud interactions by studying these processes at intensively instrumented cloud and radiation testbed sites. Sandia's four key roles in these activities are described below.

6.1.10.4.1 Development and Monitoring of New Instruments

The cloud and radiation testbed sites are climate observatories. As such they require highly sophisticated instrumentation that can operate in the field around the clock, all year, with minimal operator attention. One critical need is water vapor profiles. Water vapor plays a key role in cloud formation and in propagation of the earth's thermal energy through the atmosphere, yet existing instrumentation lacks adequate vertical and temporal resolution. During the past several years, 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 both night and day. In 1996, we successfully placed this system in a fully automated field unit now in place at the Oklahoma cloud and radiation testbed site. Since then, the unit has been operating continuously as one of our base-line instruments. We continue to work on extending the capabilities of this instrument both to higher altitudes and to the retrieval of aerosol properties. We are also working on the site integration, algorithm development, and data handling of wide-field-of-view cameras developed by the Scripp's Institute for measuring cloud distributions in the sky. We have already developed an operational data instrument that provides atmospheric radiation measurement scientists with summary statistics of the local cloud field several times per hour. We also have demonstrated that these same instruments can provide quantitative radiometric maps of the diffuse portion of the sky's solar radiation-information very difficult to obtain by any other means

6.1.10.4.2 Site Manager for the North Slope of Alaska Cloud and Radiation Testbed Site

Our principal site on the North Slope of Alaska began operating in 1997. This site is a long-term facility near Point Barrow at the northernmost tip of Alaska, just outside the town of Barrow. A secondary site near the village of Atqasuk, 100 kilometers inland from Barrow, began operations in 1999. The instruments for Atqasuk had previously been located aboard an icebreaker frozen into the Arctic ice pack for a year during 1997 and 1998. The North Slope of Alaska and adjacent Arctic Ocean locale was chosen because evidence from Greenland ice cores suggests that the Arctic exerts a controlling influence on global climate and because the Arctic exhibits 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). These factors provide an opportunity to conduct stringent tests of our understanding of the earth's radiation and cloud interactions. Sandia manages the planning, implementation, and operation of this site. Also, we 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 arctic environments, especially the National Science Foundation's Arctic Systems Science Program and the National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory Barrow Station.

6.1.10.4.3 Unmanned Aerospace Vehicle Program

The Atmospheric Radiation Measurement Program emphasizes ground-based measurements. However, airborne measurements are critical for obtaining information about radiative fluxes, water vapor profiles, and cloud top properties in the atmosphere. An ideal measurement platform is an aircraft that can hover continuously at high altitudes above a cloud and radiation testbed site. The DOE asked Sandia to lead a multilaboratory program to develop the necessary instrumentation and measurement techniques to use unmanned aerospace vehicles for climate measurements. In 1996, the newly developed General Atomics Altus unmanned aerospace vehicle conducted a record-setting continuous scientific flight of twenty-six hours over the Oklahoma cloud and radiation testbed site. In 1997, the Altus set a new altitude record of 43,500 feet for a single-stage turbocharged engine and was used as part of a large test at the atmospheric radiation measurement site. In 1999, in a joint mission with the National Aeronautics and Space Administration, we used a two-stage turbocharged Altus to extend these measurements to 55,000 feet and study tropical cirrus clouds and their effect on the radiation budget. The instruments on the Altus and on the Twin Otter aircraft that flew directly below it allowed Sandia to measure the up- and down-welling fluxes above and below cirrus clouds and also to relate these to the cloud microphysical properties measured by instruments aboard both aircraft. This mission provided a unique and valuable data set.

In addition to unmanned aerospace vehicle-based measurements, the Atmospheric Radiation Measurement Program also obtains manned aircraft measurements as appropriate. We used the Twin Otter to continue our investigations of the so-called enhanced absorption effect, that is, whether clouds absorb significantly more solar radiation than predicted by models. Preliminary analyses indicate some solar absorption in excess of most model calculations, but the observed effect was smaller than that observed in the Atmospheric Radiation Measurement Enhanced Shortwave Experiment.

6.1.11 Integrated DOE Activities (Work for Other DOE Locations, Contractors, and Offices)

Sandia performs work for other DOE elements as requested to support programmatic and institutional requirements. Requests may include special programs administered by DOE Headquarters, DOE field offices, and facilities within the National Nuclear Security Administration's weapons complex. The DOE's portions of alliances among the DOE, its managing and operating contractors, and industry are included in this category.

Ongoing support includes site safeguards and security in New Mexico and Nevada, and environmental and site studies. Services include vehicle fleet maintenance, fuel and repairs, local telephone support, and utilities. Intermittent support includes such activities as training and classes, performance assessments, peer reviews, data collection, and technical studies related to programmatic support.

Requests from integrated contractors are managed in relation to program work from the DOE that requires Sandia support. Collaborations between DOE laboratories may be funded in this manner, as may minor tasks to support deliverables to the DOE.

6.2 Work for Non-DOE Sponsors

6.2.1 Work for Other Federal Entities

Approximately 20 percent of Sandia's programmatic work is conducted for agencies other than the DOE. Such work strengthens our capabilities and makes cost-effective use of existing federal investments in Sandia. Work for other federal entities includes conventional defense, strategic defense, counterproliferation and nonproliferation, treaty verification, environmental cleanup and monitoring, energy uses, high-performance computing, safeguards and security, radiation effects, materials development and characterization, law enforcement, microelectronics, microelectromechanical systems, manufacturing, photonics, robotics, transportation, and space flight applications. The capabilities developed through this work have established expertise not found in industry or in other government agencies. Therefore, these opportunities to contribute technological solutions to agencies other than the DOE help to solve national needs. In addition to helping maintain Sandia's abilities to perform DOE missions, Work for other federal entities also benefits the supported agencies by leveraging multi-agency funds.

Before undertaking a project of this type, we ascertain that the work complies with applicable laws and federal regulations. Projects must be consistent with and complementary to Sandia and DOE missions. The work must not adversely impact Sandia's execution of assigned DOE programs or be in direct competition with the domestic private sector. We also determine that the work will not burden DOE programs in the future. Our customers use Sandia's unique facilities and resources to resolve critical technical issues. Often this work is completed jointly with private industry, as needed to meet the customer's objectives.

6.2.1.1 Air Force

Sandia provides support throughout the Department of the Air Force. Pentagon-initiated programs link to the unified commands of the DOD, National Nuclear Security Administration Defense Programs, field agencies, program offices, and Air Force technology planning integrated product teams. A fairly large amount of support is concentrated in work for the Air Force Technical Applications Center, the Space and Missile Systems Center, the Aeronautical Systems Center, and the Air Force laboratories. We provide research and development, prototyping, modeling and simulation, proof of concept, and hardware and software deliverables. Testing, studies, and data analysis are other common deliverables. Sandia provides technology in remote sensing

Sandia supports the US Air Force with hardware and software deliverables used in test launches such as this one at Vandenburg Air Force Base in California.

and verification, environment and energy, safeguards and security, command and control, testing programs, military systems, microelectronics, aerospace systems, and component engineering. The Air Force uses Sandia's expertise in nuclear burst detection, advanced sensors, space and seismic phenomenology, spacecraft components and survivability, applied energy, and nuclear energy. Also, multiple memoranda of understanding between the DOE and the Air Force support joint efforts on much of our Air Force-sponsored work. Sandia's future work with the Air Force will include long-term projects and partnerships between the DOE and the Air Force in which goals are common or complementary.

Ongoing projects include the following: research and development technologies in support of aircraft fire suppression, comprehensive test ban treaties, integrated correlation and display systems, electromagnetic pulse sensors for global positioning system launches, electronic safing and arming devices, high-efficiency solar cells, imaging systems, military strategic/tactical and relay testing support, protection of nuclear assets, physical security support and intrusion detection, radiation environment testing and certification, radiation-hardened components, radiation safety, battery development, space sensors and ground stations, laser capabilities, high-density optical interconnects, material characterization for weapons applications, structural testing of large land-based antennas, tagging technologies, simulation of high-frequency radar systems, automatic target recognition techniques, precision munitions and penetrating weapons assessments, reliability testing, modeling for applications to conventional munitions, weapons of mass destruction countermeasures, parachute system development, flight data vulnerabilities analysis, miniaturized components, microwave technology, and a space nuclear thermal propulsion system. We also use three-dimensional numerical simulation to provide analysis and design of high-power microwave systems.

The technology for hypersonic ground testing of air breathing engines used in earth-to-orbit vehicles does not exist at present but would be cheaper than airborne testing. Thus, for the National Hypersonic Wind Tunnel Program, Sandia is evaluating the use of electron beam accelerators to deliver high temperatures to the high-pressure gas flow in a wind tunnel.

6.2.1.2 Army

Sandia provides support throughout the Department of the Army. As with other military services within the DOD, many efforts sponsored by the Army are conducted in support of the unified commands. Our sponsor base within the Army includes the Training and Doctrine Command and related Battle Laboratories, the Communications Electronics Command, the Army Research Laboratory, and the Soldier and Biological Chemical Command. Significant portions of our work for the Army support the Space and Missile Defense Command, the Tank-Automotive and Armaments Command, the Test and Evaluation Command, and the White Sands Missile Range. Sandia provides technology in the areas of environment, aerospace systems, military systems, safeguards and security, testing facilities and conditions, microelectronics and photonics, high-performance computing, international security, transportation, and applied energy. Other Sandia support includes safing and arming technology, parachutes, target recognition, battlefield survivability, land mines imaging, radiation testing, and robotics.

Ongoing projects include laser tracker support, solar testing, radar tagging, surveillance and reconnaissance ground equipment, ground-based intercepts, structural response of artillery projectiles, conceptual design and prototyping for an advanced Patriot missile, protection of national critical infrastructure, safer diversionary devices, fabrication engineering for transport packaging of munitions, landmine countermeasures, missile aging and surveillance, mine detectors, vehicle fire safety, battery development, evaluation of multiple-launch rocket system warhead flight performance, radiation sensing, photometric data, advanced materials characterization, autonomous target recognition, radiation hardness surveillance testing, radiation effects on electric components and systems, testing of a postboost vehicle, theater ballistic missile characterization, missile countermeasures, and studies of reduction in health care costs through medical technology.

Major programs within the Army that Sandia supports include the counterproliferation mission and the Consolidated Targets Program for ballistic missile defense. We expect to continue providing substantial support for nuclear weapons surety and conventional weapons effects.

The Strategic Environmental Research and Development Program is led by the DOD (whose executive agent is the US Army Corps of Engineers) and includes the DOE and the Environmental Protection Agency as partners. This mature program improves DOD mission readiness through environmental research. Historically, Sandia has been the major DOE laboratory participant in the program. Activities include atmospheric remote sensing and assessment, emissions monitoring for Clean Air Act Amendments compliance, kinetic mechanisms for supercritical water oxidation, solar detoxification of secondary wastes, landfill characterization system technologies, plutonium and uranium metal-forming technologies, electron beam melting, geothermal research and development, fuel testing, and in-process scrap recycling for uranium.

6.2.1.3 Navy

Sandia supports several Navy program executive offices. We also support the Office of Naval Research; the Naval Air Systems Command; the Naval Air Warfare Center; the Undersea Warfare Center; the Surface Warfare Center; the Facilities Engineering Command; the Naval Command, Control, and Ocean Surveillance Center; and the Pacific Fleet Command.

Some of our work for the Navy supports the unified commands. Sandia provides technology in the areas of nuclear weapons safing and arming, conventional weapons effects, mine detection, environmental effects, materials characterization, testing facilities, missiles, and robotics. These capabilities and some of our unique facilities are the basis for our support to the Navy. Among the Sandia competencies used are component engineering, aerospace systems, high-performance computing, fuzing and technical support, nuclear waste management, environmental technology, command and control, information surety, various testing technologies, materials science and technology, military systems, trainers for the Navy Reserve, support for the United Kingdom's Trident stockpile surveillance program, renewable energy technology support, safeguards and security, microelectronics and photonics, and advanced manufacturing technologies.

Our ongoing projects are in such areas as adversary detection; stockpile surveillance; redesign of subsystems for the Tomahawk missile; chemical identification of sea mines; robot control technology; delayed detonation; environmentally conscious development of new propellants, explosives, pyrotechnics materials, and production facilities; rocket flight experiments and high-velocity impacts; modeling of penetrator concepts; modeling of critical infrastructure; component aging studies; optical ordnance systems; extended-life thermal batteries; explosively loaded structures response modeling; submarine-launched missiles support; oxidation of surrogate Navy waste in supercritical water; ship-based intercepts of ballistic missiles; operational tests of weapons; and characterization of optically initiated detonators.

Sandia supports the US Navy in a number of areas, including technology for nuclear weapons safing and arming.

For the Office of Naval Research, Sandia is examining the production of porous metal structures and the detection and tracing of a chemical plume using swarms of robotic agents. We also continue to provide support for launches from the Kauai Test Facility for ballistic missile defense.

6.2.1.4 Ballistic Missile Defense Organization

Because of the interrelationship of DOD departments, some of the Sandia's work for the Ballistic Missile Defense Organization is actually funded by the military services. We also support the Ballistic Missile Defense Organization through its offices in DOD Headquarters, the Program Management and Operations Office for Theater Missile Defense, the Phase One Engineering Team, and the Technology Readiness Program. Sandia provides technology in the areas of countermeasures, space technology, pulsed power, threat definition, smart targets, rocket launch services, reentry vehicle technology, missiles, smart mines, sensors, testing, instrumentation, control technology, radiation hardening, microwaves, and computing. Some support is based on our experience in nuclear weapons design and on the National Nuclear Security Administration's Inertial Confinement Fusion Ignition and High Yield Campaign.

Sandia also provides technology in the areas of radiation-hardened satellite communications transceivers; flight tests; analysis of strategic defense systems; and development, analysis, and testing of potential countermeasures.

6.2.1.5 Defense Threat Reduction Agency

Sandia supports the Defense Threat Reduction Agency in the areas of testing, physical protection, tamper protection, transportation of nuclear materials, arms control verification, radiation testing and safety, simulation, and weapons storage. In conjunction with the National Nuclear Security Administration, the Defense Threat Reduction Agency assists the former Soviet Union in safely reducing its nuclear arsenal. Sandia provides technology in various testing programs, military systems, aerospace systems, international security, safeguards and security, fusing and technical support, microelectronics and photonics, and high-performance computing.

Sandia supports the agency's Cooperative Threat Reduction Office by providing physical protection assistance to the US/Russian Security Assessment Training Center in Sergiev-Posad. The primary purpose of this project, supported by the

Russian Ministry of Defense, is to create a testbed for evaluating physical protection equipment and subsystems for deployment to approximately 120 weapon storage sites.

Sandia also supports the Arms Control Technology Development Office in its efforts to enhance the safety and security of Russian nuclear warheads under the control of the Russian Federation Ministry of Defense. Under the auspices of the Warhead Safety and Security Exchange, a companion program to the Cooperative Threat Reduction program, this work provides an opportunity for the evaluation of advanced monitoring technologies, techniques, and processes. The Russian and US defense departments use this program to explore technical solutions for future monitoring regimes.

Sandia also developed a draft strategic partnership plan for potential projects with the Defense Threat Reduction Agency's Office of Onsite Inspections. This plan includes US inspections of foreign facilities under arms control treaties, planning and preparing for future agreements, and tasks that foster US arms control and threat reduction initiatives. The agency's Office of Onsite Inspections participates in a collaborative project with Sandia, the Russian Institute of Automatics, and the Russian Ministry of Defense.

Other Sandia support includes physical protection in Belarus and Ukraine, assistance in nuclear material protection control to the Republic of Kazakstan via the International Atomic Energy Agency, conducting arms control symposia, and modifying Russian railcars. We also provide support for synthetic aperture radar open-skies-related activities, research and development for arms control verification and compliance, consultation on radiation safety, modeling and testing analysis of radiation effects, ion-beam and x-ray simulation, advanced assurance and reliability, fuel fire testing and modeling, upgrades of adverse weather sensors for munitions, field testing of anti-intrusion devices, research and development for intrusion detection, capture and recording of underground test historical digital data, design and construction of the DECADE radiation effects testbed, development of Microchemlab elements, thermionic converter testing, and conventional weapons testing. The Sandia Cooperative Monitoring Center conducts workshops and training for numerous countries to demonstrate technologies for monitoring potential hostile actions and preventing conflict arising from misinformation or speculation.

6.2.1.6 Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency plays a central role in developing advanced technologies and systems that could be crucial to the nation's defense against biological attack. As part of one of the Immune Buildings teams, Sandia is developing computational tools to design and optimize the physical protective features of such buildings. We are also developing systems using Sandia-developed decontamination foams that could suppress biological agents released in a building. Sandia also has significant contracts to support the Defense Advanced Research Projects Agency in the area of robotic swarms.

6.2.1.7 Other Department of Defense Support

In addition to projects initiated by agencies within the DOD, many efforts originate from the Office of the Secretary of Defense and other offices within the DOD. In this area, Sandia supports the joint DOD/DOE Munitions Technology Development Program established through a memorandum of understanding. This program develops innovative warhead explosives and fuse technologies to improve nonnuclear munitions across all service mission areas. Technology coordination groups of technical experts from the DOD and DOE establish deliverables and monitor activities. Sandia also provides the following directly to the Office of the Secretary of Defense: security support for the US European Command/North Atlantic Treaty Organization, instrument concepts for theater missile defense, concepts for the collection of automatic target recognition sets, and laser tracking. Additionally, the DOD and DOE have a memorandum of understanding for counterproliferation work under which Sandia supplies counterproliferation architecture analysis to the DOD.

In the future, Sandia's expertise in munitions and counterproliferation and our ability to aid the DOE in leveraging program capabilities will be used to meet DOD needs.

6.2.1.8 Nuclear Regulatory Commission

Sandia is one of the largest contributors of research to the Nuclear Regulatory Commission (NRC). Our modeling, experimental, and analytic capabilities enable us to provide accurate answers concerning regulatory issues. We currently provide the NRC with data on risk information (to identify alternatives to existing regulations), assessment of fire risk, evaluation of reactor pressure vessel lower head failure, characterization of reactor containment performance, assessment of cooling system pressurized thermal shock, modeling of integrated severe accident sequences, modeling of accident consequences, and analyses of spent nuclear fuel storage and transportation, human performance, and seismic events.

Sandia is a leader in risk information analysis of regulations to achieve a balance between prescriptive requirements and performance-based concepts for nuclear power plant operation. We anticipate a major role in helping the NRC develop the regulatory framework for the next generation of nuclear power plants.

Sandia is also an international leader in nuclear power plant severe accident sequence modeling. Sandia's MELCOR computer code models all significant plant physical phenomena and is continually benchmarked by the international reactor safety community against new experimental data.

6.2.1.9 Department of Transportation

Sandia supports the Department of Transportation with research on the safety, security, and efficiency of the nation's transportation systems.

We assist the Federal Aviation Administration with physical security of commercial airports and the safety of passenger and cargo aircraft. An ongoing project for the Federal Aviation Administration involves aging aircraft studies in the Airworthiness Assurance Nondestructive Inspection Center. We are also developing techniques to assess nonstructural safety aspects of aircraft such as smoke propagation and wire integrity.

We supply expertise in nondestructive evaluations, packaging, tamper-resistant containers, radioactive materials transport, materials characterization, risk assessment, fire modeling, and systems engineering. Individual states, the border patrol, and the travel and transportation industry are all possible partners for the technologies being developed to meet Department of Transportation needs.

We support the nondestructive inspection of Coast Guard and Air Force aircraft, an aviation safety system development and validation center, advanced automatic train control, a Federal Aviation Administration explosives detection portal, an urban/rural intelligent corridor application, a prototype transit bus using advanced electric propulsion, fire modeling for aircraft safety, package performance standards guidance, commercial vehicle safety, and airport vulnerability assessments.

The Department of Transportation's Office of Pipeline Safety is interested in many of our capabilities for use in the inspection of natural gas pipelines.

6.2.1.10 National Aeronautics and Space Administration

Sandia's support for the National Aeronautics and Space Administration (NASA) encompasses support to the Jet Propulsion Laboratory, Johnson Space Center, Wallops Flight Facility, Marshall Space Flight Center, Stennis Space Center, Kennedy Space Center, Goddard Space Flight Center, and NASA Headquarters. We partner with universities and NASA research centers. We provide technical support for spacecraft safety and reliability, monitor projects for specific missions, evaluate space events, develop sensors and micromachining technology, furnish imaging techniques, support several metrology areas, assist with reentry and recovery efforts, and assist with onboard experiments. Sandia provides technology in the areas of remote sensing and verification, development testing, and exploratory military systems. We also provide expertise in space phenomenology such as temperature microelectronics, analysis of material characteristics, parachute systems, aerodynamics, and environmental monitoring.

During the last three years, Sandia has supported the NASA Ames Research Center in a series of flight tests to demonstrate advanced thermal protection system materials. If these advanced materials perform as expected, they will facilitate a revolutionary class of space transportation vehicles with sharp leading edges and nosetips that minimize drag and increase performance.

Sandia's ongoing support for NASA includes developing capillary electrophoresis for continuous monitoring and environmental analysis, coupling capillary electrokinetic chromatography with immunochemistry techniques to solve complex chemical analysis problems, developing portable hydrogen sensors and x-ray radiation detectors, mapping terrain using the scannerless range imager, conducting spacecraft shielding studies, developing ultrahigh-temperature ceramics for advanced thermal protection, developing solar wind collectors, and developing rocket recovery systems and a rocket booster decelerator subsystem.

6.2.1.11 Department of State

Sandia's work for the Department of State includes the Technical Assistance Safeguards, Nonproliferation, and International Affairs programs. We provide analysis and design recommendations for enhanced security of embassies and other structures. We provide technical support to the International Atomic Energy Agency for verifying compliance with nonproliferation treaties, and we provide technical assistance to the Department of State for managing the International Science and Technology Center in Moscow and the Science and Technology Center of Ukraine. We also evaluate and provide related support for Mexico's renewable energy rural electric applications project.

Sandia supports the National Nuclear Security Administration (NNSA) Second Line of Defense Program, a cooperative effort with the Department of State. The NNSA Material, Protection, Control, and Accounting Program is considered the first line of defense for the protection of special nuclear materials. The Second Line of Defense Program provides rapid, integrated, sustainable systems to minimize the risk of nuclear proliferation and terrorism. This risk reduction is accomplished through cooperative efforts with the Russian Federation and other countries to strengthen the overall capability to detect and deter illicit trafficking of nuclear materials across international borders. When available, indigenous equipment and technologies are integrated and installed to monitor, detect, and respond to movement of nuclear materials at border crossings and to promote the long-term sustainability of the installations. Sandia is the lead laboratory for this effort, with funding provided by the NNSA and the Department of State Nonproliferation and Disarmament Fund and Nonproliferation, Antiterrorism, Demining, and Related Activities Fund.

Our support to the International Atomic Energy Agency (IAEA) through the Department of State and the DOE's Office of Defense Nuclear Nonproliferation complements our International Security Program role. The International Atomic Energy Agency employs both material accounting

procedures and containment and surveillance techniques to provide safeguards required by the Treaty on the Nonproliferation of Nuclear Weapons. We are providing technical leadership to a working group of international experts producing information technology security evaluation criteria for safeguards equipment systems. Newly developed containment and surveillance equipment is being accepted for routine IAEA application. A training course on unattended and remote monitoring systems is being developed for IAEA technicians and will be offered initially in the fall of CY 2001. Sandia provides training, maintenance, and documentation; containment and surveillance consultation; and assistance with training and inspection of physical security systems.

6.2.1.12 International Science Center Programs

Sandia participates in two international science center programs sponsored by the Department of State. The International Science and Technology Center is headquartered in Moscow, and the Science and Technology Center of Ukraine is headquartered in Kiev. Our projects with these science centers are intended to reemploy former weapons scientists in alternative fields. The countries involved are Russia, Ukraine, Georgia, Armenia, Belarus, Kyrgystan, Kazakhstan, and Uzbekistan. More than 24,000 Russians have been employed through the International Science and Technology Center and almost six thousand Ukrainians through the Science and Technology Center of Ukraine-with smaller numbers for the other countries.

Sandia participates in about seventy-five programs through the International Science and Technology Center and fewer through the Science and Technology Center. The programs enhance communications with former Soviet Union counterparts in many areas of technical interest to Sandia. These areas include treaty verification, safe transportation, advanced electronics, prosthetics, wind power, pharmaceuticals development, agricultural implements, photovoltaics, and batteries. Many of these projects are closely coupled with the Initiatives for Proliferation Prevention and the Nuclear Cities Initiative programs.

6.2.1.13 Environmental Protection Agency

Sandia supports the Environmental Protection Agency (EPA) via a number of interagency agreements. Numerous memoranda of understanding exist between the DOE and the EPA for joint research and development. Sandia also teams with other agencies and groups to support EPA efforts.

Sandia is funded directly by the EPA Office of Research and Development to operate the Advanced Monitoring Technologies Center of the Environmental Technology Verification (ETV) Program. The ETV Program verifies testing for new and innovative technologies intended for environmental applications such as drinking water protection, air pollution source control, ambient air monitoring, greenhouse gas control, and contaminated site characterization. ETV Program tests are conducted by impartial organizations such as Sandia to establish credible performance parameters under realistic conditions. The resulting performance data help the user community select and purchase technologies that best match a particular application. Sandia combines its skills in experimental design and data analysis with its access to a variety of test facilities to help achieve ETV Program objectives.

Sandia works closely with the EPA Superfund Innovative Treatment Evaluation Program through its leadership role in the DOE Innovative Treatment and Remediation Demonstration Program. The two programs collaborate closely because they share common objectives. Both programs examine cost and performance data for new and innovative remediation treatments through technology demonstrations at contaminated sites.

Sandia has a variety of research and development programs of direct interest to the EPA, particularly in sensor and analytic system development. Sandia-developed systems such as microscale gas and liquid chromatography are well suited for a variety of applications in air and water monitoring.

Sandia is also directly funded by the EPA Office of Water to assess domestic water resources and their associated supply, treatment, and distribution infrastructures. According to the President's Commission on Critical Infrastructure Protection, the United States is so dependent on these infrastructures that they are a national security concern. Recent threats and isolated attacks on the water distribution system suggest a trend that could put our water infrastructure at risk. Many sources of risk (internal and external to the country) pose potential threats to the nation's water systems.

In partnership with the EPA, water industry associations, and water utilities, Sandia is developing a comprehensive program for protecting the water infrastructure by reviewing the entire water delivery system with the intent of improving the security and lowering the consequences of an attack. Our specific responsibilities include extensive review of all drawings, operations, procedures, unusual occurrence reports, and security systems; site visits with representatives from the EPA, American Water Works Association Research Foundation, and major water utilities to review all major facility operations; development of a generic security risk assessment process for use by water utilities; recommendations for security upgrades based on the results of the assessment; and training in security awareness and security risk assessment. Presently this program is focusing on more than three hundred municipalities, each with more than 100,000 users. An expansion of the assessment to all community systems is planned.

Sandia's ongoing direct and indirect support of the EPA will likely continue to focus on verification testing, analytic system development, and water supply infrastructure vulnerability assessment. Other areas of Sandia/EPA collaboration will include the development of risk assessment

techniques, decision support models, and resource management software tools.

6.2.1.14 Department of Justice

Sandia supports the Department of Justice's National Institute of Justice via an interagency agreement. We operate the Border Research and Technology Center in San Diego to support National Institute of Justice local law enforcement on border issues. We operate the Center for Civil Force Protection to provide information on force protection technologies for civilians. Our efforts in school security have shown positive results in reducing crime and violence in the pilot schools, and we have held national conferences to bring the education community into discussions of security issues and system solutions. We also work with the corrections community to develop tools for the evaluation of security system effectiveness and to provide training on the proper selection, installation, and maintenance of security equipment.

6.2.1.15 General Services Administration, Bureau of Reclamation, and the US Mint

Sandia is developing system engineering concepts for the General Services Administration, the Bureau of Reclamation, and the US Mint to provide protection against terrorist attacks. This support includes development of tools for risk management and for evaluating the cost-effectiveness of security upgrades.

6.2.1.16 Other Federal

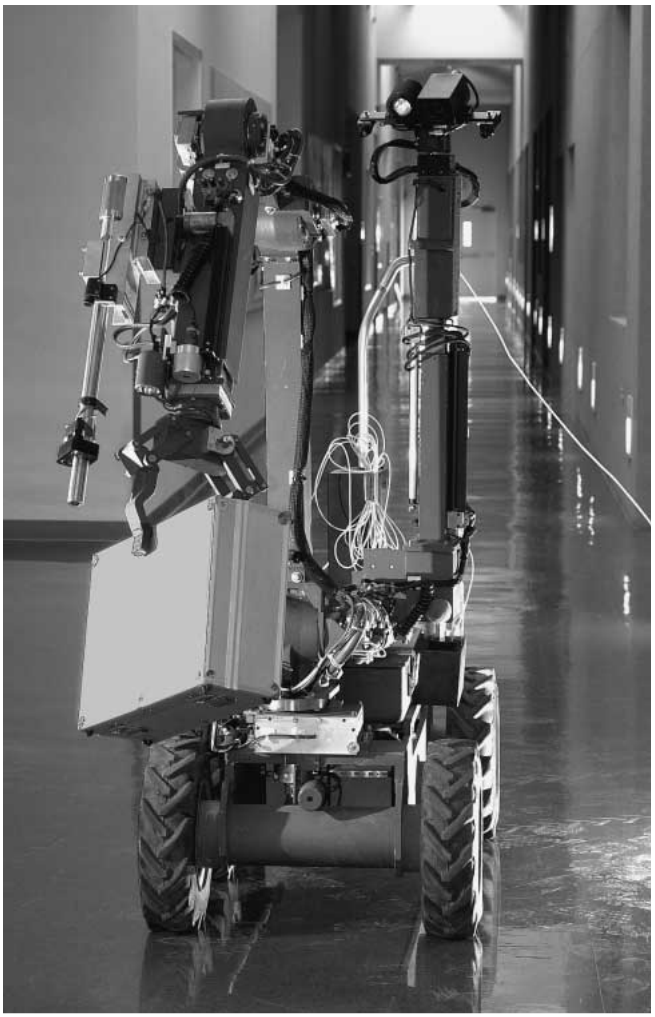
Specific activities are expected to continue with the Department of Commerce (International Arms Control Conference and testing for the national, voluntary, laboratory-accreditation program), the Department of Interior (information technology and critical infrastructure studies), the Federal Emergency Management Agency (mobile emergency response support systems), the National Institutes of Health (prosthetics research with Russia), and the National Science Foundation (Leadership Academy for Science Education Reform). We will also continue work with the Defense Intelligence Agency, the National Security Agency, and other groups.

6.2.2 Work for Nonfederal Entities

Nonfederal sponsors, private organizations, state and local government organizations, and foreign customers benefit from partnerships with Sandia ranging from research and development to testing and characterization. Such work complements existing DOE programs and makes available to sponsors unique capabilities not available from private industry or universities. Sandia also seeks to transfer appropriate technology to industry, governmental organizations, and universities.

Partnerships between Sandia and nonfederal agencies can be established via many different means—including cooperative research and development agreements, memoranda of understanding, personnel exchanges, technical assistance, user facilities agreements, work for others projects, and designated capabilities arrangements. Designated capabilities are preapproved by the DOE and documented in an umbrella statement of work. For a complete listing of Sandia designated capabilities, technology deployment centers, and user facilities, see section 8.2.

Sandia performs work for nonfederal sponsors through Work for Others funds-in agreements, which are bilateral sales contracts between Sandia and the sponsor. The work must be consistent with the mission of the DOE and Sandia



A Northrup Grumman REMOTEC Wolverine Police Robot carries a mock suitcase bomb. Sandia Modular Architecture for Robotics and Teleoperation (SMART) patented software provides intelligence that enables robotic self-adjustment with minimal human intervention.

and must not place the DOE or Sandia in direct competition with the private sector. The broad range of work in this category includes providing radiation-hardened microelectronics components, providing assembly test chips, collaborating on the design of solar cells for solar panels, determining spectroscopic information about chemicals that may be in the atmosphere at remote locations, developing advanced energy storage devices and materials, developing synthetic aperture radar and platforms, testing a lunar probe for the Japanese Institute of Space and Astronautical Science, providing training in physical protection of nuclear facilities and materials, assessing the vulnerability of microprocessor-based systems and software, designing countermeasures against terrorist activities, developing techniques for extracting information about the state of stress in the earth using rock core samples, verifying reactor records of assembly burnup of spent fuel at US nuclear electric utilities, solving very large nonlinear quasi static problems required for accurate computer models of springback in metal stamping, providing peripheral process equipment with degrees of intelligence to self-adjust without human intervention, and developing stimulation diagnostic technology to improve natural gas recovery.

6.3 Laboratory Directed Research and Development Program

The National Defense Authorization Act for FY 1991 established the Laboratory Directed Research and Development (LDRD) Program at the DOE national laboratories. This act authorized expenditures up to 6 percent of a laboratory's total budget to "maintain the scientific and technical vitality of the laboratories; enhance the laboratories' ability to address future DOE missions; foster creativity and stimulate exploration of forefront science and technology; serve as a proving ground for new research; and support high-risk, potentially high-value R&D (research and development)."[4]

6.3.1 Strategy

Sandia's value as a national resource is based on our world-class science, technology, and engineering. These capabilities must remain on the cutting edge because the safety, security, and reliability of US nuclear weapons depend directly on them. Under the guidance of Sandia's Laboratory Director-and with National Nuclear Security Administration (NNSA) and DOE concurrence-the LDRD Program provides the flexibility to invest in short- to long-term, high-risk, and potentially high-payoff research activities that stretch Sandia's science and technology capabilities.

LDRD supports Sandia's four primary strategic objectives (see section 2.2): nuclear weapons; nonproliferation and materials control; energy and critical infrastructure; and emerging threats. To meet our objectives, LDRD funds innovative research and development initiatives up to thirty-six months in duration, attracting exceptional research talent across Sandia disciplines.

Sandia's LDRD Program provides the leadership necessary to do the right research in the right way. The insight generated from basic research allows Sandia to manage our intellectual assets for the benefit of the entire nation. The LDRD Program has two strategic goals:

- to conduct leading-edge, use-driven research supporting all mission assignments but focusing primarily on our national security mission; and
- to provide scientific and technical leadership through collaborations.

Throughout its history, research at Sandia has reflected changing societal, political, and environmental needs. A perceived nuclear threat prompted the Atomic Energy Act of 1954, fostering research and development to maximize scientific and industrial progress. During the 1973 and 1974 oil embargo, the Energy Research and Development Administration redirected research toward energy-related concerns. Congressional legislation in 1977 (Public Law 95-39) led to employee-suggested research, which assumed its present form as LDRD in 1991.

Authorized by federal law and implemented under DOE Order 413.2A, LDRD is Sandia's sole source of nonprogrammatic research funds (see table that follows). LDRD is financed by an assessment on all costed work at Sandia. More than 55 percent of LDRD projects directly supports weapons work (and more than 22 percent provides indirect support), although only 52.8 percent of LDRD annual funding comes from the tax on Sandia nuclear weapons costed work. Overall, approximately 96 percent of LDRD projects provide benefits in basic and applied research to national security needs. In FY 2000, LDRD funded 122 new ideas selected from 976 ideas submitted. In FY 2001, LDRD funded eighty-eight new ideas selected from 1107 ideas submitted.

LDRD Funding (Millions of Dollars)

FY 2000	FY 2001	FY2002
50.9 (4 percent)[a]	70.6 (5 percent)	78.0 (5.5 percent)

[a]Assessment on costed work.

[4] U.S. Department of Energy, DOE Order 413.2 (5 March 1997), Section 1.

6.3.2 Impact

LDRD uses recognized metrics to track and assess the impact of Sandia research both qualitatively and quantitatively. Metrics include intellectual property, programmatic performance, citations in relevant literature, and customer satisfaction.

The intellectual property metric is based on patent applications, patent disclosures, and copyrights. These have been trending upward. In FY 1992, Sandia submitted fifteen patent applications, forty-nine patent disclosures, and six copyrights. By FY 2000, we had submitted fifty-eight patent applications, one hundred patent disclosures, and five copyrights.

The programmatic performance metric is based on external recognition and milestones. In FY 2000, two LDRD projects won DOE Office of Basic Energy Sciences awards for outstanding scientific accomplishment; one Sandian who conducted LDRD work was elected Fellow in the American Society of Mechanical Engineers; and two graduate students who contributed to LDRD work received awards. LDRD-sponsored work received an award for Recognition of Exceptional Service to the DOE Office of Solar Energy Technologies. In FY 2000, LDRD contributed to 250 refereed publications, a substantial increase since record-keeping began in FY 1992. Since 1992, the number of patents granted and copyrights issued has increased substantially.

The metric based on citations in relevant literature pioneered by the Institute for Scientific Information (ISI) focuses on institutional and national performance measures. This method measures impact on the scientific community by tallying the number of times published research is cited by other researchers. The institute reviews at least four thousand of the world's most influential journals. Using this metric, we tallied citations of Sandia's LDRD-related papers in research publications from thirteen federal laboratories, the top 112 federally funded US universities, and eleven internationally recognized corporations. At these institutions, Sandia's LDRD-related engineering publications from 1994 through 1999 (the most recent five years for which data are available) were cited 3.38 times the world average, placing us second among the 140 institutions measured. In materials science, LDRD papers were cited 2.03 times the world average, outranking the Massachusetts Institute of Technology, Stanford University, Lawrence Livermore National Laboratory, and Westinghouse. In physics, LDRD papers were cited 2.28 times the world average, outranking both the University of California at Berkeley and Hewlett Packard. During this time period, Sandia LDRD produced 465 papers, of which 70 percent were cited one or more times-1.22 times the world average. This places citations of Sandia's LDRD papers above those of Carnegie Mellon University and Los Alamos National Laboratory. These trends in intellectual property performance are shown in table that follows.

Intellectual Property Performance from 1996 through 2000

	1996	1997	1998	1999	2000
Citations in Refereed Publications	265	371	407	342	250
Citations in Other Publications	243	247	223	284	161
Patent Disclosures	30	65	79	104	100
Patent Applications	20	31	48	64	58
Patents Granted	1	23	7	10	16
Copyrights Granted	0	9	12	15	5

6.3.3 Process

The LDRD process rigorously evaluates proposals. Our process minimizes the time to identify, review, and fund research; establishes meaningful metrics for tracking and assessing impact of the work; and maintains the highest degree of customer satisfaction. To measure customer satisfaction, we use reviews, surveys, and number of awards.

LDRD management balances top-down guidance with bottom-up technology ideas, fostering a "community of excellence" by emphasizing collaboration, partnerships, and ongoing external technical and programmatic peer review. Research investigations are funded in three categories: incremental (short-term), radical (intermediate-term), and fundamental (long-term). The percentages for each category are shown in the table that follows.

The LDRD Program process begins when upper management establishes a framework for strategy and investments, followed by a call for proposals. Electronic submittal of proposal briefs increases the number of ideas submitted and minimizes preparation time. Each proposal is assessed for technical merit, growth potential, impact on future labo-

LDRD Funds Invested in Short-, Intermediate-, and Long-Term Research

Fiscal Year	Short-Term (0-1 year)	Intermediate-Term (2-4 years)	Long-Term (5-10 years)
1997	27%	67%	6%
1998	33%	56%	11%
1999	36%	56%	8%
2000	35%	57%	8%
2001	28%	59%	13%

ratory activities, and the degree to which it supports Sandia's strategic goals. The DOE gives final concurrence.

LDRD Program collaborations with industry, government, and universities can accelerate scientific breakthroughs. This collaborative network (see table that follows) keeps us abreast of technological change, avoids duplication of effort, and increases the flow of knowledge. All types of collaborations increased substantially during FY 2001.

LDRD Collaborations

Fiscal Year	Universities	Government Agencies	Industrial Companies
1997	64	18	57
1998	122	44	67
1999	96	33	39
2000	83	10	20
2001	106	57	74

In FY 2001, 72 percent of all LDRD projects had dual-use (defense and industrial) applications and supported all National Nuclear Security Administration (NNSA) critical technologies. In FY 2001 Sandia invested in science and technology, mission technologies, and Grand Challenge research. Projects in the science and technology and Grand Challenge categories are prioritized to ensure overall relevance to Sandia's core nuclear weapons mission.

Projects in science and technology strengthen Sandia's research foundations. Investments in such research provide critical support to our present nuclear weapons capabilities and our future science and technology needs. For FY 2002, Sandia's science and technology research foundation investment areas include

- materials science and technology,
- computational and information sciences,
- electronics and photonics, and
- engineering sciences.

Additional science and technology investment areas for FY 2002 will include

- pulsed power sciences,
- advanced manufacturing science and technology,
- biotechnology,
- Microsystems and Engineering Sciences Applications (MESA) complex technologies, and
- strategic objectives in Science and Technology and Nuclear Weapons.

Sandia's FY 2002 mission technologies investment areas include

- emerging threats,
- nonproliferation and materials control,
- energy and critical infrastructures, and
- differentiated technologies.

LDRD projects address a broad range of areas of urgent concern to the NNSA, DOE, and Sandia. LDRD projects develop advanced sensing technologies, investigate low-volume production of freeform composite components, and improve our fundamental understanding of physics of materials used in highly specialized weapon components. Projects known as Grand Challenges provide an opportunity to conduct multidisciplinary explorations addressing the toughest national-security-related technical challenges.

The selection process for funding new ideas is extremely competitive. The LDRD Program funded only 8 percent of the new ideas (88 out of 1107) submitted for FY 2001. Each funded project strengthened Sandia's core science and technology base and focused on future DOE and national needs. The projects permitted our staff to explore innovative science and technology having high potential for future payoff.

6.3.4 Results

Although citation analysis reflects one institution's intellectual debt to another, results with the potential to dramatically impact our national security mission are the best measure of achievement for LDRD-funded work.

During FY 2001, 291 research and development projects were under way, including 159 new starts and 132 continuing projects. Although the LDRD Program's contribution to some of the most successful research at Sandia is not always visible, many noteworthy technologies have been developed with LDRD participation. These technologies are described in the following sections.

6.3.4.1 Automatic Planning of Life-Cycle Assembly Processes

Assembly planning is used to identify and sequence motions that combine separated parts into a product. The assembly planning methodology first disassembles a product to determine the assembly sequence. Sandia has coordinated various research efforts to create Archimedes, an assembly planning software that enables fast and accurate generation, manipulation, visualization, and optimization of disassembly sequences. Archimedes can be used to solve problems in assembling, manufacturing, maintaining, sustaining, and dismantling complex systems.

The Archimedes intelligent software can automate many manufacturing processes that have traditionally been the most costly, time-consuming, and error-prone throughout a product's life cycle. The tool enables faster, more error-free, and higher quality assembly sequences without physical prototypes. The system ensures model validity before the planning begins, and design changes can be tested immediately for their effect on optimal assembly sequences. Scripts can be created to control robots, analyze cost information, and examine ergonomic considerations.

Results of Archimedes-related LDRD have been featured in strategic DOE documents, including the DOE Strategic Plan.[5] Automated simulation and analysis tools resulting from this research may lead to the remote disassembly of terrorist devices and may also reduce the number of mockups required for training personnel in maintenance operations and depot repair.

Archimedes has been used to significantly reduce assembly time for the missile interceptor target array and the AIM-9X guidance sector—the latter a collaborative effort with Raytheon. Pantex and Honeywell have also used Archimedes to reduce the time required for B61 parachute replacement and to remanufacture the B61 nose assembly. Lockheed Martin will use Archimedes to reduce total life-cycle costs for the Joint Strike Fighter, saving billions of dollars.

6.3.4.2 Interconnection Technology for Next-Generation Integrated Microsystems

Microsystems of the future will require interconnection technologies with increased density to facilitate the integration of electronics, optics, and microelectromechanical systems (MEMS) in a single package. Currently available high-density interconnect technologies are designed strictly for specific components (e.g., electronic, mechanical, and optical). These technologies do not offer the level of flexibility and integration required in future microsystems.

Sandia is researching and developing a multilayer interconnect technology applicable to numerous future microsystems. This technology consists of a thin-film deposited benzocyclobutene dielectric with copper conductors on a variety of substrates. Passive components (including resistors, capacitors, and inductors) may be embedded within the interconnect structure. Optical interconnections can be created with wave guides and micromirrors deposited on the top layers of the structure.

Important applications for this technology include the miniaturization of radars and other weapons-related components, chip-scale packaging of microwave electronics, integrated radio frequency MEMS, optical microswitches, microgyroscopes, mobile chemical analyzers, and ultrahigh-speed (10 gigabits per second) data link circuits.

6.3.4.3 Thin-Skin Deployable Mirrors for Remote Sensing Systems

Sandia is researching and developing technologies to create a thin-film, ultralight (less than one kilogram per square meter), deployable mirror that may represent the future of space telescopes and surveillance satellites. This space mirror will be fabricated using a "smart" material that changes shape when struck by electrons fired by a computer-controlled electron gun.

This research departs from the existing Hubble telescope and the upcoming National Aeronautics and Space Administration (NASA) Next Generation Space Telescope, which use heavy (15 kilograms per square meter) polished glass mirrors. The new type of space mirror will be fabricated from a piezoelectric thin-film system that may be folded, carried on a small booster rocket, and then opened to its full diameter in orbit. An electron gun will be used to correct the shape of the film mirror as desired. The mirror's surface may be adjusted to within 10 millionths of an inch—the accuracy required for optical-quality imaging.

The technology is still in its early stages but has already captured the interest of NASA officials and the remote-sensing community. This technology is based on Sandia LDRD and has made significant progress in the critical areas of mirror-figure sensing, control algorithm development, electron gun actuation, and space-implementation assessments.

6.3.4.4 Adaptive 3-D Sensing for Human-Machine Cooperation

For the past decade, Sandia research has developed applications of flexible robotic systems in unstructured environments that are equally cost-effective whether customers need to produce ten or 10,000 items. The resulting robotic systems combine various sensor-based controls-including computer vision, grasping (dexterous manipulation) capabilities, and autonomous motion planning to ensure the robots routinely and properly react to novel situations.

The Adaptive 3-D Sensing for Human-Machine Cooperation Project is extending Sandia's sensing, reasoning, and control technologies to allow the safe and effective cooperation of humans and intelligent machines in a variety of operations. In many environments, putting people and robots together may lead to improved solutions compared to using either robots or humans alone. This project seeks to simultaneously use the best skills of both humans and machines. For example, robots can perform highly repetitive tasks untiringly, powerfully, and fast. Conversely, humans can work in cluttered or changing environments and can reason through problems.

Potential applications for this human-robot interface technology include DOE missions in small lot manufacturing, dismantlement, materials monitoring and handling, environmental waste management programs, and reductions of worker exposure to hazards.

6.3.4.5 A Novel Microcombustor for Sensor and Thermal Energy Management

Sandia is developing a small (dual in-line package mounting) and stable combustion system (microcombustor) that will permit the use of several very useful macroscopic

[5] *U.S. Department of Energy Strategic Plan (Strength through Science: Powering the 21st Century). September 30, 2000.* Electronic files are available at http://www.cfo.doe.gov/stratmgt/plan/doesplan.htm.

combustion devices and processes in microsystems. The motivation for this research is compelling. For example, the energy density of some common fuels is fifty times that of the best high-output batteries (e.g., nonrechargeable lithium manganese dioxide). Therefore, a tiny fuel tank (the microcombustor) could conceivably replace several bulky batteries in hand-held microanalytic systems (e.g., Sandia's Microchemlab) and provide efficient heating of essential components.

The results of this research have extensive potential applications. For example, the microcombustor may be used as a thermal energy management alternative to batteries, chemical detector for gas analysis, and microreactor for chemical production. Thus far, the results of this research have demonstrated stable, self-sustaining flames and successful flame-based detection of chemicals.

6.3.5 Future Directions

The US nuclear weapons research, development, design, and production program has been firmly committed to scientific and technological excellence throughout its history. The LDRD Program has been an integral component of sustaining the world-class science and technology required to meet Sandia's goals for enhancing national security and reducing the global nuclear danger.

In recent years, Sandia has aligned its corporate structure with its strategic objectives using strategic business units (SBUs) and the Science and Technology Strategic Management Unit (SMU). For FY 2002, the LDRD Program will be aligned with the "mission challenges" defined by the SBUs (i.e., mission technologies) while balancing the emphasis between the SMU and mission needs.

The Science and Technology SMU will prioritize research to ensure overall relevance to Sandia's nuclear weapons mission while anticipating future directions. All SBUs (including nonweapons) will be strongly encouraged to participate in the SMU research process. Inter-SBU collaboration will be encouraged and maximized by the mission technologies participants.

The key LDRD process elements (e.g., technical calls, a competitive Sandia-wide selection process, technical and programmatic peer review of proposals) will remain unchanged. Our Chief Technology Officer will be accountable for LDRD Program implementation and will serve as Sandia's interface with the National Nuclear Security Administration and the DOE. Sandia's Mission Council will be accountable for the strategic direction of the LDRD Program and will approve and prioritize Grand Challenge projects.

The LDRD Program is truly the lifeblood of the laboratories. LDRD is respected for its innovative research and teamwork, which underpin Sandia's scientific and technical vitality. Over the next fifteen years, LDRD is expected to play a significant role in the revitalization of the weapons stockpile.

MAJOR PROGRAMMATIC INITIATIVES

This chapter presents proposals for consideration by the National Nuclear Security Administration (NNSA) and the DOE. Sandia's strategy for implementing major initiatives has several components. The primary component is to improve Sandia's capabilities so that greater value will accrue to the NNSA, the DOE, and the nation. Project proposals respond to NNSA and DOE needs and may produce novel technologies with potential for new commercial applications. Consistent with stewardship of public resources, all work will include collaboration with other federal laboratories, industry, and universities through cost-sharing arrangements. Sandia also will support the research and development needs of small and midsized businesses through special cooperative arrangements and technology outreach programs.

The following subsections propose either new work or major program enhancements designed to improve Sandia's capability to meet the needs of government customers. The funding requirements are for either new or enhanced program elements, and as such are not included in the chapter 9 budget tables.

7.1 Nuclear Weapons

7.1.1 Microsystems and Engineering Sciences Applications (MESA) Complex

Microelectronic components have long been critical to almost every National Nuclear Security Administration (NNSA) Defense Programs mission, initiative, and program. Such components have largely determined the reliability of weapons systems, the precision of weapon delivery to the target, and the operability of weapons in the severe environments encountered during delivery. Satellites that monitor compliance with international arms control agreements also require the special durability offered by the radiation-hardened microelectronics for which Sandia is the world leader.

Today, Sandia has pioneered a new and far more advanced form of microcomponent—the integrated microsystem. Microsystems are a new generation of integrated circuits capable of thinking, sensing, acting, and communicating. These amazing devices are created by combining integrated

circuit, microelectromechanical system, sensor, and photonic technologies on a single chip. Sandia already is exploring a component that would combine radiation-hardened microelectronics, chemical and mechanical sensors, and a wide array of miniaturized electromechanical micromachines to inaugurate new kinds of stronglinks, inertial sensors, trajectory sensing safing systems, and weapon monitors. Sandia's rapid progress and the advantages offered by these new types of integrated components are so compelling that the United States must make every effort to integrate them into planned cycles of weapons component replacement and refurbishment as soon as possible.

The stockpile is aging, the components within existing weapons are aging, and key components need to be replaced within the next decade. In many cases, we cannot replace these components by building replicas of the original designs because the supplier base, technology, materials, and design tools needed to build the obsolete components no longer exist. In other cases, modern environmental regulations prevent the use of older materials and methods. In all cases, the cost to replicate obsolete technologies will be high.

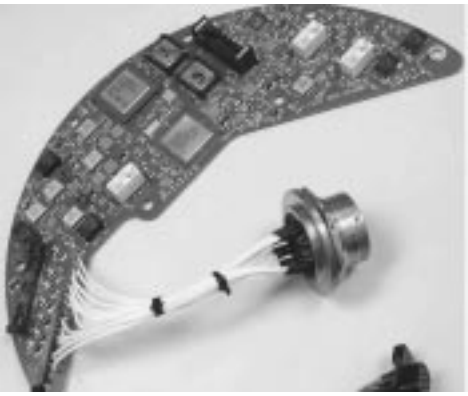
Microsystems can be used to affordably refurbish the stockpile while gaining critical advantages in the changing global security environment. First, microsystems are so small that a single microsystem can replace dozens of much larger and heavier older components. More functions (specifically safety and security) can be incorporated in a comparable space. The smaller size of microsystems allows the use of highly integrated, expanded coverage, and enhanced-fidelity joint test assembly functions in systems that can diagnose and communicate their condition at all times. Second, microsystems are extremely tolerant of shock and vibration. Microsystems have been taken to 100,000-gravity levels without failure. Third, microsystems are modular and inherently reconfigurable, enabling the development of an integrated component suite suitable for use in multiple weapon platforms. Fourth, microsystems are inexpensive because they are batch fabricated. For example, the cost of airbag deployment systems in cars that use conventional technology is about $1,200 per system. In contrast, deployment systems using microsystem technology pioneered at Sandia can perform this same function for less than five dollars. Because microsystem components are lighter and smaller to carry, they also can reduce the cost of future delivery systems. Finally, microsystems are reliable because they are batch fabricated using integrated circuit techniques. Thus, they achieve the same high levels of process control and reliability as those found in integrated circuits.

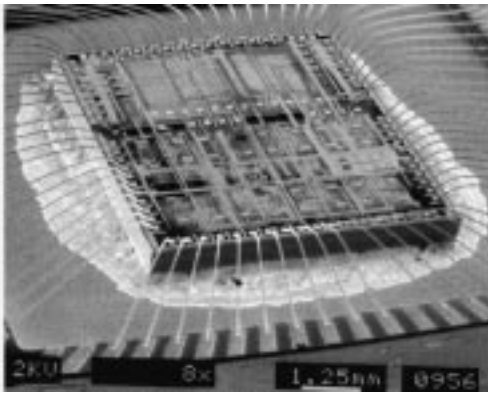
In addition to the advantages that derive from using modern technology in weapons, the exciting new technologies associated with microsystems also will help Sandia recruit and retain our share of the nation's top scientists and engineers. Refurbishing the stockpile is not easy, and it continues to require the best efforts of our brightest technical minds. To motivate such people to come to Sandia and to stay here, we must offer them stimulating and challenging work.

To help integrate the expertise of our top scientists and engineers, we are developing advanced science-based computational tools that will be used in the design and qualification of microsystems for weapons applications. These computational tools integrate Sandia's multidisciplinary strengths in materials science, engineering science, computational science, physics, chemistry and microsystems technologies to address all aspects of microsystem qualification, from fabrication and packaging to performance and reliability. The tools cover the full range of engineering phenomena, including electromagnetics, structural response, material response, fluid transport, and thermal transport. They are based on phenomenology ranging from the atomic scale upward.

As various external review groups have noted, working at Sandia is stimulating and challenging because we are the world leader in microsystems. There is no comparable commercial capability, and even with technology transfer there will not be an adequate commercial capability to meet pressing stockpile needs. Thus, maintaining Sandia's integrated microsystems capability is probably the only way to meet the long-term needs of our stockpile stewardship mission.

Today, Sandia has only research, development, and demonstration capabilities for these amazing devices. We use two existing facilities: the Compound Semiconductor Research





As the stockpile ages, key components in weapons can be replaced by much smaller and less expensive microsystems.

Laboratory (which has aged to the point where it must be recapitalized) and the Microelectronics Development Laboratory (which is the nation's foundation for defense radiation-hardened microelectronics, but also needs equipment recapitalizing). If Sandia is to meet the need for micro-systems in the stockpile, we must develop these capabilities.

Sandia can best meet critical stockpile needs using new microsystem technology but we cannot do so by neglecting other responsibilities. We must preserve essential capabilities in radiation-hardened microelectronics. Of the total chip market, the market share of radiation-hardened microelectronics needed by the NNSA, the DOE, and the DOD remains at no more than 0.5 percent. Nonstandard design and special fabrication techniques are required to enhance the radiation resistance of integrated circuits and devices, neither of which is of interest to high-volume commercial vendors. Therefore, commercial circuits cannot meet mission requirements for radiation resistance. A decade ago, there were fifteen suppliers of these devices. Now only two vendors remain to bid on the production of replacement digital circuits required for the Stockpile Life Extension Program, and these vendors face financial risk because of the high infrastructure cost and limited market. Only one vendor remains to build the radiation-hardened nonvolatile memories for circumvention and code-storage applications. Consequently, NNSA would encounter a substantial delay without Sandia's microelectronics program. Such a delay could affect large portions of the stockpile.

As insurance against such a contingency, Congress authorized the National Defense Electronics Partnership in FY 1998. This partnership mandates that Sandia retain the institutional memory for radiation-hardening technology and sustain the supporting infrastructure for developing radiation-hardened microelectronics. Through the National Defense Electronics Partnership, volume production would be performed by vendors in the private sector; however, Sandia would provide any components with production volumes too small to interest the private sector. This focused program allows Sandia to sustain and develop radiation-hardening technologies for quick transfer to industry as needed. The program also expedites the entry of new suppliers into this specialized market. Because Sandia must continuously exercise the process of designing, producing, and validating radiation-hardened microelectronics, this capability provides a limited in-house production capacity that could furnish replacement parts while new suppliers are being established.

Congress has designated Sandia as the contingency development and fabrication facility for radiation-hardened microelectronics. We meet our responsibilities through the Microelectronics Development Laboratory by using facilities, equipment, and staff that the NNSA and the DOE have already assembled. The Microelectronics Development Laboratory, which is equipped to manufacture 0.5-micron semiconductors on six-inch wafers, is upgrading to 0.35-micron circuit capability on industry-compatible eight-inch wafers, which will enable Sandia either to rapidly transfer radiation-hardened integrated circuit designs and technology to industrial partners or to manufacture such circuits if necessary.

Sandia manufactures microelectronic chips using the Engineering Test Stand, a prototype Extreme Ultraviolet Lithography machine.

Funding Requirements for the Microsystems and Engineering Sciences Applications Complex
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Construction (Project Engineering Design)	12.0	0.0	0.0	0.0	0.0	0.0
Construction (Total Engineering)	39.0	93.0	140.0	70.0	0.0	0.0
Other Project Costs	3.6	3.7	4.1	4.2	3.4	1.5
Total Cost	54.6	96.7	144.1	74.2	3.4	1.5
Direct Personnel	25	25	25	25	25	25

If Sandia is to meet the need for microsystems in the stockpile, we must recapitalize both the Compound Semiconductor Research Laboratory and the Microelectronics Development Laboratory. To complement the Microelectronics Development Laboratory's capabilities, we also need a facility that will produce certified microsystem products for NNSA Defense Programs systems. Moreover, to accomplish this goal in the time frame required to meet pressing stockpile refurbishment schedules, Sandia must rely on and incorporate the most advanced elements of our integrated product and process design capabilities. For example, we must exploit concurrent engineering techniques and computational modeling and simulation technologies to develop modular design tools, thus enabling weapon component engineers to design, develop, engineer, test, and certify microsystem replacements on a greatly accelerated schedule.

To meet this objective, we must develop a Microsystems and Engineering Sciences Applications (MESA) complex to integrate the recapitalizing of the Compound Semiconductor Research Laboratory and the Microelectronics Development Laboratory and to develop the new capabilities required to fulfill pressing stockpile refurbishment needs.

7.2 Nonproliferation and Materials Control

Since the 1950s and the Eisenhower Atoms for Peace days, the United States has met the challenges of nuclear proliferation. The advanced countries of the world must continue to support the legitimate expansion and use of nuclear power while preventing the proliferation of nuclear weapons. The International Atomic Energy Agency and the Nuclear Nonproliferation Treaty served the world well in this regard until the 1990s. Now, with the experiences in the Persian Gulf and more recent events in India and Pakistan, the efficacy of that system of proliferation control has been cast into doubt. To reduce the risk of further proliferation, and to reinstate a regime of effective nonproliferation, the DOE has an opportunity to use its national laboratories to reassert US influence in the international nuclear arena.

7.2.1 Treaty Verification/ Nonproliferation Technology

The National Nuclear Security Administration Office of Defense Nuclear Nonproliferation develops (through the national laboratories) the technology to monitor compliance with treaties relating to nuclear testing limitations. As these restrictions increase, technologies to monitor compliance must continue to evolve.

Sandia continues to support a program in conjunction with Los Alamos, Lawrence Livermore, and Pacific Northwest national laboratories and the US Air Force to develop sensors and data processing technologies that will enable the nation to monitor provisions of comprehensive test ban treaties. These technologies encompass space-based and earth-based sensor systems. The space-based sensors include advanced optical and electromagnetic pulse sensors. The earth-based sensors include seismic, infrasound, radionuclide, and hydroacoustic systems. Successful development and deployment of these systems will allow the United States, and in some cases our international partners, to monitor treaty compliance.

The National Nuclear Security Administration Office of Defense Nuclear Nonproliferation has long used the national laboratories to develop technology to detect activities associated with nuclear weapons proliferation. Recently, the National Nuclear Security Administration broadened its responsibilities in this area to include other weapons of mass destruction, notably chemical and biological weapons.

The Comprehensive Test Ban Treaty (CTBT) is being discussed by Consultant to the President's CTBT Task Force Sid Drell, former Joint Chiefs of Staff Chairman General John Shalikashvili, Sandia Senior Vice President Roger Hagengruber, and Sandia Executive Vice President Joan Woodard (left to right).

Sandia is developing new capabilities to detect the proliferation of nuclear, biological, and chemical weapons of mass destruction. In partnership with Los Alamos National Laboratory and the US Air Force, we developed a multispectral imaging sensor capable of accurate radiometry; this sensor was integrated into a satellite launched in CY 2000. We also are developing an active ultraviolet laser system that can remotely detect materials associated with various proliferation activities.

The development of more capable sensors with greater resolution and sensitivity is essential to our continued success in the remote monitoring of proliferation-related activities. These sensors also must be small, light, and power-efficient. To this end, we are forming a partnership with our microelectronics group to develop extremely small satellites. Success in this venture will ensure our continued access to a broad spectrum of space-based sensor platforms.

Funding Requirements for Treaty Verification/Nonproliferation Technology

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	95.0	101.0
Direct Personnel	310	312

7.2.2 Global Nuclear Management

This initiative builds on last year's Global Nuclear Materials Management Initiative, which focused on Sandia's support of the National Nuclear Security Agency's efforts to extend US influence on international discussion of nuclear matters.

The Global Nuclear Management Initiative is needed to stimulate discussion about and create activities through which the nuclear energy community can team with the nonproliferation community to ultimately create the next generation of nuclear reactors, which must be inherently proliferation resistant. Such discussion includes the value of nuclear energy in relation to increased use of fossil fuel, special nuclear material, pharmaceutical and agricultural isotopes, radioactive waste, and associated environmental concerns.

Therefore, we have begun to build an integrated framework comprised of policy and technical issues for global nuclear management. Specifically, we established several Laboratory Directed Research and Development (LDRD) projects jointly between Sandia's Nonproliferation and Materials Control and Energy and Critical Infrastructure groups.

One LDRD project is developing a decision-making methodology to ensure the safe, secure, and legitimate use of defense, excess, and civilian nuclear materials. Sandia has used this methodology to analyze the risk of nuclear weapons proliferation by nonweapon states. Another LDRD project is using a simulation model to analyze possible scenarios for nuclear energy, nuclear waste, and weapons systems issues. We are also using the LDRD framework to consider the risk of proliferation within the nuclear fuel cycle.

We presented (and subsequently published) a paper on global nuclear management in Beijing at the Seventh International School on Disarmament and Research on Conflicts (ISODARCO)-Beijing Seminar on Arms Control. This conference brought together nonproliferation experts from China, Canada, Europe, Japan, Russia, and the United States to discuss nuclear weapons nonproliferation and disarmament issues.

Sandia provided technical support to the International Atomic Energy Agency (IAEA) Trilateral Initiative, a joint effort of the IAEA, Russia, and the United States. This initiative focuses on verification that excess plutonium under IAEA safeguard is not used for weapons. We also submitted abstracts for presentations to the IAEA and other international forums.

We have held nuclear strategy workshops with US federal sponsors, think tanks, and nongovernment organizations. We have incorporated global nuclear management issues into the University of New Mexico Public Policy Institute's national security survey to obtain public views on these issues. We also presented a position paper at the

Congressional Nuclear Caucus in 2001, during which Senator Domenici introduced legislation to support nuclear energy technologies.

Sandia is using the Global Nuclear Management initiative to apply our crosscutting competencies in such areas as systems analysis and engineering to the benefit of the National Nuclear Security Administration, the nation, and the world.

Funding Requirements for Global Nuclear Management

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1
Operating	1.5
Direct Personnel	6

7.2.3 Materials Protection, Control, and Accounting

The dissolution of the Soviet Union in 1991 weakened the effectiveness of their existing nuclear security. Recognizing the danger presented to global nuclear security if these materials were stolen, Russia and the United States, in cooperation with other countries, began efforts to safeguard Russian nuclear materials. Up to a thousand metric tons of fissile material is estimated to be the legacy of Russia's fifty years of nuclear weapons and nuclear power programs. These materials are highly dispersed in approximately 250 buildings located at forty different sites across Russia.

The objective of the National Nuclear Security Administration's Materials Protection, Control, and Accounting Program is to reduce the threat to US security from unsecured Russian weapons-usable nuclear material by providing a first line of defense and preventing nuclear proliferation and nuclear terrorism. The program employs a three-part approach: secure the material by installing physical security and accountancy upgrades appropriate for the level of material attractiveness and the threat of theft; reduce the number of targets for theft by consolidating material into fewer buildings at fewer sites and also converting excess highly enriched uranium into low enriched uranium; and encourage the development of Russian capabilities and commitments to operate, maintain, and regulate these security improvements for the long term.

Sandia participates in the Materials Protection, Control, and Accounting Program in cooperation with the National Nuclear Security Administration and other national laboratories. Our involvement has included work at Russian Federation Navy sites, defense and civilian facilities of the Ministry for Atomic Energy of the Russian Federation, and national infrastructure (transportation, communication, training, and sustainability) projects. In a February 2001 report, the General Accounting Office identified four sites where Materials Protection, Control, and Accounting work in Russia had been demonstrably successful in reducing the risk of nuclear materials proliferation: the Mayak Production Association, the Institute of Physics and Power Engineering (Obninsk), and Navy Fuel Storage Sites 49 (Murmansk) and 34 (Vladivostok). Sandia provided the project leadership for all work mentioned at those four sites.

Our work with the Russian Navy includes protection of fresh highly enriched uranium fuel and nuclear warheads. Work this past year resulted in the consolidation of fresh fuel owned by the Northern and Pacific fleets into two secure storage locations. The fresh submarine fuel was previously stored in twenty unsecured sites. Also completed this year were comprehensive security upgrades for the Sevmash Submarine Building Plant and four refueling ships. For the weapons facilities, rapid physical security upgrades were completed for thirty-seven sites, comprehensive physical security upgrades were completed at five sites, and vulnerability assessments and comprehensive upgrade designs are in progress. As a result of these activities, about 48 metric tons of highly enriched uranium are now more secure, and the risk of theft for virtually all Russian Navy strategic warheads has been reduced.

Other accomplishments of this program include increasing the security of nuclear material in transit by hardening over sixty trucks and thirty railcars, thereby establishing secure transport of nuclear materials within and between twenty sites.

Funding Requirements for Materials Protection, Control, and Accounting

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1
Operating	90.0
Direct Personnel	51

7.2.4 Transparency

The concept of transparency, or nuclear arms reduction verification, was initiated as a part of ongoing strategic nuclear arms control discussions. Transparency was developed by the National Nuclear Security Administration (NNSA) with the assistance of the US national laboratories and the Russian nuclear institutes. Sandia has been instrumental in transparency efforts and continues to work with the NNSA.

Beginning with a goal of irreversible and verifiable dismantlement of nuclear weapons, the work has extended to the entire process of global nuclear materials management. This effort includes monitoring weapon status during transportation, storage of components and special nuclear material, various aspects of the civilian nuclear fuel cycle, and the ultimate disposition of weapon-usable materials.

Funding Requirements for Transparency
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1
Operating	2.5
Direct Personnel	8

7.2.5 Preventing the Spread of Proliferation-Relevant Knowledge and Expertise

Sandia has worked with the National Nuclear Security Administration Office of Defense Nuclear Nonproliferation on programs to prevent the spread of proliferation-relevant information from scientists, engineers, and technicians who are suffering extreme economic hardship after the downsizing of the former Soviet Union's weapons complex. Our efforts involve the International Science and Technology Center, the Initiatives for Proliferation Prevention, and the Nuclear Cities Initiative. The Initiatives for Proliferation Prevention address the problem by identifying technical capabilities in the Russian weapon institutes that may have commercial potential and then matching those capabilities with industrial partners in the west. The Nuclear Cities Initiative is a companion program that focuses on near-term but sustainable employment of individuals within the Ministry for Atomic Energy of the Russian Federation (Minatom) nuclear complex. The principal vehicle for these projects is direct contracting with the Russian principal investigators at nuclear weapons sites.

Funding Requirements for Preventing the Spread of Proliferation-Relevant Knowledge and Expertise
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1
Operating	4.2
Direct Personnel	3

7.2.6 Expanded Cooperative Monitoring Center and Program

The end of the Cold War has resulted in a dynamic world characterized by rapid industrialization, regional rivalries, localized arms races, and competition for living space and resources—all at a time when the spread of advanced technology is increasing global military capabilities, including weapons of mass destruction and their delivery systems.

Weapons of mass destruction are a means of furthering regional ambitions and challenging international efforts to moderate those ambitions. The proliferation of military technologies and expanding threats of nuclear, chemical, or biological aggression already are degrading global stability. Sandia's responsibilities for arms control, nonproliferation, and counterproliferation are critical for counteracting this instability.

The success of the National Nuclear Security Administration/DOE and the United States in meeting these responsibilities ultimately will depend on our ability to

- work cooperatively on the international scene,
- build trust and confidence among nations by our actions and intentions,
- place elements of policy into our relationships with the world's nations and institutions, and
- reduce the regional and global insecurities that drive the proliferation of weapons of mass destruction and the means to deliver them.

Since its creation in July 1994, Sandia's Cooperative Monitoring Center (CMC) has helped the DOE (and subsequently the National Nuclear Security Administration) achieve their security objectives through cooperative technical collaboration. Sandia's vision for the CMC is to help achieve a peaceful world through technology. The CMC develops technical capabilities to support international cooperation on nonproliferation, arms control, the environment, and other strategic issues. Through workshops, conferences, training sessions, and programs, the CMC promotes global nuclear materials management, regional security, arms control, resource management, and environmental security.

The CMC focuses a wide range of technical and analytic capabilities on national cooperative security objectives. Our contributions include development, testing, demonstration, and operation of nonproliferation and validation technology; modeling and analysis using game theory; methodologies for system design and evaluation; technical collaborations; training opportunities; and the Visiting Scholars Program. More than one hundred countries have participated in CMC programs, including Russia and the countries of the former Soviet Union, northeast Asia, south Asia, Southeast Asia, Latin America, and the Middle East.

Funding Requirements for the Expanded Cooperative Monitoring Center and Program
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2	Year 3	Year 4	Year 5
Operating	3.8	3.8	3.8	3.8	3.8
Lease Cost for International Programs Building	1.5	1.5	1.5	1.5	1.5
Total Cost	5.3	5.3	5.3	5.3	5.3
Direct Personnel	9.5	9.5	9.5	9.5	9.5

The CMC provides a unique facility for meeting post-Cold War security challenges that address unprotected nuclear material in other countries, the need for nuclear weapons reductions, the need to limit or eliminate weapon and missile proliferation, the need to contain regional instability, and the need to cope with increasing competition for natural resources. These challenges include the possibility for increased international cooperation, new arms control initiatives, confidence-building and transparency measures, and new peace processes.

The CMC also facilitates the development of human relationships and technology to support international cooperation on security issues. The CMC has pioneered approaches that enable the United States to engage in critical cooperative efforts with foreign visitors while providing the necessary separation between foreign nationals and Sandia's work force and restricted areas. However, the success of the CMC has placed great demands on current facilities and on Sandia's capabilities to meet all requests. An International Programs Building, which will be built by FY 2002, will house the new CMC. It will include improved space for visiting scholars, conferences, and meetings; a library; a global situation room; teaching laboratories; system development and testing laboratories; and support offices.

Although Sandia has always stressed compliance with security procedures for foreign visitors, recent security concerns have caused us to reexamine these visits. The existing CMC was created in anticipation of this need, but we will continue to ensure that the success of our programs and the growth of our operations do not impact our future vigilance.

7.3 Energy and Critical Infrastructure

7.3.1 The Center for Integrated Nanotechnologies

At the invitation of the DOE's Office of Basic Energy Sciences, Sandia and Los Alamos national laboratories are developing plans for a Nanoscience Research Center in New Mexico. This facility will be one of five regional Nanoscience Research Centers sponsored by the Office of Basic Energy Sciences. The New Mexico Center will be called the Center for Integrated Nanotechnologies.

The Center for Integrated Nanotechnologies will develop the scientific principles that govern the performance and integration of nanoscale materials and will educate a new generation of scientists, thereby building the foundation for future nanotechnologies. We expect the Center for Integrated Nanotechnologies to play a significant role in

- advancing understanding and control of materials at the nanoscale;
- providing nanofabrication, characterization, theory, and integration capabilities that leverage existing facilities and expertise;
- providing a broad interdisciplinary research environment that stimulates new collaborations among the national laboratories, academe, and industry; and
- educating a nanoscience work force and developing future technologies.

Technical research at the Center for Integrated Nanotechnologies will be divided among four categories: nanophotonics and nanoelectronics, complex functional materials, nanomechanics, and nano/bio/micro interfaces.

Funding Requirements for Center for Integrated Nanotechnologies
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	4.0	4.0
Direct Personnel	14	14

7.3.2 Energy Portfolio

Sandia's energy portfolio focuses on power for peace and prosperity. The need for energy can lead to conflict between nations, so Sandia provides technologies and policy studies that support US efforts to assure that all countries have access to sufficient and affordable energy.

Our national prosperity is closely linked to the availability of affordable, reliable, and clean energy. Sandia's history of nuclear weapons work and our exceptional systems analysis and engineering capabilities are applicable to many types of energy research. To promote peace and prosperity worldwide, Sandia provides systems analyses for a balanced portfolio of energy options and can develop technologies to support this portfolio by teaming with other DOE laboratories, industry, and international partners.

We propose to continue supporting the DOE in assessing energy options that balance cost, environmental impact, safety, security, and reliability. Because of energy transmission and end-use issues, Sandia's surety capabilities are also applicable to this initiative.

Funding Requirements for Energy Portfolio
(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	2.0	2.0
Direct Personnel	6	6

7.3.3 Critical Infrastructure Surety

The US infrastructure is a complex system of interdependent elements whose uninterrupted operation is vital to the national security and economic well-being of the country. This infrastructure is vulnerable to malevolent threats from terrorists or cyber attackers. Furthermore, this infrastructure is increasingly complex and interdependent, which makes it subject to increased vulnerability and cascading failures. Sandia has capabilities that can improve the surety (i.e., the confidence that a system will perform in acceptable ways during normal, abnormal, and malevolent circumstances) of infrastructures critical to US security. Infrastructure surety is the new national security challenge.

7.3.3.1 Critical Infrastructure Interdependencies

Experience has shown that loss of service in one infrastructure element can produce indirect but potentially severe collateral damage in other infrastructure elements. For example, the telecommunications infrastructure depends heavily on the electric power infrastructure. Although models of individual infrastructure elements have been developed, no comprehensive models of the entire system exist to show the interdependencies among them.

Sandia is addressing this problem with our capability for simulating complex systems, a capability that grew from our mission of nuclear weapons stockpile surety. Our simulation capabilities can be applied to modeling the interdependencies in the US infrastructure. Sandia's computers, among the fastest in the world, are currently running detailed simulations of a variety of complex systems. We use microsimulation techniques to analyze the short- and long-term effects of policy decisions as well as the impact of unexpected disruptions on national infrastructures. Dynamic simulation techniques are used to analyze the performance of such infrastructure elements as electric power, telecommunications, and water. These models are also used to analyze the impacts of interdependencies and resulting cascading failures.

7.3.3.2 Consequence-Based Methodology for Infrastructure Surety

Specific malevolent threats to the infrastructure are difficult to define. We need a different approach to identify critical nodes and design protective measures. However, because of the lack of a specific threat definition, private industry is unwilling to invest in infrastructure protection, although industry acknowledges that certain consequences are unacceptable.

Sandia has developed a consequence-based methodology to better assess national infrastructure risk and reliability issues. We have identified important critical nodes, fundamental causes of failures, threat scenarios, and specific failure modes of infrastructures. This consequence-avoidance approach has clear appeal for both private industry and government agencies because it can optimize protection strategies. Extending such results to economic modeling may efficiently prioritize allocation of protection options.

A similar approach has been used as the basis for assessment of nuclear power plant and weapon safety. Sandia has led the nation for more than twenty years in the application of probabilistic risk assessment to the problem of designing safe, secure nuclear reactor facilities.

7.3.3.3 Indications and Warning System

Several studies have demonstrated that an adversary could attack the US infrastructure while disguising the attack as a series of apparently random events by computer hackers. No capability exists within the nation to warn of such attacks, so providing timely indications and warnings may be the most difficult technical challenge we face. In addition, the complexity of the infrastructure means that it is difficult to operate the system reliably. A good example is the recent power grid situation in California. Sandia is in a unique position to supply some of the technology needed for an infrastructure monitoring and detection system, and to use the data to develop indications and warnings capabilities. We have developed many pattern-recognition techniques for real-time target detection using a variety of ground-, air-, and space-based sensors. Sandia also has developed methodologies for determining monitoring regimes; small, inexpensive smart sensors; and advanced information technologies for real-time data collection, security, analysis, availability, presentation, and decision-support systems.

New microsimulation models using Sandia's high-performance computers have recently proven viable. Sandia has a key role in monitoring and reporting systems for counterproliferation. We manage several international programs in cooperative monitoring. These National Nuclear Security Administration/DOE-funded programs include the Modular Integrated Monitoring System, the Integrated Nuclear Materials Monitoring System, and the Integrated Intrusion Detection and Access Control Automation System. These programs provide a technical basis for designing an effective warning system for the US infrastructure.

7.3.3.4 Transportation Surety

Sandia has extensive experience as a systems laboratory tasked with engineering and ensuring the safety, security, and reliability of very high-consequence systems such as nuclear weapons and power systems. This experience (coupled with our broader expertise in engineering and science, human factors, information systems, and aviation safety) provides a unique capability to assist the Federal Aviation Administration and the National Aeronautics and Space Administration in transportation surety efforts.

To this end, Sandia is involved with several complementary projects. One is the Airworthiness Assurance Nondestructive Inspection Validation Center, which initially focused on the structural problems of aging aircraft but has expanded to include developing and validating improved inspection and maintenance technologies, deploying them to civilian and military users, and developing new test beds for nonstructural systems such as wiring.

Another project involves the Aviation Safety Critical Elements and Necessary Tasks Program, which supports both aviation regulation and certification and the Office of Aviation Research. Sandia's nonintrusive explosives detection portal, which can detect very small quantities of explosive residue on both baggage and personnel, is in the process of being commercially manufactured.

Funding Requirements for Critical Infrastructure Surety

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	5.0	8.0
Direct Personnel	25	32

7.3.4 Systems and Policy Analysis

Protecting critical domestic and international infrastructures requires early identification and understanding of economic, political, technological, environmental, and social trends that may result in serious future threats. The consequences of these trends and of major policy responses must be systematically identified and understood. Early identification of trends, forces, and discontinuities can provide lead time to develop advanced technological solutions.

Systems and policy analysis and related modeling at Sandia will help identify emerging issues associated with the surety of critical infrastructure, develop a policy- and technology-based comprehensive understanding of the issues, and identify specific areas in which technology will

make a difference. To support this effort, Congress recently established the National Infrastructure Simulation and Analysis Center, a consortium involving Sandia and Los Alamos national laboratories. This center will assemble and use the models necessary to support analysis of the nation's infrastructure. Where appropriate, Sandia's technology will link with domestic and international institutions.

Funding Requirements for Systems and Policy Analysis

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	1.7	3.0
Direct Personnel	5	10

7.3.5 Nuclear Energy Initiative

Sandia's Nuclear Energy Initiative includes the nuclear energy, transportation, and repository programs and is a complement to the Global Nuclear Management initiative.

The nation is responsible for its own security and to some extent the security of the rest of the world against a nuclear exchange. Sandia thinks that this situation and the threat of environmental deterioration offer a significant leadership opportunity to the United States. In theory, a renewed US emphasis on nuclear power would address world security, economic, and environmental threats. In practice, we must address significant technical challenges.

Nuclear power is part of our history and should be part of our future. In the early 1950s, President Eisenhower recognized the potential for nuclear power to be put to beneficial use and also that international collaborations were needed to control the proliferation of nuclear weapons. His Atoms for Peace plan led to the construction of about four hundred nuclear power plants around the world. Approximately one hundred of these plants are in the United States.

In the 1970s, the United States was dominant in both nuclear power and weapons technology. Since then, a number of factors (including cost and fear of radiation) have slowed the development of nuclear power in the United States. However, global partnerships were forming in Europe, the Soviet Union, Northeast Asia, and elsewhere that continued advancing nuclear power technology. Today, the United States remains dominant in nuclear weapons capabilities but is less involved in developing reactors and processing nuclear fuel.

The United States must promote policy and technology investments that improve national security and prevent environmental degradation. Research investments should include a new generation of efficient, safe reactors that burn weapons-grade materials and replace fossil fuel plant emissions. These reactors must be monitored in a safe way that is acceptable to the world. This is a complex international policy issue because stakeholders include industry, environmentalists, governments, and utilities. We think that establishing the United States as a leading technology and policy provider in this area is clearly in the nation's best interest.

In the United States, the cost of existing nuclear power per kilowatt-hour is generally less than that of renewable energy, except for wind and biomass. However, the high capital outlay required to build additional current-generation designs and scheduling uncertainties are major disadvantages. Research on new designs, such as high-temperature gas-cooled nuclear reactors—which have far greater efficiency, significantly less complexity, and minimal proliferation potential compared to current light-water reactors—is essential for the next generation of nuclear power plants to become reality.

Policy analysis, research, and technology development and deployment will form the core of any systems-level solution. The Nuclear Energy Initiative is committed to

- facilitating the energy security of the United States by developing a revitalized nuclear infrastructure,
- helping to close the cradle-to-grave nuclear fuel cycle by developing permanent solutions for waste disposal,
- creating new technologies that make new nuclear power plants economically competitive as well as safer and more environmentally benign compared to conventional plants, and
- resolving the difficult nuclear policy decisions required for the United States to regain an international leadership role.

Funding Requirements for Nuclear Energy Initiative

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	3.0	8.0
Direct Personnel	10	25

7.3.6 Navajo Nation/ National Laboratories Partnership

7.3.6.1 Navajo Nation and Sandia National Laboratories Memorandum of Understanding

Sandia and the Navajo Nation signed a historic memorandum of understanding to create technology partnerships that use Sandia's expertise and resources to help address technical issues on the reservation. The memorandum authorizes support of future collaboration and technology transfer, with emphasis on energy, environment, education, economic development, and communication.

7.3.6.2 Navajo Tribal Utility Authority Partnership

Sandia has a strong relationship with the Navajo Nation, particularly through the Navajo Tribal Utility Authority. Under this partnership, the photovoltaic program will expand via the joint development of strategic, multi-year plans focused on sustainable renewable energy projects and associated businesses.

The plans will include determining life-cycle costs of fielded, stand-alone photovoltaic systems; collecting data on and monitoring installed systems; building technical assistance and capacity; developing sustainable business and growth of present activities; and monitoring and evaluating installed projects and the overall implementation plan.

Public Law 106-511 (Section 602, Navajo Electrification Demonstration Program) provides the Navajo Nation with a program to ensure that every household on the reservation that requests it has access to a reliable and affordable source of electricity by the year 2006. The requested appropriation is under consideration. Sandia supports this program and will assist as requested.

7.3.6.3 Village/Community Integrated Off-Grid System

Sandia has proposed to the Navajo Nation and the Navajo Tribal Utility Authority the concept of a Village/Community Integrated System known as INet. The concept calls for sustained and integrated communications, education, health, environment, energy, and economic development on tribal lands through effective technology and capacity-building partnerships. Sandia would work with the Navajo Tribal Utility Authority to develop the system into a suite of tribally owned, managed, and operated infrastructure-related technologies to improve the quality of life of rural Navajos.

This effort will involve many ongoing independent programs and activities. INet integration will be based on advanced information technology and indigenous energy resources. The system will more efficiently deliver social and economic benefits and reach larger segments of the populations than previously possible.

Sandia will utilize our world-class technical strengths, systems engineering expertise, and strong relationship with the Navajo Nation to lead development of the INet. Sandia's American Indian Outreach Committee will help identify appropriate Native American partner entities and will provide liaison between Navajo and non-native participants. This will ensure that the initiative's approaches are consistent with local cultures and that the Navajo Nation assumes ownership in building and using the new infrastructure.

7.3.6.4 Environmental Program Partnership

The DOE and the Navajo Nation both must deal with soil and water contamination by uranium and processing chemicals. An environmental program partnership between the Navajo Nation's Environmental Protection Agency, the DOE national laboratories, and the US Environmental Protection Agency could benefit all parties. The proposed partnership would address both technical and cultural issues. The Navajo Nation would benefit from technology transfer while the national laboratories would profit from lessons learned that may be applicable to other Native American sites.

The national laboratories have capabilities in risk assessment, decision analysis, remediation, and restoration technologies. The proposed partnership would adapt these technologies while respecting Navajo cultural traditions. The national laboratories can provide information on the availability of various environmental cleanup capabilities and on the establishment of an information technology infrastructure for decision-making. This process would include a review of existing risk-assessment and decision-making, as well as elicitation and development of decision criteria that incorporate Navajo goals and values.

The Navajo Nation would take the lead in defining and developing project plans, site selection, priorities, remediation objectives, and funding. The national laboratories would support implementation of environmental restoration decisions. The Navajo Nation would contract for and manage the remediation of selected sites (including the deployment of selected technologies), while the national laboratories would provide technical support for the contract and deployment processes. This support would include training and mentoring.

The national laboratories will transfer their technical expertise to the Navajo Nation, which will in turn provide

feedback to the laboratories on the success of the technology transfer. Transfer of information and culture will occur through exchanges of personnel.

Funding Requirements for Navajo Nation/ National Laboratories Partnership

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	0.4	0.4
Direct Personnel	2	2

7.3.7 Hanford Site

The US nuclear weapons program generated its first high-level waste in the mid-1940s, when irradiated nuclear fuel rods were processed to recover uranium and plutonium for nuclear weapons production. This liquid waste is stored in underground tanks at the Hanford Site in western Washington State. Over the years the tanks have corroded and started to leak. In addition, the Hanford Site also must deal with decontamination and decommissioning of nuclear reactors, management of transuranic waste, and disposal of low-level waste. Numerous opportunities exist for Sandia to support the DOE in the management of the Hanford Site.

7.3.7.1 Performance Assessment as a Programmatic Decision Tool

The DOE established the River Protection Project to protect the Columbia River from contamination. Strategic analyses defined an integrated risk-based strategy for completion of the project's single-shell tank waste-retrieval and tank-farm closure mission. These strategic analyses are based on a systems approach that includes programmatic, technical, and financial uncertainty with conservative assumptions in human health risk and waste immobilization.

The project's analyses used a deterministic approach and did not fully characterize the uncertainty. In addition, the deterministic approach did not support programmatic decisions and resource allocation based on impact of uncertainty in the performance measures.

Sandia proposes to enhance the existing performance assessment capability using a probabilistic method to select factors important to the project. We would put a Monte Carlo shell around the system now being used for deterministic calculations so that uncertainty can be identified, quantified, and tracked.

The resulting performance assessment and decision analysis will provide sufficient capability to answer defensibly the following questions based on long-term performance impact:

- What level of retrieval is necessary for each tank and tank farm to meet performance objectives?
- What is the prioritization of tanks to be cleaned on a worst-risk-first basis, considering the total risk from all important radionuclides and realistic uncertainty throughout the system?
- Which data are needed and which are not needed to complete tank waste retrieval and tank farm closure efficiently (i.e., to identify which and how much characterization and monitoring data are enough for individual tanks and tank farms)?
- What are the relative risk benefits of various retrieval technologies?

Sandia's proposed work interfaces well with other activities at Hanford. The scope of work represents local dedicated studies of tanks and tank farms at a resolution appropriate for decision-making about waste retrieval and tank farm closure.

7.3.7.2 Probabilistic Assessment of Waste Qualification

Sandia proposes to perform a probabilistic assessment of sampling and process methods for the qualification of high-level waste immobilized in glass. The objective is to evaluate variations and track uncertainties in selected glass to determine the probability of accepting such waste for disposal at Yucca Mountain.

We will perform a systematic decision analysis to synthesize existing data, related uncertainties, and variations. We will then perform a multi-attribute utility analysis to assess impacts of uncertainty and variations in the feed, processing, sampling, and analytic systems. We will consider such factors as cost, turnaround, radiological risk for workers and the public, schedule, and quality. We will compile data and related uncertainties and variations for each alternative based on existing information where available and on expert elicitation where information is not available.

To perform independent assessment and verification using a probabilistic assessment tool we must

- identify variation and uncertainty affecting estimates of glass composition, including sampling uncertainty and analytic uncertainty;
- evaluate the nonradioactive composition data base used to develop property-composition models and corresponding uncertainty expressions;

- use the Bechtel G2 model (a graphical, object-oriented software) and incorporate uncertainty expressions, compliance requirements, and processing constraints;
- develop a performance parameter based on currently approved Yucca Mountain waste acceptance criteria; and
- perform a probabilistic assessment using G2 model output to determine whether the selected waste stream could fail to meet disposal waste acceptance criteria.

7.3.7.3 Apatite Reactive Zone Project

Preventing leachate from migrating out of high-level waste storage tanks is a significant issue at Hanford. Technologies developed through the Sandia Laboratory Directed Research and Development Program are being explored for use at the Hanford Site. These technologies include the design of in situ barriers in soil and groundwater for sequestering actinides, strontium, heavy metals, metalloids, technetium, and selenium. Laboratory tests, field trials, and field deployment are proposed to determine the effect of these techniques on leak mitigation.

7.3.7.4 Decontamination and Decommissioning Demonstrations in the Former Soviet Union

Sandia has begun discussions with the DOE Office of River Protection at Hanford to explore opportunities to collaborate with the former Soviet Union. Specifically, the United States National Nuclear Security Administration/DOE could conduct field tests of decontamination and decommissioning equipment on former Soviet Union spent nuclear fuel reprocessing canisters and other large systems. These field tests would demonstrate the effectiveness of decontamination and decommissioning techniques on problems that also exist at Hanford.

Funding Requirements for Hanford Site

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	2.1	2.6
Direct Personnel	10.5	13

7.3.8 Soil and Sediment Transport Laboratory

As the DOE's scientific advisor for the Waste Isolation Pilot Plant, Sandia has developed many capabilities applicable to other agency needs. The new Soil and Sediment Transport Laboratory has conducted various experiments for a variety of projects. Federal agencies such as the US Army Corps of Engineers, the Environmental Protection Agency, the DOE, and the Department of Agriculture have provided funding for this facility.

Sandia designed and constructed a mobile flume and erosion-testing device to perform erosion experiments on mixed sediments under high-shear stress conditions. The following experiments are part of an ongoing collaborative project with the US Army Corps of Engineers. We completed an analysis of sediment grain coatings from the Housatonic River (Western Massachusetts) using an x-ray diffractometer and a scanning electron microscope. We will modify the high shear-stress flume for bedload and suspended bedload measurements. The modification allows a device to be attached to the high shear-stress flume, separating these types of loads from the bulk erosion currently measured by the flume. We will design and construct a new flume for oscillatory flow-induced erosion. This will enhance the flume's capabilities to perform high shear-stress erosion experiments in coastal waters.

Funding Requirements for Soil and Sediment Transport Laboratory

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	0.6	0.7
Direct Personnel	3	3.5

7.3.9 Water Safety, Security, and Sustainability

Secure and sustainable access to fresh water is an increasingly critical issue. In the United States, the water supply infrastructure is highly vulnerable to both natural and human disruption. Additional concerns include the presence of contaminants in municipal water supplies, potential chemical or biological attacks, and the vulnerability of aging water distribution systems.

Providing adequate water for growing western cities, major agricultural enterprises, and economic development along the US/Mexico border is an increasing challenge. New Mexico faces many of these water distribution challenges and can serve as an effective test bed for developing solutions. Recent droughts have pitted farmers against environmentalists in disputes over allocation of Rio Grande water. Growing populations in Albuquerque and Santa Fe will demand more water than is available from either ground or surface water in the state.

Sandia could provide technical assistance to the farming members of the Carlsbad Irrigation District to better plan the storage, delivery, and use of water in the Carlsbad Project.

The surface waters of the Pecos River are allocated by the state of New Mexico to three major entities. First, each year a percentage of surface water is delivered to the State of Texas; this amount is governed by the Interstate Streams Commission. Second, a fixed portion of water is delivered to the farming members of the Carlsbad Irrigation District. Third, a specified amount of water must be maintained to support the wildlife habitat in the Pecos River. Because the Pecos River and its reservoirs contain a limited amount of water, the resource must be allocated efficiently.

In other regions of the world where the United States has security interests, severe stresses related to pollution, inadequate supply, and lack of coordinated boundary management are complicating factors. These regions include the Indian subcontinent, Korea, and the Middle East. International organizations increasingly recognize water as an international security problem. In May 2000, Fortune Magazine noted that water is likely to become as important in this century as oil was in the last.

To meet the water challenges of the coming years, we are developing technological solutions that will address water safety, security, and sustainability.

Sandia is developing water system infrastructure vulnerability assessment methodologies and mitigation technologies. We are demonstrating these technologies on multiple water systems at multiple scales. This work builds on Sandia's unique expertise in physical and cyber security of sensitive materials and facilities.

Sandia is applying emerging microsystem sensor technologies to develop real-time water monitoring systems for active system management and protection. Advanced decision management and modeling tools will directly interface with these real-time monitoring systems.

We are developing and field testing technologies that reduce costs and increase water supplies. These technologies include removal of arsenic and future regulated contaminants, desalination of brackish waters, evaporation suppression, and economic processing of watershed management biomass byproducts.

Sandia's Cooperative Monitoring Center has facilitated international collaborations for seven years. We are now developing effective international water issue facilitation mechanisms and bringing water technology solutions to the US/Mexico border area and to water-stressed international arenas that have significant security implications for the United States.

Funding Requirements* for Water Initiative

(Dollars in Constant FY 2001 Millions; Personnel in FTEs)

	Year 1	Year 2
Operating	8.0	20.0
Direct Personnel	32	80

* In addition to the DOE, agency partners include the Environmental Protection Agency, the Department of Interior, and the Department of State. Agencies with primary responsibility own the programs; funding requirements refer to Sandia's participation.

RESOURCES AND MANAGEMENT OF RESOURCES

8.1 People

Sandia's outstanding staff, which includes technical professionals, administrative support staff, and skilled labor, is the key to our mission success. We strive to attract and retain a diverse world-class work force, to include all employees in achieving Sandia's business objectives and National Nuclear Security Administration/DOE strategic goals, and to create a work environment that promotes well-being and job satisfaction. We strive to have the best workplace for people and the best performance from people to support "exceptional service in the national interest."

8.1.1 Laboratories Composition

At the end of September 2001, Sandia had 7,686 regular employees (see table that follows). In addition, the work force includes high-school through graduate-level students (approximately eight hundred new and returning students at the peak of the summer programs); two hundred postdoctoral appointees and persons on limited-term assignments; and almost five hundred staff augmentation contractors. Employees are located in Albuquerque, New Mexico; Livermore, California; the Pantex Plant in Amarillo, Texas; the Waste Isolation Pilot Plant in Carlsbad, New Mexico; the Kauai Test Facility in Hawaii; and the Tonopah Test Range in Nevada. Sandians also support the Yucca Mountain Project in Nevada. More than seventy employees are on special assignments at various US locations (primarily Washington, DC) and at several worldwide locations.

Sandia's work force is tailored to support our national security role and to help our nation secure a peaceful and free world through technology. Approximately 69 percent of Sandia's employees work in engineering or science-related technical positions and have an average of 16.4 years of service. Other employees work in administrative areas, in crafts, and as skilled labor. Three labor unions at Sandia/New Mexico represent about 14 percent of the employees. Skills in demand at Sandia include a wide range of information technology specialties and various engineering disciplines, such as electrical and mechanical engineering. Other disciplines include materials science, physics, chemistry, and mathematics—providing Sandia with a broad range of technical capabilities.

Eighty-eight percent of Sandia' technical professionals have college degrees, of which 31 percent are PhDs. Seventy-seven percent of the administrative professionals have college degrees, of which 46 percent are master's degrees.

Laboratories Staff Composition (9/30/2001)[a]

	PhD	MA/MS	BA/BS	Other [b]	Total
Professional Staff					
Engineers	674	1,040	259	6	1,979
Scientists	681	477	238	10	1,406
Other Technical Areas[c]	27	212	181	442	862
Management/Administration[d]	27	374	200	198	799
Support Staff					
Technicians	1	21	227	876	1,125
All Other	1	29	145	1,340	1,515
Laboratories Total Staff	1,411	2,153	1,250	2,872	7,686

[a] These numbers represent an actual head count and are not adjusted for full-time equivalency.
[b] Associate or no degree.
[c] All technical management and staff with degrees/study in fields other than science or engineering.
[d] All Sandia management and staff.

8.1.2 Planning and Evaluation

Sandia's Human Resources staff works with line organizations to plan our future. Planning is important to Sandia's continued success and to the individual's ability to contribute in a rapidly changing environment. The People strategic objective falls in the purview of Human Resources.

During FY 2000, Sandia executive management devoted considerable time to reevaluating the vision, highest goal, and values for Sandia to reflect the dynamic environment that constitutes national security. With this high-level direction defined, three- to five-year goals were established from which tactical goals were derived for the current year. These tactical goals cascade into division and center plans throughout Sandia, which then link with individual performance goals for the year. We link individual performance goals to Sandia's strategic goals to help align people and their work with present and future missions.

Human resources planning and evaluation processes are a continuous cycle in which feedback from internal and external sources is used to monitor progress. Techniques used include analysis of industry best practices, external and internal surveys (many of them web-based), focus groups, self-assessment work force teams, town meetings, and 360-degree assessment for managers. In March 2001, a Human Resources Strategies and Services function was created, which affords a central point for coordinating customer input and formulating strategies.

In CY 2000 and 2001, several surveys were conducted to obtain feedback from Sandia's work force. The Human Resources Customer Satisfaction Survey was sent to a random sample of 4,435 employees. The response rate was 38 percent. The survey included questions on staffing, performance management, health and benefits services, training, employee relations, and web-based applications. In addition, an Employee Preferences Survey sponsored and funded by Lockheed Martin collected key retention information from exempt employees. Each survey provided important feedback that helped Human Resources monitor Sandia's pulse.

For the fifth consecutive year, Human Resources was rated "outstanding" in the DOE Laboratory Appraisal. In FY 2000, we were measured in four areas of the DOE Laboratory Appraisal: cost-effective training programs, work force management planning, consolidation of student programs, and development of a Total Rewards Strategy. We received "outstanding" ratings in all four areas. The leadership exhibited through the Total Rewards approach was recognized as an area of excellence and benefiting the National Nuclear Security Administration/DOE complex by providing a direct link between attraction/retention strategies and business objectives. A second area of excellence, Sandia's Summer Technical Student Intern Program, also was recognized by Lockheed Martin as a best business practice.

8.1.3 Human Resource Programs and Initiatives

Sandia's provides a wide range of products and services to management, employees, dependents, and retirees. The goal is to provide effective, cost-efficient services convenient to the customer. Human Resources customer service managers are deployed to the line organizations to serve as links.

Best business practices are used to comply with the terms of the management and operating contract. We reviewed, revised, streamlined, and merged personnel policies with Sandia's web-based business rules system. We also provided web-friendly, just-in-time electronic services and information.

Sandia's focus on a Total Rewards Strategy emphasizes ways that employees are compensated for contributions. This rewards package includes pay, benefits, learning and development opportunities, and work/life factors. The Total Rewards Strategy is a key marketing component of Sandia's recruiting and during new employee orientation. The current rewards package is evaluated annually against industry perquisites. Actions are under way to address process and program improvement. This year we provided a Total Rewards Annual Review booklet that contains personalized information about compensation.

8.1.3.1 Pay and Performance

Sandia's compensation system attracts, retains, and inspires a world-class work force. We offer financial compensation competitive with high-level research and development companies across the country, and we link individual compensation directly to performance. Sandia offers both a base salary and nonbase compensation. The annual Compensation Increase Plan reflects the monetary compensation necessary to maintain a competitive position in the highly competitive technical marketplace.

Compensation ranges are established for each job classification, within which an individual's pay is targeted to reflect relative contribution and specific critical skills. A committee of vice presidents meets monthly to consider Sandia's position and policies on compensation-related issues. Evaluations of monetary compensation for technical managers and technologists were a focus in CY 2001.

Lockheed Martin has recognized Sandia's performance management system as an industry best practice. Our system seeks to link each individual's activities to overall Sandia goals through an approach known as "line of sight." Employees negotiate specific work objectives with their managers, and those objectives tie directly to higher-level organizational goals. At the end of each review period, the employee's performance is evaluated against the established objectives and demonstrated attributes such as teamwork and communication. This approach assigns each employee an overall value of contribution, which determines monetary compensation.

Professional development also is a key part of the performance discussion. Each employee has an opportunity to express specific development goals. With management support, these goals can be pursued through course work, negotiated assignments, or on-the-job coaching and mentoring. The performance attributes are linked directly to development resources (e.g., courses and literature) so that employees can focus their attention on areas for which they are held accountable.

Beginning in FY 2001, the published roles and expectations for managers are reflected directly in management performance criteria on their evaluation forms. In addition to their responsibilities for programmatic objectives, managers are evaluated on employee management effectiveness, demonstrated leadership, and support of corporate-wide initiatives. A major activity in 2001 was recognizing managers who do an outstanding job on the "people" component of their work.

Although performance problems are few (less than 1 percent), they can impact both efficiency and morale. We provided managers with additional guidance so they can replace an employee having performance problems. Sandia's internal web offers comprehensive instructions about the entire performance management process as well as feedback and coaching resources for managers.

8.1.3.2 Benefits, Health Services, and Work Environment

Sandia takes an integrated approach to the well-being of employees and their families. The approach includes onsite and offsite health care, preventive programs, financial health, and a variety of work-life balance initiatives and opportunities.

Most of Sandia's 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 National Nuclear Security Administration/DOE management and operating contractors. Employees have a choice of health care plans that allow access to in-network and out-of-network providers and facilities. Employees also may enhance their existing benefits package with the purchase of increased coverage for dental care, long-term disability, and long-term care.

Occupational medicine programs assure that employees are able to perform their jobs optimally. These programs include medical surveillance, fitness for duty, medical case management, employee assistance, emergency medical response, onsite medical services, and an international travel clinic. A multidisciplinary team of health care providers assists employees with a variety of workplace issues, including return-to-work evaluations following an illness, spinal-care education, and work site ergonomic evaluation.

The Employee Assistance Program provides onsite consultations and offsite referrals to help employees cope with personal issues that may affect their health, family life, or job performance. In FY 2001, the Employee Assistance Program helped 640 participants. An expanded rescue team provides onsite emergency medical services, responding to 911 calls with state-of-the-art equipment and ambulances that can transport critical cases to Sandia's urgent care clinic or to community hospitals.

An onsite health promotion program encourages Sandians to take a proactive approach to their own health care by providing assessment services and onsite screenings to analyze personal and occupational health risks. Convenient onsite health education classes, expert guest speakers, and fitness activities are available to help employees maintain optimal health. Fitness club memberships are available to employees at reduced rates, and organizational programs tailored for work groups are also available. The onsite health promotion program helped 3,700 participants in FY 2001.

To enhance employee productivity, Sandia offers an onsite child care referral service, an eldercare referral service, a compressed workweek option, an updated leave and part-time work policy, and telecommuting. Employees have access to commuter and carpooling assistance and to a top-rated credit union.

In FY 2001, the vacation donation plan enabled Sandians to give colleagues 2,093 hours for family emergencies. During the winter holiday, Sandia provided baskets of fruit for seriously ill or hospitalized employees. Renovations at Sandia's cafeteria reduced maintenance costs, improved safety, and provided more efficient traffic flow. The renovated cafeteria contributes to a better work environment and saves travel time by providing meals to the work force.

Sandia's benefits and health services programs help nurture a strong relationship with the surrounding community by bridging onsite and offsite programs. The medical case management team works closely with primary care physicians to resolve return-to-work and worker compensation issues. The health promotion team provides educational opportunities to dependents by bringing classes and health fairs to the community. Recognizing that financial stability is an important component of health, the health promotion team works closely with Sandia's Credit Union to bring financial education to employees and their families. Sandia retirees are also invited onsite for monthly health education classes and for a popular annual retiree picnic. A commuter assistance program encourages employees to explore alternative ways to travel to and from work by providing city bus, car pool, bicycle route, and city street construction information. The blood donation program offers employees a convenient opportunity to give to the community by bringing United Blood Services onsite weekly. Sandia is one of New Mexico's largest contributors, having donated 1,448 pints of blood that helped 4,334 patients in FY 2001.

A multimedia approach is used to communicate benefits packages and health care services. Centralized customer service groups, hotline numbers, onsite health plan representatives, medical case managers, and consultants help employees to understand and access services and benefits. Programs are advertised monthly via print, web, email, Sandia television and all available cross-media formats. Some educational programs are televised live onsite; others are teleconferenced to remote sites or recorded for use as intranet web movies, compact disks, and video tapes.

Sandia's benefits and health services are balanced with careful stewardship of National Nuclear Security Adminis-

Sandia's rescue team trains to provide emergency medical services. Here Marie Goldberg is a "patient" being prepared for ambulance transport by Sandia paramedics Dale Claycomb and Jim Romero.

tration/DOE funds and compliance with laws, regulations, and DOE orders. The result is a competitive, cost-effective, integrated benefits package for all employees.

8.1.3.3 Awards and Recognition

Sandia offers numerous awards acknowledging employee achievements in meeting overall mission objectives. Awards are an important element of our Total Rewards Strategy.

Funds are available throughout the year to reward individuals or teams. Also, individual performance awards are tied directly to performance objectives in the annual compensation review. Employees promoted to the distinguished level within their classifications—or those appointed senior scientist, senior engineer, or senior administrator—receive additional recognition. Employee and team achievements also may be recognized in town meetings, newsletters, lobby displays, and web-based communications. Each year a ceremony is held to distribute royalty checks to Sandia inventors responsible for innovations that have been transferred to industry.

Sandia also sponsors corporate recognition programs. In FY 2001, the Sandia President's Quality Award recognized thirty-one teams that made exceptional contributions using quality processes. The Employee Recognition Award honors individuals and teams that contribute to Sandia's technical excellence or that provide exceptional service and leadership. During FY 2001, fifty-nine individuals and sixty-two teams were honored. Sandia's executive management selects nominees from the Employee Recognition Award recipients for consideration in Lockheed Martin's prestigious NOVA awards program.

Sandia supports a service awards program that acknowledges employees every five years. A revamped service awards program allows employees celebrating anniversaries a wider selection of gift choices while helping Sandia control costs, reduce administrative burdens, and address security concerns. In addition, Sandia supports employee retirement celebrations. This year we offer immediate recognition for employees obtaining a BS, MS or PhD in a field relevant to Sandia's business. We present a nonbase spot award when the degree is obtained.

8.1.3.4 Learning and Development

Sandia's corporate training, development, and education programs maintain and increase our technical and business capability; meet mandated and compliance-related training, development, and education requirements; and assist Sandians in preparing themselves for future technological advances. Areas of study include business skills and knowledge, engineering, material science, project management, computer science, weapons, leadership and management development, and compliance-related subjects such as Lockheed Martin's ethics training. In addition to classroom training, employees also have access to self-study, computer-based training courses that provide job-related training and development opportunities. During FY 2001, 98,838 student course completions were recorded, including corporate-wide mandatory training.

The competency-based development curriculum and the associated 360-degree assessment process are Sandia's foundation for leadership, management, and staff development. Our four-step development process includes individual assessment, planning, implementation, and reevaluation. The corporate-wide mentoring program and organization-specific mentor programs continue to grow and are offered to all employees who wish to establish supportive learning relationships. For example, in the Knowledge Management Program, which maintains the expertise of Sandia weapons specialists, each new intern is assigned a senior specialist as a mentor.

This year Sandia launched its first Information Technology/Computer Science Retraining Program. This innovative program addresses our increasing demand for information technology and computer science skills and the competition from the external market for the same skills. Four training tracks were created and deployed in FY 2000. Ten Sandians graduated from Tracks 1 and 2, which focused on fundamental software development and data exploitation and analysis. Ten Sandians graduated from Track 3 and were certified in system administration. Sandia/California retrained ten Sandians in the areas of information systems and engineering skills. After retraining, participants join new organizations to work as Information Technology/Computer Science professionals.

Sandia celebrated the graduation of its first class of weapons interns in September 2000. The Weapons Intern Program is a two-year program established in 1988 to preserve legacy weapons knowledge while training future weapons specialists. Fifteen individuals completed the program. The newest course of study (Materials Science and Advanced Manufacturing) is composed of five courses to help Sandians develop solutions to materials and processing problems through the application of fundamental science and new technologies.

In addition to more than two hundred in-house courses, Sandia offers these degree-related programs:

- the Tuition Assistance Program, which pays tuition for employees enrolled in university continuing education courses;
- the University Part-Time Program, which pays full salary and tuition for full-time study while working at Sandia on a part-time basis;
- the Doctoral Study Program and the Special Masters Program, which pay expenses and stipends for full-time study toward the PhD and Masters degree;

- the One-Year-On-Campus Program, which pays expenses and provides stipends for new employees with a bachelor's degree so they can study full-time for a master's degree; and
- the Distance Learning Program, which provides seminars and full-semester courses in degree-related programs via video links to Sandia sites from universities or other locations.

In partnership with other Sandia organizations, the Corporate Training, Development, and Education organization delivers eleven courses electronically to employee desktops via our corporate intranet. Courses were produced using state-of-the-art technology and offer a convenient, cost-effective approach to training. Of the 98,838 student completions recorded in FY 2001, approximately 34 percent were completed electronically.

Sandia successfully transitioned its corporate infrastructure to the Oracle data base software. End-user training continues to be vital to deploying this initiative, with more than 2,400 completions this fiscal year.

8.1.3.5 Staffing

Sandia's work force is our most valuable asset. We manage this asset with strategic planning that analyzes current skills, identifies future needs, and assures that future needs are met. We use a variety of multiyear work force management strategies to attract people with needed skills, retain them and enhance their skills, and inspire them to perform to their full potential. Through the use of teams, Sandia continually assesses and improves both hiring processes and systems.

During FY 2001 Sandia implemented Top Recruits, a web-based tool that helps managers identify outstanding candidates. A skills profile data base provides an internal inventory of employee skills. This data base defines corporate capabilities and matrixes Sandia employees to support new initiatives. Since September 1999, the staffing organization has provided a monthly new employee orientation program to provide comprehensive information on Sandia's operations and shorten the time needed for employees to become productive.

Various mechanisms for internal movement keep the work force agile. During FY 2001, 889 employees changed jobs or organizations via Sandia's internal-movement mechanisms. A web-based post-and-bid system allows regular employees to nominate themselves or be nominated for internal job openings. New this year is a web-based job posting subscription service that employees can use to track new job openings. In the first year, 15 percent of regular employees used the service and 165,000 job notifications were emailed to subscribers.

Sandia maintains a recruitment and university relations program to attract top-level talent for regular and temporary employment. During FY 2001, Sandia hired 247 regular and 226 temporary employees. Internship programs provided qualified students with an opportunity to expand their career horizons while supplying Sandia with a mechanism to identify candidates for future regular employment. In FY 2001, 833 students were employed through internship programs.

Sandia's student internship programs provide training in research, applied science, technology, and engineering.

8.1.3.6 University Relations

University Relations programs establish and maintain strategic relationships with universities to assist our research programs and help Sandia recruit the very best talent nationally. These programs contributed greatly to Sandia's ability to attract and hire more than a thousand regular and student employees in FY 2001.

Nationwide recruiting efforts focus on candidates from the physical sciences and engineering disciplines at leading institutions. This year Sandia took extra steps to recruit and make its presence known on campus. Each Sandia recruiter receives training to ensure that we are properly represented and that a diverse pool of candidates is selected. All recruiters hold other regular job assignments and recruit on a part-time basis only. Sandia participates in joint recruiting activities with Lockheed Martin recruiting teams at twenty-three schools, eight national minority candidate events, and many specially focused sourcing activities. We support several teams of volunteer technical recruiters that focus on PhD, MS, and BS candidates. A special recruiting team helps to identify and hire information technologists.

The Campus Executive Program, which is established at twenty-nine campuses, provides Sandia executives with an opportunity to establish relationships with leaders of university research and engineering programs. For the last two years, Sandia has sponsored Deans' Day, a conference for deans of engineering and other executive-level representatives of the Campus Executive Program. The goal is to identify opportunities to strengthen relationships between the universities and Sandia. A modification of Deans' Day, called University Day is planned for late CY 2001. The goals are similar to Deans' Day, but with a broader scope and audience.

We advertise in national science and engineering journals, selectively use other national media, and use local newspapers for job placement advertising. We advertise in minority publications to attract candidates from underrepresented populations. We also participate in industry and university activities such as the National Association of Colleges and Employers, the Society for Human Resource Management, and various technical and ethnic associations to increase Sandia's visibility as a national laboratory.

8.1.3.7 Labor Relations

At the Sandia/New Mexico site, three labor organizations represent approximately 14 percent of the employees. This figure has remained relatively stable during the past few years. The Office and Professional Employees International Union (Local 251, AFL-CIO) represents 436 office and clerical employees. The Atomic Projects and Production Workers Metal Trades Council (AFL-CIO) represents approximately 478 employees of skilled trades and other occupations. The Security Police Association (Local 7002, AFL-CIO) represents approximately 125 uniformed security personnel.

At regular intervals, Sandia negotiates new labor agreements with the unions. In July and August of 1999, the Office and Professional Employees International Union and the Production Workers Metal Trades Council signed three-year agreements that will expire in 2002. The Security Police Association is in the last year of a five-year agreement that will end in December 2001.

8.1.3.8 Work Force Diversity

Work force diversity is the primary focus of Sandia's Diversity Program. The objective is to build an inclusive work culture that capitalizes on employee differences and similarities to achieve maximum productivity at all levels. Sandia is distinguished as a leader within the National Nuclear Security Administration/DOE complex, Lockheed Martin, and the Albuquerque community for it sound, systematic approach to equal employment opportunity and diversity. The Diversity Program continues to build on systematic approaches to promote inclusion of all employees in achieving strategic goals and business objectives.

8.1.3.8.1 External

Since 1993, Sandia has led or participated in a series of community forums that bring together more than one hundred community leaders to discuss diversity-related issues. Initially sponsored by the DOE, Lockheed Martin, and Sandia, this initiative is now led by the Diversity Leadership Council, a group of twenty Albuquerque-area executives who represent business, government, education, and the community. Forums have focused on current and future work force issues and on ways to augment our base of awareness-building coalitions of interest and inclusion. The council is forming partnerships to establish a diversity institute that will continue to provide leadership and guidance to area businesses.

In FY 2001, a collaboration was initiated among Sandia, Los Alamos, and Lawrence Livermore national laboratories. This collaboration will address work force issues and share best practices that enhance the work environment.

8.1.3.8.2 Internal

Strategies to support line organization ownership of diversity leadership are developed and initiated by Sandia's Corporate Diversity Team. Corporate workplace issues are identified through interactions with division diversity/employee councils and through analysis of feedback and survey data. An extensive awareness curriculum is available; its modular design allows organizations to access resources on an as-needed basis. The curriculum includes a variety of

self and group awareness workshops, web-based tutorials and resources, and a calendar of diversity events.

Following the success of the DOE's mandatory equal employment opportunity/diversity stand-down in FY 2000, division diversity/employee councils examined employee input and identified opportunities for improvement.

8.1.3.9 Equal Employment Opportunity and Affirmative Action

Sandia is committed to maintaining an inclusive work force where all employees are treated fairly and equitably regardless of race, religion, gender, age, national origin, veteran status, sexual orientation, or disability. This commitment applies to recruiting and hiring; promotion; transfer; compensation and benefits; Sandia-sponsored training, education, and tuition assistance; layoff and return from layoff; and social and recreational programs.

Sandia supports affirmative action outreach/inreach committees and equal employment opportunity networking groups. Sandia's six outreach/inreach efforts include the American Indian, Asian, Black, Hispanic, Women's Program, and Disabilities Awareness committees. Each committee has twelve to twenty members representing various job classifications and organizations. Committees support women, minorities, and disabled employees in career development and raise Sandians' awareness of cultural, gender-related, and disability issues. Key issues affecting women, minorities, and disabled employees are brought to the attention of management. Committee activities include career fairs, conferences, tours, lectures, cultural celebrations, and advisory sessions.

Sandia's complaint process provides a fair and objective investigation of employee allegations of discrimination. Employees are encouraged to report concerns to management, human resources representatives, equal employment opportunity and affirmative action analysts, or the Ethics Office. Sandia exceeds the letter of the law by providing additional employee services such as dispute resolution and mediation. Since 1993, services for resolving certain disputes have been available to all employees through the Corporate Ombuds Office.

Sandia's Affirmative Action Program helps create a balanced work force from a broad pool of qualified people. Hiring and promotion practices reflect our commitment to improve employment opportunities for minorities, women, individuals with disabilities, disabled veterans, and Vietnam-era and other covered veterans. We annually review the percentages of minorities and women in the employee population. We set goals for hiring and promoting qualified minorities and women in areas where they are underrepresented.

Sandia's FY 2001 Affirmative Action Program offers detailed profiles of Sandia's diverse work force and documents FY 2001 accomplishments and FY 2002 goals. An annual internal review analyzes each component of the Affirmative Action Program, including information relevant to employee compensation and formal charges of discrimination.

Our president, executive vice president, vice presidents, directors, and managers implement Sandia's Affirmative Action Program. Each vice president is accountable for support of the Affirmative Action Program. The Laboratories Leadership Team monitors progress through a quarterly review.

Recommendations from self-assessment reviews are incorporated in operational planning activities, ensuring Sandia's continued commitment to equal employment opportunity and affirmative action.

8.1.3.10 Agile Human Resource Systems

Most of Sandia's human resources services are accessible electronically through the Human Resources home page. Employees can bid on job openings, enroll in classes, access their own personal benefits data, and link to corporate guidelines and policies. A number of unique services are available electronically:

HR Queries software allows electronic access to work force statistics and trend data. A web-based pension modeling tool is available to assist employees in retirement planning.

Dinero is an electronic tool for coordinating and managing the annual corporate-wide performance and compensation review. Comprehensive instructions about the entire performance management process and resources for managers about feedback and coaching skills are available on the web.

A skills profile data base provides an internal inventory of employee skills. A post-and-bid system allows regular employees to be nominated for internal job openings. A job posting subscription service enables employees to receive email notification of new postings.

The Training Education and Development System (TEDS) Everyone software is used to track and maintain training at Sandia, allowing individuals to view their training requirements and completions and to enroll, revise, or withdraw from courses. Approximately 34 percent of course completions at Sandia are accomplished electronically.

Achieving Results Through People offers web-based tutorials on issues of diversity and on effective behaviors for creating and managing inclusive work environments.

Top Recruits is a web-based tool that helps managers identify outstanding external candidates.

A New Hire web site enables new employees to acclimate faster to the Sandia environment. The site includes training information, contacts, key deadlines, and other information to help orient new employees as quickly as possible.

8.1.4 Outreach

Sandia's outreach programs are designed to strengthen mathematics, science, and technology education; enhance public science literacy and work force diversity; and stimulate collaborations with local and national academic, government, and industry partners.

Sandia volunteers work directly with students in programs that include reading, science, mathematics, engineering, technology, and medicine. Volunteers also assist with science fair judging and science education. Current programs reach approximately four hundred students. The Rocket Reader Literacy Program's goal is to bring every child to reading at grade level by the third grade. The three Hands-On/Minds-On programs focus on Native American, African American, and Hispanic sixth- through twelfth-grade students to enhance understanding of science. Former Science Education and Outreach Program participants have begun to enter Sandia's student intern program and employment pipelines.

Sandia joins with members of the governor's business executives to improve the educational system in New Mexico through the Strengthening Quality in Schools Program. This program involves twenty-three school districts and more than seven hundred superintendents, principals, teachers, and parents.

Also, the National Nuclear Security Administration's Readiness in Technical Base and Facilities effort directly funds a suite of formal education programs intended to address the 1999 Chiles Commission concerns about hiring and training a new generation of workers. These programs are described in 6.1.1.3.3 (Special Projects).

8.1.5 Community Involvement

Sandia is an involved and responsible corporate citizen and a caring partner in the community. Our community involvement principles are to

- remember that we and our families are part of the community fabric;
- respect the values, culture, and quality of life of our community;
- listen and respond to the needs of our community;
- participate in realizing the vision of a vital and sustainable community;
- foster mutual understanding and trust through communication and cooperation;
- build effective partnerships with our community; and
- meet present needs without compromising the safety and welfare of future generations.

Sandia is actively involved with local governments and neighboring communities. Sandia's strategy integrates our people, resources, and technology to improve the quality of life for our employees and fellow citizens. Sandians are active members of many local committees, boards, and organizations. Sandia also maintains working relationships with various city, county, regional, and state agencies.

Sandia operates the National Atomic Museum for the National Nuclear Security Administration/DOE. The museum, located in Albuquerque, preserves and exhibits the history of the nuclear age. Exhibits focus on nuclear defense but include peacetime uses of nuclear energy and nuclear science. Each year, the museum conducts the Science is

Students had a chance to discuss Sandians' jobs with them at the first School-to-World event.

Everywhere Summer Camp program, serving two hundred children from ages eight to twelve. New Mexico's first Zoomzone, a place where children explore science as part of the public television program Zoom, is also located at the museum.

The Sandia Volunteer Program provides opportunities for Sandians (current or retired employees and family members) to participate in activities that benefit surrounding communities and support Sandia's focus on education and youth. This year Sandia contributed over 35,000 pounds of food to the Roadrunner Food Bank, completed seventeen projects at ten community-based organizations on Make a Difference Day, painted a senior citizen's house for Christmas in April, and sponsored a diaper drive for New Futures High School. Sandia's education programs include elementary through high school and encourage students to consider science, mathematics, engineering, and technology careers. Education efforts include the School-to-World Career Fair, Crosslinks (a hands-on science program), Family Science Nights, Advanced Technology Academy partnerships, Environmental Education Outreach, student enrichment programs for underrepresented groups, and job shadowing opportunities. Sandia also provides mentors, Junior Achievement presenters, science fair judges, and career speakers. Sandia is dedicated to building a world-class education system and we join with several organizations to enhance education in New Mexico.

Sandia/California's community outreach supports programs in the Livermore and other East Bay communities. Each year California volunteers participate in the United Way Week of Caring and the Holiday Spirit Drive. Sandia/California also works with local school districts in the areas of mathematics and science by conducting a Science Bowl, cosponsoring an Expanding Your Horizons in Math and Science for Young Women conference, participating in science fairs, upgrading and networking classrooms, and giving classroom presentations and demonstrations. In the past year, Sandians and retirees have been instrumental in donating and purchasing over 1,200 books for Project Roadrunner, an ongoing literacy and learning program for Livermore's Marylin Avenue School.

Contributions by Lockheed Martin are strategically allocated to nonprofit organizations and activities that complement Sandia's overall objectives in education, health and human services, civic, volunteer, and cultural areas. Both Sandia locations use a portion of these funds to support projects such as the Thunderbird Awards for deserving high-school seniors. In addition, employees at all locations contribute generously to the United Way and other worthwhile programs such as the Shoes for Kids project.

The mission of Sandia's Supplier Relations Program is to match Sandia's needs for products and services with diverse suppliers who can provide high-quality products and services as needed and cost effectively. To achieve this mission, the program has established three major goals:

- to establish and implement activities that increase Sandia's economic impact;
- to enhance partnerships among line organizations, purchasing, and all Sandia suppliers; and
- to actively leverage Sandia's resources to benefit the business community's economic and educational systems.

The Supplier Relations Program joins with the business community to facilitate access to Sandia. Of the $411 million in commercial contracts placed in FY 2000, nearly $206 million were placed with New Mexico businesses and $57 million were placed with California businesses. A number of initiatives were also implemented in FY 2001 to enhance relationships and communication with the supplier community.

Supplier Relations is targeting procurement card users for training and socioeconomic awareness by inviting card users to outreach breakfasts and lunches and by issuing invitations to trade fairs so that card users can meet small, minority, and women-owned businesses in the community. A retired Sandia technical director is helping engage technical requesters in our socioeconomic programs. A "road show" also was developed for presentation to technical organizations. Sandia is working with University of New Mexico to develop a regional data base of small, minority, and woman-owned businesses and their capabilities. This data base will be useful for internet purchases. A supplier and customer recognition program was developed to recognize suppliers for a specific achievement and to acknowledge customers who have "gone the extra mile" to enhance supplier relations. Sandia supports local business development organizations and recently provided an executive to support one of the local business development organizations whose membership is composed of more than three hundred small, minority, and women-owned businesses.

The above initiatives enable suppliers to better understand Sandia's requirements and participate as long-term partners. The Supplier Relations Program has been recognized for improving communications with potential suppliers and contractors and increasing procurement opportunities for small businesses.

Sandia received the DOE Managing and Operating Contractor of the Year in April 2000 for achieving the highest ranking in the utilization of small and disadvantaged businesses in FY 1999. The Small Business Administration awarded Sandia the Dwight D. Eisenhower Award for Excellence in June 2000 for utilization of small businesses. This is a national award for large business prime contractors that have excelled in their utilization of small businesses. The

US Hispanic Chamber of Commerce named Sandia the Southwest Region Business Advocate of the Year in October 2000. This award was presented for the many community outreach, procurement, and education initiatives within the Albuquerque Hispanic business community.

The Supplier Relations Program received the Small Business Administration Frances Perkins Vanguard Award in May 2001. This is a national award that honors government and industry for excellence in the utilization of women-owned small businesses as prime contractors and subcontractors. A staff member received the National Association of Purchasing Management's 2001 Charles J. McDonald Minority Business Advocate Award in April 2001 for outstanding contributions to small, minority, and women-owned businesses. Sandia staff received three Rio Grande Minority Purchasing Council awards in November 2000 for Government Volunteer of the Year, Government Advocate of the Year, and Technical Requester of the Year.

Sandia's involvement with businesses, educational institutions, community associations, and government is based on effective communication, cooperation, and mutual trust. This network enables us to identify emerging issues, analyze them for potential opportunities or impact on Sandia, and determine the best course of action. When appropriate, Sandia's technology is linked to addressing these issues.

8.2 Designated Capabilities, Technology Deployment Centers, and User Facilities

Two of the Sandia facilities described below are funded by the DOE Office of Science: the National Solar Thermal Test Facility at Sandia/New Mexico (section 8.2.1) and the Combustion Research Facility at Sandia/California (section 8.2.2).

8.2.1 Designated Capabilities

When industry wants Sandia to provide services covered by a designated capability statement of work, we can place a work agreement in one to three weeks, depending on negotiations with the sponsoring partner. Although use of preapproved DOE statements of work is restricted to industry, federal agencies may access Sandia's designated capabilities through the DOE Work for Others Program. Sandia-designated capabilities approved by the DOE are described below.

Advanced Batteries Research, Engineering, and Evaluation

Sandia provides technical assistance in the design and development of advanced energy storage devices and materials, testing and evaluation of battery cells and systems, and fabrication of prototype batteries.

Agent-Based Evolutionary Computing Methods for Microsimulation

Sandia applies microsimulation and agent-based evolutionary computing to solve problems intractable to traditional simulation technologies.

Archimedes: Computer-Aided Geometric-Based Assembly Optimization

Archimedes, a planning and visualization software tool, streamlines an assembly process by using data from computer-aided design programs to quickly generate visual output of the most efficient assembly sequence. Output can be in the form of a video loop or graphic display on a workstation screen or videotape. The sponsor defines assembly process constraints or quality metrics, and Archimedes automatically determines alternative assembly sequences that satisfy those specifications.

Assembly Test Chips

Sandia provides training, documentation of chip design, and test chips. We provide test chips in the requested chip configuration and trains sponsor staff to gather and interpret test chip data.

Center for System Reliability

Sandia provides access to a proven systems approach to reliability, including design-for-reliability, reliability modeling and analysis, training and optimization techniques, predictive maintenance, infrastructure reliability modeling and analysis, network reliability improvement, and independent assessment and qualification.

Class in CTH Software Package

This three-day class covers the capabilities and use of CTH, the Sandia-developed high-strain-rate and large-deformation continuum mechanics software package. Instruction includes a series of lectures on the use of CTH and hands-on assistance in applying CTH to problems of interest.

Design, Evaluation, and Test Technology

Sandia provides full test engineering and analysis support for component and system testing. Available environments range from normal use to extreme accident conditions. Diagnostics include nondestructive testing, photometrics and optics, and electronic data acquisition. Tests range from characterization of circuit board solder strength to full-scale impact testing of transport vehicles.

Engine Combustion Issues

This capability supports tasks related to engine combustion efficiency and emission formation in the following areas: port fuel-injection gasoline engines; direct-injection

gasoline engines; heavy-duty diesel engines; high-speed, direct-injection diesel engines; diagnostic development; and fuels evaluation.

Environmental Technology Verification Testing

Sandia verifies and reports on the performance of environmental monitoring and site characterization technologies. This testing is conducted in collaboration with the US Environmental Protection Agency's Environmental Technology Verification Program.

Explosive Components Facility

Sandia provides explosive component design, production, and stockpile surveillance services. We also provide performance and exploratory tests of explosives and explosive components.

Geomechanics Research, Development, and Applications

Sandia provides expertise, facilities, and equipment in geomechanics research, development, and applications to identify and model deformation and failure processes in rocks and other related porous, pressure-sensitive materials (such as ceramics and composite materials). We also offer characterization, measurement, and modeling of thermal, thermomechanical, and transport processes in competent rock strata, natural fractures, and other related materials, including studies of coupled effects.

Geoscience Center Flow Visualization and Processes Laboratory

Sandia investigates basic and applied experimental designs and numerical simulations of fluid flow and transport in natural or manufactured porous and/or fractured media at a variety of scales from laboratory to field experiments.

High-Temperature Drilling/Logging Instrumentation

Sandia offers high-temperature (greater than 200 degrees centigrade) logging and drilling tools unique to our geothermal research. Presently available measurements include temperature, pressure, steam or fluid flow; steam or fluid downhole-captured samples; and inclination, azimuth, and natural gamma counts.

Manufacturing and Industrial Capabilities

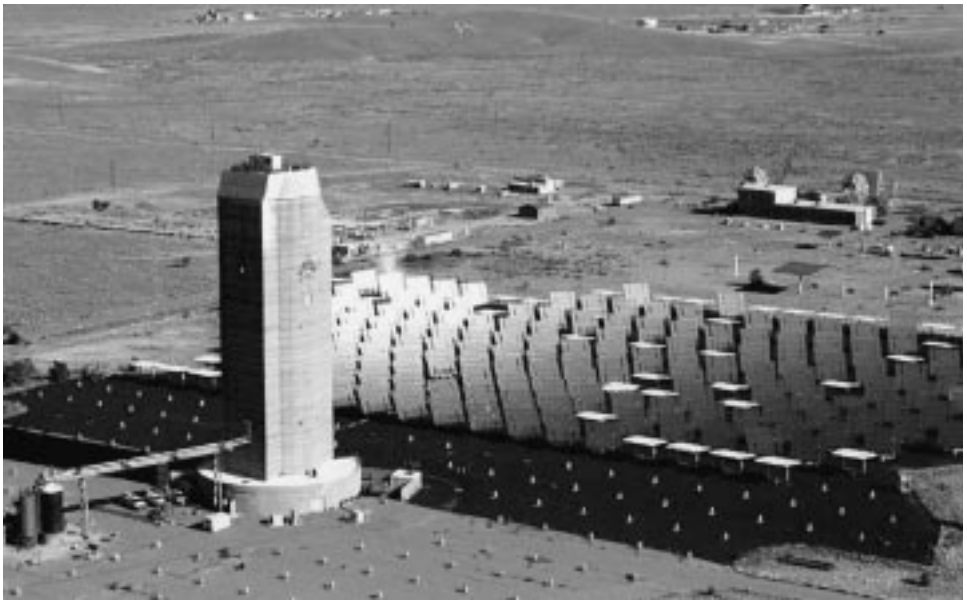
Sandia assists sponsors by providing software tools, technology capabilities, or devices. Specific capabilities include adaptive machining sensor and laser-based tool path generation; an automated component cleaning robot instruction program; the HoldFast™ computer-aided design tool for creating manufacturing fixtures; robotic edge finishing for chamfering and deburring; minilab portable analysis instrumentation; and Stage Right and Remote Telerobotic Vehicle for Intelligent Remediation (RETRVIR) hazardous material handling vehicles. Sponsors can increase manufacturing or industrial efficiency, effectiveness, and safety.

Materials and Process Science

Sandia performs microstructural, chemical, and physical analysis and testing of materials; the manufacturing processes used to produce the materials; and the degradation mechanisms encountered in service.

National Solar Thermal Test Facility

Sandia develops and tests solar thermal components and systems, conducts thermal testing under intense heat flux, and performs optical experiments for astronomy and laser applications for sponsors in the commercial sector.



Sandia's solar furnace is used for thermal testing and optical experiments.

Photovoltaic Systems Support

Photovoltaic support includes technical assistance, development, fabrication, testing, evaluation, and modeling of photovoltaic systems and components to assist industrial implementation of the technology.

Physical and Chemical Sciences

Our capabilities in this area span the fields of semiconductor physics, electronic materials, nanostructures, surface physics and chemistry, plasma and chemical processing, lasers and optics, pattern recognition, remote sensing, ion/solid interactions and effects physics, and advanced materials sciences. In this area, Sandia employs a wide range of multidisciplinary capabilities based on the physical and chemical sciences, from first-principles modeling and atomic-scale measurement to remote laser sensing and new approaches to pattern recognition.

Plasma Materials Testing

Sandia provides high-heat-flux testing and evaluation of fusion components and advanced modeling of plasma/material interactions using high-power electron beams to generate high-heat fluxes that simulate fusion reactor environments.

Primary Standards Laboratory

Sandia's Primary Standards Laboratory develops and evaluates measurement standards, systems, techniques, and procedures; certification standards; measurement assurance programs; technical assessments; measurement uncertainty analyses; technical consultation; and training of metrologists.

Pulsed Reactor Capabilities

Various electronic devices may be irradiated at the Sandia Pulsed Reactor Facility, the Low-Dose Gamma Irradiation Facility, and the Gamma Irradiation Facility. Capabilities include neutron and gamma irradiation of devices from government weapons programs, evaluation of irradiated devices to determine degradation in performance, and documentation of radiation-damage effects by the Radiation Metrology Laboratory.

Software Quality Engineering Support

We offer Sandia's Software Quality Engineering Program capabilities to sponsors. Capabilities include training and education courses in a variety of software quality engineering areas, project management, requirements management, inspections, measurement, process definition, and testing and reliability. We also offer software process improvement-development and improvement of specific education and training materials.

Soil and Sediment Transport

Sandia provides the means to determine erosion and subsequent transport of the eroded material at depth in the sediment and at high shear stresses. This work contributes to the Water Surety Initiative.

Subsurface Environment

Sandia evaluates environmental problems that relate to contamination of the subsurface and that consequently may threaten the long-term integrity of water resources. Present tasks include technology development and testing, with field-scale and pilot testing at real sites.

One of Sandia's pulsed reactor capabilities is the Gamma Irradiation Facility (GIF), which has three cells. The largest cell, shown here, can accommodate a tank or a satellite.

Switch Tube Technology

Sandia provides product and process design using our product family of arc-discharge vacuum switch products, including the Poco Sprytron design. Two laboratories are dedicated to the development and applied research of arc-discharge switching device technology and will perform high-rigor and other fabrication and test work.

Underground Storage Technology

Sandia provides advice and assistance for underground storage technology, including extremely large structural analysis simulations of storage cavern arrays, analysis of the complex dissolution kinetics of cavern creation, and design analysis of plugs and seals for long-term performance.

Unique Sandia Systems Applicable to Specific Environmental Problems

Sandia addresses global problems in environmental remediation. Tasks include development of a systems sensitivity analysis methodology, integration of technical and public policy concerns, physical modeling and simulation, and risk assessment methodology.

VxInsight™

Sandia assists various sponsors by using VxInsight™, a data-mining and knowledge-management tool that uncovers implicit relationships within large data bases and allows the user to explore these relationships with a three-dimensional, graphic user interface.

8.2.2 Technology Deployment Centers/ User Facilities

Technology deployment centers/user facilities are a unique set of scientific research capabilities and resources primarily intended to satisfy DOE programmatic needs. They are accessible to private-sector users through reimbursable user-facility agreements. Although user-facility agreements are restricted to industry, federal agencies may access them through DOE Work for Others agreements. Sandia's technology deployment centers/user facilities are described below.

Advanced Batteries Engineering Facility

This New Mexico facility designs, prototypes, tests, and evaluates energy storage systems.

Center for Security Systems Evaluation

This New Mexico center designs, tests, analyzes, and evaluates security equipment and related systems.

Combustion Research Facility

This California facility studies combustion processes and products ranging from those inside internal combustion engines to combustion-generated pollutants in the environment.

Component Modeling and Characterization Laboratory

This New Mexico laboratory models and characterizes electronic and electromechanical components.

Design, Evaluation and Test Technology Facility

This New Mexico facility uses numerous specialized technologies to design, document, evaluate, and test the response of items ranging from components to full-scale systems in simulated use or abnormal environments.

Electronics Quality/Reliability Center

This New Mexico center is used for reliability and failure analysis of electronic components ranging from cables and connectors to high-speed integrated circuits.

Electronics Technology Facility (Microelectronics Development Laboratory)

This New Mexico facility develops, evaluates, and fabricates various microelectronics applications in a Class I clean room.

Engineering Sciences Experimental Facility

This New Mexico facility contains numerous specialized areas, including laboratories for thermal/fluid science experiments and diagnostics, high-bays for large-scale experiments, aerosciences facilities, and the Sandia parachute laboratory.

Facility for Acceptance Calibration and Testing

This New Mexico facility, operated by Sandia's Monitoring Technologies Department, tests and calibrates seismic verification systems and sensors. The facility is located in a remote area of Kirtland Air Force Base where users can operate without disturbing other programs. The site was recently upgraded and will be supported by the National Nuclear Security Administration's Office of Nonproliferation and National Security in future fiscal years.

Geomechanics Laboratory

This New Mexico laboratory characterizes pressure-sensitive materials, rocks, and concrete.

Intelligent Systems and Robotics Center

This New Mexico center applies intelligent systems and robotics technologies to areas such as manufacturing, environmental cleanup, weapons production and dismantling, and biomedicine.

Ion Beam Materials Research Laboratory

This New Mexico laboratory uses ion-beam analysis to examine a wide spectrum of materials from semiconductors to metals and ceramics.

Manufacturing Technologies Center

This New Mexico center provides analytic tools for research and development of manufacturing sciences and processes.

Materials and Process Diagnostics Facility (Advanced Materials Laboratory)

This New Mexico facility offers laboratories, instrumentation, and personnel skilled in microstructural, chemical, and physical analysis of materials. Areas of application include structural, electronic, and biomedical studies of manufacturing processes and in-service degradation mechanisms.

Mechanical Test and Evaluation Facility

This California facility supports material, structural, and climactic testing; agile manufacturing; nonlinear constitutive thermomechanical modeling; and a wide range of test and evaluation laboratories.

Photovoltaic Sciences Facility

This New Mexico facility offers advanced measurement, test, design engineering, evaluation, and production of photovoltaic components and systems.

Plasma Materials Test Facility

This New Mexico facility provides high-heat-flux testing, and design and evaluation of plasma-facing and other high-heat-flux components.

Primary Standards Laboratory

This laboratory for calibration standards, devices, and facilities is located in both California and New Mexico.

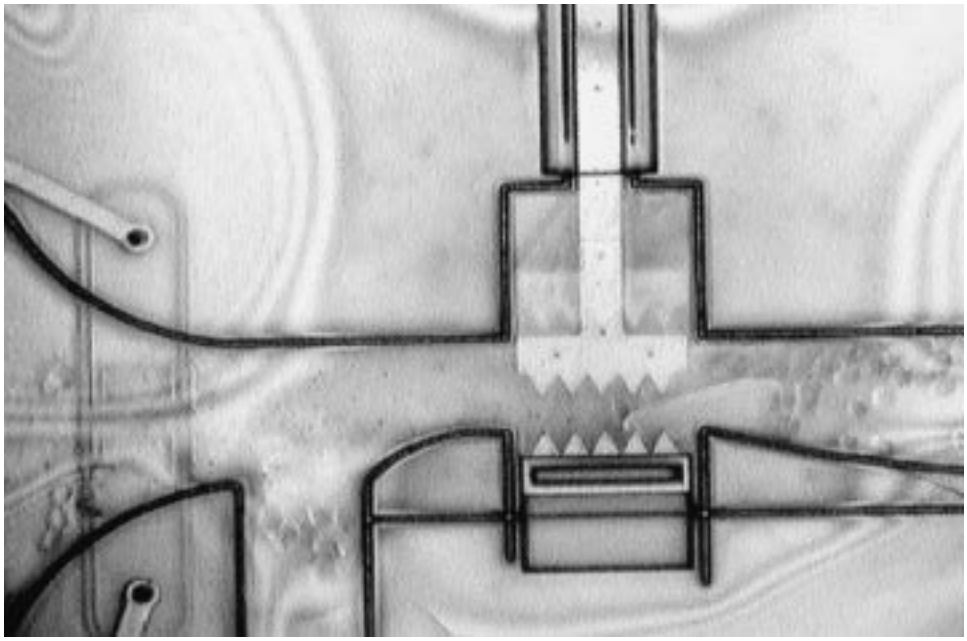
Pulsed Power and System Validation Diagnostics Facility

This New Mexico facility offers pulsed power accelerators, laboratories, lasers, remote sensing, advanced computation, and diagnostics for intense energy states of matter, intense magnetic fields, and hostile environments. The facility also offers applications such as ion beam hardening of materials.

Radiation Detector Analysis Laboratory

This California facility offers comprehensive, sophisticated detector-array and imaging system characterization. Capabilities include specialized analysis of detector-grade crystals and x-ray detector response. The Radiation Detector Test Facility is part of this facility.

Sandia's Intelligent Systems and Robotics Center is developing systems such as this microjaw, which will be used for biomedical purposes.



Sandia Orpheus Site

This New Mexico test site and mobile geothermal research laboratory is used to develop and evaluate methods for employing acoustic waves in deep wells.

Sandia Thermal Test Facilities (Radiant Heat Facility and Lurance Canyon Burn Site)

These New Mexico facilities offer capabilities unique in the United States. The Radiant Heat Facility offers high-power, multichannel, programmable radiant heat systems and a method for simulating a variety of fire environments. The Lurance Canyon Burn Site offers enclosed pool fire test facilities that meet air quality regulations, an extensive data base of measurements in large pool fires, and techniques for acquiring and interpreting data from both liquid hydrocarbon pool fires and solid rocket propellant fires.

Shock Technology and Applied Research Facility

The Shock Technology and Applied Research (STAR) Facility is a state-of-the-art facility that can provide a full range of projectile and target interactions. Impact velocities from 0.01 to 16 kilometers per second are available with a broad range of diagnostic and analysis capabilities. A diverse technical staff with many years of experience is available for consultations.

8.3 Sites, Facilities, and Utility Systems

Sandia's executive management offices and larger laboratory complex are located within Kirtland Air Force Base in Albuquerque, New Mexico. This primary research and development site is composed of five technical areas within nearly 3,000 acres of DOE-owned land, plus nearly 8,600 acres permitted to the DOE for Sandia's use. The site benefits from its proximity to other major defense laboratories and testing facilities, universities, and high-technology industry.

The Sandia complex in Livermore, California covers 410 acres. This research and development site benefits from its proximity to world-class research universities and the high-technology environment of the region.

Sandia's Kauai Test Facility in Kauai, Hawaii occupies approximately 130 acres at the Navy's Pacific Missile Range and two acres located at the Kokole Point launch site. The primary purpose of this test facility is to provide a safe and efficient site for conducting sounding rocket operations.

Sandia's Tonopah Test Range is located on the northern portion of Nellis Air Force Base in Nevada. The site covers more than 335,600 acres and is permitted to the DOE for Sandia's use. Sandia's operations at this site include research and development tests, compatibility testing of weapons and DOD aircraft, and stockpile surveillance tests.

Sandia personnel also work in offsite leased facilities in Albuquerque, New Mexico; Carlsbad, New Mexico; Washington, DC; Barrow, Alaska; and Livermore, California.

Sandia has a variety of special-purpose test facilities and supporting infrastructure for defense and nondefense research and development. These include

- manufacturing facilities to support War Reserve production for the nation's nuclear stockpile;
- the largest pulsed power complex in the world-used for testing weapons components, simulating inertial confinement fusion, and studying atomic physics in the x-ray spectrum;

Aerial view of Sandia National Laboratories/ Albuquerque, New Mexico.

- nuclear reactor facilities to simulate power reactors and evaluate the effects of radiation on weapon components;
- computing facilities to simulate and model complex phenomena;
- environmental testing facilities to subject components and systems to extreme environments;
- a network and communications infrastructure for Sandia's supercomputers and storage servers;
- a combustion research facility with laboratory space, diagnostic tools, and subject matter experts available to users from industry and academe; and
- robotics laboratories to develop prototype systems with National Nuclear Security Administration/DOE applications, including nuclear weapons dismantling and retrieval and repackaging of radioactive wastes.

Some activities involve partnerships with universities, industry, and other laboratories to develop technologies that also have national security applications. These partnerships may be housed in unclassified Sandia facilities or in facilities developed through land-use planning with city, county, state, and other agencies. Sandia continues to consider site accessibility enhancements while stringently protecting classified information.

Environmental restoration activities at Sandia/New Mexico and Sandia/California are enhancing site availability. At the present budget and schedule, Sandia's New Mexico site will be restored by 2006 (locations either will require no further action or will have been cleaned), assuming funds continue at current levels. All other Sandia sites have achieved No Further Action status.

8.3.1 Infrastructure Management

8.3.1.1 Comprehensive Planning and Management

Sandia's physical infrastructure is a strategic asset of the United States, and we optimize this asset by cost-effectively developing and maintaining it to support our missions. Sandia assesses issues that could impact critical programs while minimizing environmental and economic impacts. Comprehensive planning provides efficient transitions through both anticipated and unanticipated events.

Sandia's comprehensive planning process links the mission-focused implementation plans of the strategic business units and the strategic management units with the physical infrastructure necessary to enable engineering excellence, science, and research in the variety of programs that Sandia conducts to fulfill its national security requirements. The output of the planning process is a mission-driven physical infrastructure plan aligned with mission needs and our vision for the future.

The Corporate Sites Planning process integrates mission requirements with physical infrastructure capabilities to develop plans for sites and physical assets. The Corporate Sites Planning Council annually solicits mission and support requirements, integrates those requirements with existing physical infrastructure, and provides a list of specific prioritized actions and construction projects (including associated funding strategies) to the Infrastructure Council for its

Aerial view of Sandia National Laboratories/ Livermore, California.

approval. The Infrastructure Council approves requested construction projects and associated funding strategies based on the ten-year strategic vision. Sandia's funding sponsors provide final funding approval.

Our planning principles guide the infrastructure development process and support progress toward our vision, which is to

- modify existing assets to provide required capabilities for new and continuing missions, when economically feasible;
- acquire new assets only to help achieve mission objectives that cannot reasonably be met in existing or converted facilities;
- dispose of, remove, or shut down excess assets to reduce liabilities and operating costs in order to make resources available for new capabilities or to improve the appearance of the site; and
- maintain existing assets in "fit-for-mission-use" condition.

The Facilities Management and Operations Center oversees Sandia site development, monitors space and real estate, and operates and maintains the physical infrastructure. Facilities management strives to maximize customer satisfaction and minimize life-cycle costs for operating and maintaining facilities and infrastructure to support Sandia missions. To improve customer satisfaction, the facilities center provides a single point of contact for customers who have physical infrastructure needs. To enhance understanding of these needs, we developed internal lease agreements to document customer requirements and balance the level of service to be provided by the facilities center.

The Facilities Management and Operations Center also prioritizes operations and maintenance resources. The physical infrastructure is maintained in fit-for-mission-use condition by an approach that identifies the essential systems of a given facility on the basis of mission work performed there. Fitness-for-mission-use keeps essential systems operating within the required performance time. The level of service depends on the priority of the program, the economic impact of loss, and other consequences that would result from a shutdown.

Sandia's Major Renovation Program improves the work environment and reduces overall operation and maintenance costs. The program establishes extensive renovations for buildings that are beyond their economically useful lives. Candidates for major renovation are identified based on planning principles that consider mission need, life-cycle asset management, condition assessment, and seismic vulnerability issues. Major renovations extend the economically useful life of a building by approximately twenty years.

Sandia's Restoration Program addresses major backlog activities that will repair or replace full or partial building systems or major equipment items significant enough to require engineering review or design. We prioritize these activities using a scoring method with a graded approach that focuses the available budget on facilities and activities important to our missions. This program ties very closely with the amount of funding provided for the Major Renovation and General Plant Project programs.

Sandia's Space Management Program evaluates underutilized and excess space. The program seeks to fully utilize existing onsite space to reduce the need for temporary and leased space, explores alternative methods for obtaining turnaround space, and identifies the best fit to accommodate new or changing mission needs. When organizations must be relocated, those performing potentially synergistic work are located together when possible. Buildings identified as having no further programmatic use are taken out of service.

Because some of Sandia's work involves hazardous and radioactive materials, all space in structures returned to the indirect program inventory is assumed to be contaminated until sampling or other information proves otherwise. Contaminated buildings undergo decontamination and asbestos abatement in accordance with coordinated master planning for the site. An environment, safety, and health committee monitors, reviews, and approves decontamination.

Encroachment of neighboring communities is a concern at both the New Mexico and California sites. Kirtland Air Force Base surrounds much of the New Mexico site, and Sandia has a close working relationship with the US Air Force for maintaining strategic and operational alliances and capabilities. The California site is negotiating innovative land use plans to match the demands of the community with Sandia's requirements. We have increased our involvement with the planning, development, and use of adjoining properties at both major sites to assure that Sandia's concerns for partnership development and buffer areas are addressed.

8.3.1.2 Future Use Planning

The DOE Land and Facility Use policy requires that all DOE land and facilities be managed as valuable national resources. Therefore, the DOE's local office established a working group for the Kirtland Federal Complex. The working group provided a site summary to the Future Use Project Office at DOE Headquarters and provided input to the Citizens Advisory Board. As the Sandia Environmental Restoration project moves toward its closure phase, the Citizens Advisory Board, Sandia, and the DOE recognized the need for a new, more interactive model for future government-citizen involvement. The board continued until the end of FY 2000 and has been replaced by issue-specific and limited-term working groups and an "open house" concept of moving meetings into the community. This more interactive, less

formal approach better serves Sandia as closure activities conclude and long-term stewardship begins. The Community Resources Information Office web page (http://www.abqcab.com) contains more information about the Citizens Advisory Board.

8.3.1.3 Facilities Maintenance

Sandia's physical infrastructure maintenance processes are established to meet the intent of DOE Order 430.1A ("Life Cycle Asset Management"). A maintenance program serves all DOE property used by Sandia. The Facilities Management and Operations Center supports programmatic missions and promotes operational safety, worker health, environmental protection, and property preservation by focusing resources on the most critical systems and equipment. The maintenance of programmatic property and equipment is part of each organization's operating responsibilities and is assigned to the line organizations.

The Sandia/New Mexico Nuclear Facility Maintenance Implementation Plan, written in response to the requirements of DOE Order 4330.4B ("Maintenance Management Program"), is applicable to the work performed within Technical Area V, a designated nuclear facility at Sandia/New Mexico. This plan addresses the responsibilities of facilities management personnel performing maintenance work in Technical Area V.

8.3.1.4 Energy Management

Sandia's Energy Management Program strives for efficient management of energy and control of utility costs. The program is administered by the systems engineering department of the Facilities Management and Operations Center at Sandia/New Mexico and by the facilities planning and engineering department at Sandia/California.

The Energy Management Program emphasizes performance-based management activities to meet the requirements and goals set forth in DOE Order 430.2 ("In-House Energy Management"), which was accepted into the Sandia directives base line in December 1996. Among these goals is a reduction of energy use per gross square foot of facilities space against an FY 1985 base line, with annual progress expected. This goal is incorporated in the annual appraisal agreement between Sandia and the DOE and is evaluated each year to help Sandia better manage its operating costs. Sandia's Energy Management Program also

- implements and updates our short- and long-range Energy Management Plan;
- reports energy consumption for all fuels, aided by extensive electric and gas metering systems;
- provides consultation on energy efficiency design criteria and required energy reports for new facilities;
- provides technical support for utility billing and space chargeback;
- assists in the identification and funding of energy-savings projects;
- conducts energy awareness activities; and
- works closely with the Sandia Pollution Prevention program to incorporate comprehensive resource conservation goals for projects.

8.3.1.5 Condition Assessment

The Sandia Condition Assessment Survey of critical and important facilities and systems was last conducted in FY 1996. DOE Headquarters has since discontinued direct funding for condition assessment surveys, so a graded approach is now used. Sandia's building management teams—consisting of building managers, system engineers, and maintenance staff—conduct ongoing assessments of buildings by using the condition assessment surveys as a base line. The system engineers also conduct ongoing condition and capacity assessments of Sandia's utility, circulation, and communication systems.

Sandia has established condition and capacity goals for aligning infrastructure systems with programmatic missions, which allows us to maximize both operational and investment dollars. Sandia's strategy to achieve these goals includes implementing major physical infrastructure line-item projects, general plant projects, major renovations, decontamination and demolition projects, and restoration projects.

8.3.2 General Purpose Facilities Plans

8.3.2.1 General Plant Project Program

General Plant Project Program funding is critical to National Nuclear Security Administration/DOE management of our facilities and to safe and reliable facility operations. Historically, general plant projects used capital funds, which were between 1.0 and 1.5 percent of total operating funds. Now, general plant project and capital equipment funds are taken from operating funding to expedite the allocation of resources for operations, maintenance, and other infrastructure activities. Thus, Sandia has gained flexibility in determining the amount of general plant project and capital equipment funding needed to maintain infrastructure and to respond immediately to changes in requirements. The funding limit for General Plant Project Program is $5 million per project.

General Plant Project funding is provided by the Nuclear Weapons Strategic Business Unit and is allocated to infrastructure and similar projects to maintain essential systems. The Nuclear Weapons Strategic Business Unit provides

funding for general plant projects and implementation in support of the National Nuclear Security Administration's Stockpile Stewardship and Stockpile Management programs. This funding is provided as part of the Operations of Facilities under Readiness in Technical Base and Facilities (see section 6.1.1.3). Even with this planned funding, not all identified general plant projects can be funded each year. However, organizations now have the liberty to reprogram operating funds to general plant projects to meet their programmatic requirements within established sites planning principles.

The process to identify, prioritize, and develop general plant projects requires the preparation of brief project summaries in standard format for all submittals so that projects can be compared on an equal basis by the Corporate Sites Planning Council. A scoring system for prioritizing submittals of project proposals considers the following criteria:

- impact on Sandia and National Nuclear Security Administration/DOE missions if the project is not performed;
- a qualitative cost/benefit analysis;
- potential effects of outstanding issues on cost, schedule, performance, or project viability; and
- impact on operational efficiency.

8.3.2.2 General Purpose Equipment Requirements

General purpose equipment is used in laboratory administrative and management activities. Indirect dollars are reprogrammed to provide capital funds for this equipment.

8.3.3 Inactive Surplus Facilities Plan

Sandia facilities are maintained according to their fitness for mission use. We have received no funding for the Surplus Facilities Inventory Assessment effort. We optimize existing space by renovating facilities to extend their useful lives when renovation is possible and cost effective. Facilities that are beyond their economically useful lives and have no current or planned mission become candidates for demolition through the Decontamination and Demolition Program. The general intent of this program is to demolish excess substandard facilities to offset projected growth and clear sites for future projects.

8.3.4 Facilities Resource Requirements

Although Sandia's goal is to stabilize the total amount of space maintained, some test laboratories are being upgraded and new ones have been proposed. New construction projects will provide mission capabilities that cannot be cost effectively accommodated in existing or refurbished facilities.

Environment, safety, and health concerns are addressed when planning for all facilities. Accordingly, the design features of all new buildings and major renovations are reviewed internally and by the DOE. In environmental protection, the DOE requires that contractors comply with the provisions of the National Environmental Policy Act and other relevant environmental laws. For each new facility and major renovation, Sandia prepares an environmental checklist/action description memorandum for the DOE. If the DOE requests further documentation, an environmental assessment or 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. The DOE also requires a safety review of new construction projects and major renovations.

8.3.5 Sandia Facilities Investment Strategy

Sandia's construction plan provides facilities needed to achieve programmatic objectives, eliminate excess and substandard space, and construct new permanent facilities. The Sandia facilities investment strategy is proposed within the guidelines of an agreement among the three national weapons laboratories (Sandia, Los Alamos, and Lawrence Livermore) and the Nevada Test Site, which results in an annual average Sandia Defense Programs budget of $46.2 million (excluding the Microsystems and Engineering Sciences Applications complex, Sandia's major system project). The National Nuclear Security Administration Defense Programs budget consists of

- $32 million in stockpile stewardship and $5.7 million in stockpile management for line item projects,
- $5 million in stockpile stewardship and $2.5 million in stockpile management for general plant projects, and
- $1 million in stockpile stewardship for decontamination and demolition projects.

In addition to the above budget, Sandia has an indirect corporate infrastructure budget of $13.2 million, which includes a number of major alteration projects. Thus, the total Sandia investment strategy is approximately $59.4 million per year.

Major construction projects through FY 2006 are discussed briefly in the following subsections. Each project includes the anticipated first year of funding and the funding source as of May 2001. The non-National Nuclear Security Administration Defense Programs projects under Section 8.3.5.3 are in addition to the budget given above.

8.3.5.1 Defense Programs Stockpile Stewardship Funding

Microsystems and Engineering Sciences Applications Complex (New Mexico)

The Microsystems and Engineering Sciences Applications complex will provide essential facilities and capabilities for integrating advanced component and subsystem design, computational simulation and engineering, and 21st-century microsystems development to ensure a safe, secure, reliable, and affordable nuclear stockpile now and in the future.

Microsystems developed and prototyped at the Microsystems and Engineering Sciences Applications complex represent the future of weapons system research and development at Sandia. Integrated microsystems with the ability to sense, think, act, and communicate will advance Sandia's ability to maintain the safety and reliability of weapons systems with modern technology. These microsystems will safely sustain the nuclear weapons stockpile into the middle of the century. Without them, the stockpile would continue to rely on technology that dates from the 1960s and 1970s. This project is ongoing; the first year of funding is FY 2001.

Model Validation and System Certification Test Center (New Mexico)

The Model Validation and System Certification Test Center will enable test capabilities to continue providing data necessary for certifying weapon systems; enhance capabilities to facilitate large volume data delivery; and replace an aging communications infrastructure to integrate command and control, data collection, processing, archival, and distribution systems. The project is ongoing; the first year of funding was FY 1999.

Storm Drain, Sanitary Sewer, and Domestic Water System Modernization (New Mexico)

This project will rehabilitate and expand the storm drain system to protect against a hundred-year storm, rehabilitate the sanitary sewer system, improve fire protection, and oversee water consumption by providing monitoring equipment for the domestic water system and adding meters at supply points. These improvements will prevent soil and groundwater contamination, increase flood protection, reduce the programmatic risks of system failures, and minimize operating and maintenance costs. The project is ongoing; the first year of funding was FY 1998.

Joint Computational Engineering Laboratory (New Mexico)

The primary mission of the Joint Computational Engineering Laboratory is to develop advanced science-based stockpile stewardship tools and prototype a "virtual enterprise" to ensure rapid development and application of high-performance computing, modeling, and simulation. The project also will integrate numerous heterogeneous information systems and technologies at a single site. The facility will provide laboratory space for information-based research and development, prototyping, and testing-as well as space for approximately 175 computer scientists, weapons designers, and weapons analysts. The project is ongoing; the first year of funding was FY 2000.

Distributed Information Systems Laboratory (California)

The Distributed Information Systems Laboratory will enable development of distributed information technologies for secure, seamless, high-performance distance computing that supports integration of the nuclear weapons complex into a virtual enterprise. The project is ongoing; the first year of funding is FY 2001.

Sandia Underground Reactor Facility (New Mexico)

The Sandia Underground Reactor Facility will provide a modern, secure, underground facility to house the existing Sandia Pulsed Reactor at a significantly lower annual security cost. The Sandia Pulsed Reactor is a unique and essential tool for the development and certification of weapon components and subsystems. However, the cost to maintain the required high level of security at the existing facility is approximately $10 million per year. After the Sandia Underground Reactor Facility is completed, annual costs will drop to approximately $4 million; thus, the project's payback period will be three to four years. The project is ongoing; the first year of funding is FY 2001.

Test Capabilities Revitalization (New Mexico)

The Test Capabilities Revitalization project will modernize Sandia's test and experimental infrastructure and our diagnostic capabilities to perform weapons qualification, development, investigation, surveillance, and model validation. The project will renovate existing facilities and provide new facilities, subject to future cost-benefit studies. Test capabilities within the scope of the project include modal, structural, thermal fluids, material characterization, non-destructive test, vibration, and mass property (located in Technical Area I); centrifuge, vibration, sled track, dynamic shock, radiography, structural, photometrics, and radiant heat (located in Technical Area III); and explosive applications, aerial cable, and burn site studies (located in the Coyote Test Field). The project will provide the National Nuclear Security Administration and the DOE with experimental and test capabilities required to have confidence in Accelerated Strategic Computing Initiative codes and maintain the enduring stockpile as part of the Stockpile Life Extension Program. The first year of funding is FY 2002.

Exterior Communications Infrastructure Modernization (New Mexico)

The Exterior Communications Infrastructure Modernization project will upgrade/replace obsolete and aging exterior communications infrastructure in the oldest part of Technical Area I. This will allow Sandia to fully leverage and enhance the capabilities of the Joint Computation Engineering Laboratory, the Distributed Information Systems Laboratory, the Microsystems and Engineering Sciences Applications complex, and other programs dependent on reliable, high-speed, high-bandwidth communications. The first year of funding is FY 2002.

LIGA Technologies Facility (California)

The LIGA Technologies Facility (formerly the Microsystems Processing Laboratory) will house clean rooms to support LIGA (an acronym from the German for lithography, electroplating, and molding) micromachining processing, prototype development, and research and development. The facility will be located within the existing Integrated Microtechnologies Laboratory complex at Sandia/California to complement and create synergy with existing microtechnology capabilities and to leverage the capability and capacity of existing utilities. Proposed core capabilities in the Integrated Microtechnologies Laboratory complex will include LIGA, thick ultraviolet photolithography, and extreme (fine line) ultraviolet lithography. The proposed LIGA Technologies Facility will allow the processing of higher quality microparts and microsystems in an efficient and safe environment. The first year of funding is FY 2003.

Nuclear Weapons Engineering and Product Support Complex (New Mexico)

The Nuclear Weapons Engineering and Product Support Complex project will provide upgraded and expanded facilities on the west side of Technical Area I for many of Sandia's traditional weapons program functions. In addition, modernization of these buildings (buildings 805, 806, and 807), which are nearly fifty years old, will bring the aging structures into compliance with current seismic and building codes. The modernization will greatly improve site utilization in this section of Technical Area I, permit demolition of deteriorated and substandard space in other parts of Technical Area I, and reduce operating costs. The most likely candidates for relocation to these buildings are weapons programs and programs located in substandard or temporary facilities that would benefit from being located near Sandia's DOD partners on Kirtland Air Force Base. Among the functions for the modernized buildings are military liaison, weapons training, knowledge preservation, systems analysis and complex integration, and other related functions. The first year of funding is FY 2006.

8.3.5.2 Defense Programs, Stockpile Management Funding

Rapid Reactivation (New Mexico)

The Nonnuclear Reconfiguration Program downsized the nonnuclear manufacturing component of the weapons complex while maintaining production capacities at a specified level. The Rapid Reactivation project will increase neutron generator production to fully support directive schedules. Production capacity will be increased from the current level of 600 units per year to a new level of 1,300 to 1,500 units per year. The project is ongoing; the first year of funding was FY 1999.

Weapons Evaluations Testing Laboratory (Texas)

The new Weapons Evaluations Testing Laboratory will replace the existing Weapons Evaluation Test Laboratory at the Pantex Plant near Amarillo, Texas. It will test weapons components and implement advanced diagnostic techniques developed by the National Nuclear Security Administration Enhanced Surveillance Campaign. The laboratory will also support new technologies for stockpile surveillance in the twenty-first century to ensure the aging stockpile remains viable. The project is ongoing; the first year of funding is FY 2001.

Recapitalization of Neutron Generator Production Facility (New Mexico)

This project will recapitalize tooling and production equipment in the Neutron Generator Production Facility (Building 870). The first year of funding will be FY 2004 or FY 2005.

Artist's conceptual design of Sandia's Weapons Evaluations Testing Laboratory.

8.3.5.3 Nondefense Programs Funding

Nanofabrication and Integration Laboratory (New Mexico)

Sandia's Physical and Chemical Sciences Center has been asked to participate in a DOE Office of Science initiative to create five nanoscience research centers across the country. One center in Albuquerque would involve Los Alamos National Laboratory, the University of New Mexico, and Sandia. The objective would be to perform collaborative, multidisciplinary research to advance the fundamental understanding and control of materials at the nanoscale, and to use that knowledge to develop new nanotechnology applications. This kind of research would require fairly sophisticated laboratory and collaborative spaces outside Kirtland Air Force Base to support partnerships and collaboration with foreign nationals. The first year of funding is FY 2002; the funding source is the Office of Science Programs' Basic Energy Sciences.

Cooperative Monitoring Center (New Mexico)

The Cooperative Monitoring Center will develop capabilities to support international cooperation on nuclear materials management, nonproliferation, arms control, the environment, and other strategic issues. Rising concerns about security at the national laboratories and the growth of international programs create the need for a new facility. This facility is proposed as an FY 2005 line item project to be located off Kirtland Air Force Base, either on DOE land west of Eubank Boulevard or east of the Microsystems and Engineering Sciences Applications complex, which would require a fence line change. The project is unique to Sandia; it must be located off base for security reasons because the Cooperative Monitoring Center regularly will have foreign visitors from sensitive countries. The anticipated size is 75,000 gross square feet of offices, light laboratories, and conference space. The first year of funding is FY 2005; the funding source is the National Nuclear Security Administration Office of Defense Nuclear Nonproliferation.

8.4 Information

8.4.1 Information Resources Management

All information created by Sandia is a corporate asset, which Sandia manages by providing appropriate protection and dissemination throughout the information life cycle. Information is protected in accordance with its value and is disseminated to users' desktops through an affordable, distributed information infrastructure.

Sandia's Chief Information Officer defines and implements corporate information processes that support our missions in science, engineering, and manufacturing by

- planning, developing, implementing, and maintaining Sandia's distributed information infrastructure;
- setting corporate process requirements for information and the information infrastructure; and
- protecting Sandia-owned and -acquired physical and electronic information consistent with its business value, applicable laws, customer requirements, and contractual requirements.

Sandia's Chief Information Officer manages the support provided by Integrated Information Services, which addresses corporate business requirements delineated in memoranda of understanding with Sandia's strategic business units (SBUs). Universal electronic connectivity gives all employees access to data services. Project acceleration services enable work groups to produce their deliverables efficiently. Shared information services enable work groups to reuse work experiences and solutions, as appropriate. Competitive knowledge services provide real-time, human collaborations for creating new business opportunities and ideas. A portion of the indirect information budget is used to align these services with goals set by the SBUs.

The Chief Information Officer and Integrated Information Services develop and sustain the information infrastructure as a competitive advantage for Sandia to solve complex science and engineering problems quickly and cost effectively.

All Integrated Information Services processes and projects are documented annually in process management plans or project definition documents. Progress against the year's annual plan is assessed quarterly and is the basis for DOE Business Management Oversight Program metrics.

The cost and quality of information services are benchmarked against other companies and reported to Sandia users. Individual user and SBU satisfaction is assessed annually.

8.4.2 Software Quality

Sandia established a Software Management Program in FY 1992 in accordance with the requirements of DOE Order 1330.1D, "Computer Software Management." The program was implemented as a good business practice that

- identified a single Sandia point of contact for software management reference;
- implemented a uniform Sandia software management policy;

- established guidelines derived from internal organizations and industry best practices; and
- encouraged development of organization-specific, results-oriented software management plans to incorporate the precepts of software quality assurance and software quality control.

The software management policy was formalized in April 1993 as "Sandia Laboratories Policy 1011: Software Management" and was converted in October 1997 to "Corporate Process Requirement 400.2.4." The DOE order and the resulting corporate process requirement have been rescinded, but the business case remains.

To improve the software engineering practices used by Sandia software organizations and to provide a company-wide ability to manage software development and maintenance processes, Sandia subsequently established the Directors' Council on Software Improvement under the sponsorship of the Weapon Systems Quality Director.

Software is becoming one of our highest-consequence products. A strong business case can be made for establishing a base line for the maturity level of software practices; determining the relationship of the maturity level to product performance, cost, and schedule measures; and establishing an organized effort to improve these practices and product measures based on business need.

Our sponsors are asking us to show them the processes we use to develop, certify, and support our products (especially weapons-related products for the DOD). We are being directed by sponsors to demonstrate that we possess the key processes and activities representative of at least a level 2 company in the Software Engineering Institute's capability maturity model. This is a modest goal for a national laboratory.

Traditional lines of business for Sandia could be lost if we cannot demonstrate cost and schedule efficiencies while maintaining our emphasis on performance and surety. Processes need to be defined to reduce risk, increase productivity, and improve product quality.

Sandia executive management meets annually with Lockheed Martin senior management. Additionally, Sandia's affiliation continues with Lockheed Martin's Engineering Process Improvement Center, which sponsors the Software Subcouncil and the Software Quality Working Group. The primary focus area is maturity level goals and implementation for software and systems engineering. The subsections below report our present status and plans for the future.

8.4.2.1 Background

The dramatic process maturity enhancements implemented by Lockheed Martin companies over the past few years have been documented by Lockheed Martin's Technical Operations Managers Council. These enhancements were measured against the standard provided in the Software Engineering Institute's five-level capability maturity model. As recently as 1998, two thirds of Lockheed Martin's significant software developing companies were at model level 2 or below. Today, twenty of twenty-four companies are at level 3 or above, and ten are at level 4 or level 5 (world class). Lockheed Martin has directed all software-significant companies to initiate planning to achieve level 4.

Sandia has been represented on Lockheed Martin's Technical Operations Managers Council for several years, and on most Lockheed Martin Engineering Process Improvement Center subcouncils. Last year, the Technical Operations Managers Council began greatly reducing the number of subcouncils but the two primary ones remain: Software and Systems Engineering. In 1999, Software Subcouncil members and Sandia began working on the software maturity challenge. These efforts culminated in the current Directors' Council on Software Improvement. We presented a briefing on the council framework to the Defense Nuclear Facilities Safety Board in March 2001 in response to their survey on software quality at Sandia.

8.4.2.2 Approach

Sandia undertakes a significant number of software development projects. Software development projects for Sandia's Use Control equipment, Accelerated Strategic Computing Initiative, and satellite ground systems are important and innovative. We also have a significant administrative and support software effort. The Directors' Council supported a Software Improvement Initiative in two phases to address each of these areas: Phase 1 of this initiative was to establish a corporate base line of software engineering practices within a representative group of Sandia's major software engineering organizations. Phase 2, which is expected to continue through FY 2005, will establish an action plan for improving current software engineering processes based on a common set of metrics and tempered by each center's business goals.

Phase 1 is well under way. We have used the Surety Assessment Center's Software Team to conduct software process assessments on major software development centers, measuring them against the Software Engineering Institute's Capability Maturity Model. By the middle of FY 2001, five such organizations had been assessed (one for the second time) and Phase 2 software improvements are under way in all five.

8.4.2.3 Future Plans

In March 2000, Sandia's corporate management initiated Corporate Process Requirement CPR001.3.2 ("Corporate Quality Assurance Program"). In FY 2001, the Directors' Council began work on a Corporate Process Requirement on Software Quality that would dovetail with this Corporate Quality Assurance Program. The Software Quality Corporate

Process Requirement will not require a particular Capability Maturity Model level for Sandia organizations, but will provide the framework for a graded approach to software quality throughout the corporation in compliance with DOE requirements.

Our long-term goal is that by the end of FY 2005 Sandia will be recognized by our primary customers as a center for excellence in software engineering and in the use of software for high-consequence operations. We plan to convince others of the value of institutionalizing solid software processes by leveraging center directors participating on the council.

8.4.3 Records Management

Records management focuses on the life-cycle of recorded information-its creation, receipt, use, maintenance, preservation, and disposition. Records management provides the right record to the right person at the right time for the right cost.

Sandia's Recorded Information Management Program supports core research and laboratory operations by improving management of information resources; fostering understanding of the importance of recorded information generated by Sandia and subcontractors; educating Sandians about their responsibility in the creation, use, and disposition of records; and explaining the federal government's role in information management at Sandia. The Recorded Information Management Program assists line organizations with information retrieval and cost- and mission-effective information management.

Records management and retention guidelines combine regulatory compliance requirements with good business practices. With certain exceptions, all records held by Sandia are government property and therefore are subject to our prime contract, to specific Sandia requirements, and to federal statutes and regulations. Sandia's Recorded Information Management Program reviews line organization information management procedures for adherence to good business practices and compliance with regulatory requirements. The program also provides leadership and partnering activities that

- integrate information services by teaming with other information providers;
- preserve and make available Sandia's corporate memory and evidence of Sandia's service in the national interest;
- work with nuclear weapons design and production agency engineers to ensure that records to support changing mission assignments remain available to Sandia product and stockpile evaluation engineers; and
- work with Sandia's defense programs in identifying, preserving, and improving retrievability of weapons data essential to national defense and stockpile surety.

Records management staff familiarize Sandia employees with proper records management practices. We have established file plan templates to standardize filing systems throughout Sandia and we continue to expand our training program in records management. In FY 2000 we developed classes for new hires and managers, the files management training module, and professional development classes for administrative assistants. In FY 2001 we offered classes on the formal review and approval process and Privacy Act regulations, and merged our required records management training with the computer security training-saving our customers time while presenting a stronger and better integrated message. In addition we provide secure and cost-effective storage for inactive records for Sandia organizations so that office space can be used efficiently for personnel and facilities. To date, we more than 33,000 boxes of records in various media on behalf of every program at Sandia.

In addition to corporate-funded services, the Recorded Information Management Program also provides dedicated records management support (through matrixed positions) to the Microsystems and Engineering Sciences Applications Complex, the Integrated Safety and Security Management Program, and the Production Division.

The Corporate Archives and History functions provide training in Sandia history and culture to the Weapons Intern Program, perform historical research requests, provide Freedom of Information Act research support, participate in professional History and Archives Societies, maintain the history site on Sandia's internal and external web sites, and publish a newsletter three times a year.

Corporate history products in the form of the general history and the history of the Waste Isolation Pilot Plant are available through the National Atomic Museum store and local bookstores. The History Program teamed with cultural resources management to provide documentation for the DOE in compliance with the National Historic Preservation Act, completing documentation on Technical Area II, writing a history of Building 828, drafting a historical context statement for Sandia's New Mexico site, and preparing eighty-one forms for Technical Area I.

8.4.4 Management of Scientific and Technical Information

The Scientific and Technical Information Management Program was established to protect the public's interest in research performed at Sandia. Because our work is largely government funded the public has considerable investment

in Sandia's operations. The public has legitimate concerns that

- technical staff manage scientific and engineering information to promote cost- and mission-effective operations;
- technical staff document their work to assure accountability and protect against fraud, waste, and abuse;
- research staff control the dissemination of information to protect national security interests; and
- results and progress on all scientific efforts are reported to the National Nuclear Security Administration/DOE and, as appropriate, made available to individuals in the research community.

Sandia's Scientific and Technical Information Management Program follows life-cycle information practices to ensure that information is produced, processed, disseminated, and properly retained for knowledge management and research purposes. The program delivers policy, procedures, training, and processes that define staff roles in generating information needed to document research efforts and responsibilities as custodians of such documentation. In addition, the program provides a corporate formal review process, a web site with documentation information, and informal processes for departmental or programmatic reviews of information. The processing of scientific and technical information for release has remained steady for the last few years, totaling 2,640 products for the first eight months of FY 2001. Previous totals are 3,067 products for FY 2000 and 3,234 products for FY 1999.

A major accomplishment this year is our compliance with the Office of Scientific and Technical Information's accelerated requirement for electronic submittal of all information products.

8.5 Protection

8.5.1 Security

The Safeguards and Security Program is responsible for protecting DOE assets at all Sandia sites in accordance with the requirements of the DOE (our primary customer), our Sandia customers, and other stakeholders. The activities of the Safeguards and Security Program include

- program management,
- protective forces,
- protection systems,
- information security,
- transportation,
- nuclear materials control and accountability, and
- personnel security.

The missions of both the DOE and Sandia have changed in response to global political changes. The security infrastructure employs automated access controls and technological improvements to cost-effectively address these changes and other Safeguards and Security needs. Onsite employees and contractors use web-based resources to enhance communication, maintain awareness, and provide up-to-date security practices that implement administrative controls.

8.5.1.1 Protection Posture

The overall objective of the Safeguards and Security Program is 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 the DOE's design basis threat guidance, locally identified risks, and other programmatic requirements. Our protection strategies are based on compliance and performance.

The Sandia protection program is based on risk management, which means that higher risks require greater protection. The complexity of analysis, thoroughness of documentation, and levels of effort are aligned to be commensurate with risk, consequences of loss or compromise, value of assets, cost of implementation, and other factors. This risk management approach eliminates unnecessary features or activities that add to the costs of implementation.

All information created by Sandia is considered a Sandia asset. Sandia manages and protects this information by ensuring appropriate dissemination and protection throughout the information life cycle.

8.5.1.2 Evolving Site Security Needs

The nature of work at Sandia has changed dramatically during the last decade. Much of our expertise and technical base is being transferred to nonweapon areas such as environment, energy, and computer and materials science-all of which have dual-use applications. A substantial portion of Sandia's work now involves law enforcement, treaty monitoring and verification, nuclear weapons reduction and dismantling, nuclear material protection, nonproliferation, and other security issues that require interaction with a large number of foreign nationals. These interactions will increase with changes in the customer mix, increased cyber communications and interactions, and staff requirements to publish and present at international conferences.

Sandia's protection systems are driven by DOE security requirements, technological developments, international security issues, and increased partnerships with private industry. Major initiatives require modification of protection systems. As a result, Sandia line organizations and customers participate in decisions about protection systems established for their programs and facilities. Sandia implements new security requirements through increased use of web-based information systems, restructured security areas, and increased employee accountability for security through the Integrated Safeguards and Security Management Program.

Sandia is expanding and strengthening our counterintelligence program. This program prevents both intentional and inadvertent disclosure of classified and unclassified controlled information. The program has three primary focal areas: traditional counterintelligence, analysis, and cyber communications. Each area is tightly coupled to and benefits from the others. The program is integrated across all Sandia sites. A major part of the counterintelligence program strategy is to ensure that all Sandians are well informed about the threat and have the necessary defensive tools to protect themselves and Sandia technologies.

In response to direction from the DOE, Sandia has strengthened its Foreign Visits and Assignments Program. The program emphasizes three key principles:

- to record and regulate all visits by international visitors to Sandia or to Sandia-hosted functions, whether or not they occur in secure areas;
- to process and control all foreign visits and assignments via the Foreign Interactions Office; and
- to require all Sandia hosts of foreign visitors or assignees to regard the Foreign Interactions Office as the information repository for the visits.

Sandia's Foreign Visits and Assignments Program involves key program elements (foreign interactions, computer security, operations security, export control, counterintelligence, and classification) in the review and approval process for hosting more than 2,000 foreign nationals annually. Hosts use a one-step process for interactions with their foreign counterparts. In response to intense scrutiny by Congress and the DOE, Sandia has implemented additional measures to strengthen our controls over foreign visits and assignments.

8.5.1.3 The Changing Face of Security

The new missions of the DOE and Sandia require changes in the security infrastructure. Information security processes will expand to address the evolution of electronic transmission capabilities. The networking environment at Sandia is being extended to all desktops by deployment of Windows 2000 operating systems for both classified and unclassified computing.

Sandians and contractors will receive frequent, comprehensive information about security threats as well as potential consequences based on loss of military and economic information. Safeguards and Security staff will join with line organizations, their customers, and the DOE to implement cost-effective risk-based security strategies documented in customized security plans to achieve more efficient protection systems. Roles, responsibilities, and accountabilities will be simplified and clarified to address protection issues. Security technologies will be employed to address physical security needs. Extensive educational programs will be focused on foreign interactions, onsite visitor control, foreign travel, and export control issues. Protection changes will be monitored through performance management processes to ensure protection of DOE assets.

8.5.2 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 conform to industry standards and DOE expectations and comply with all applicable laws and regulations on environment, safety, and health (ES&H).

8.5.2.1 Goals and Objectives

Sandia's Corporate Policy Statement 400.1, "Environment, Safety and Health," articulates our commitment to safety and affirms our intent to comply with all applicable laws, regulations, and DOE directives and to adhere to the principles of integrated safety management. Sandia's annual appraisal agreement with the DOE identifies four ES&H performance objectives:

- protect people,
- protect the environment,
- comply with regulations, and
- use good management practices.

Additionally, a Lockheed Martin corporate milestone is to reduce Sandia's "days-away case rate."

8.5.2.2 Line Operations: The Integrated Safety Management System

Sandia's Integrated Safety Management System is the primary vehicle for achieving our ES&H objectives. In accordance with our management and operating contract with the DOE, Sandia intends to "do work safely" by incorporating five safety management functions:

- define the scope of work,
- identify and analyze hazards,
- develop and implement hazard controls,
- do the work safely, and
- collect feedback to improve safety management.

Department managers are accountable for the actions of their staff and have primary responsibility for their health and safety. The person who directs day-to-day work is responsible for safety, reinforcing "line ownership." In matrixed situations involving direction from both project leaders and organization managers, any unassigned project ES&H responsibilities belong to the project manager. The ES&H customer-support team assists workers and directors and suggests options for accomplishing mission goals while managing risks associated with the work. The customer-support team and the person responsible for safety must apply the five safety management functions discussed below.

8.5.2.2.1 Define the Scope of Work

The first safety management function translates the mission into work, sets ES&H expectations, prioritizes tasks, and allocates resources. Managers enumerate the risks and hazards associated with the work. The documents and processes for prioritizing tasks and allocating resources vary with the source of funding and the organization. Regardless of the individual mechanism, priorities and resource requests eventually appear in the annual budgets that Sandia management submits to the DOE.

8.5.2.2.2 Identify and Analyze Hazards

The second safety management function identifies hazards and analyses operations and facilities according to the hazard categories. The analysis is accomplished with Sandia's Integrated Safety Management System software, which contains hazard-related regulatory requirements and is linked with the ES&H Manual.

For National Environmental Policy Act requirements, Sandia submits an environmental checklist/action description memorandum to the DOE. The DOE then grants an exclusion from further analysis and categorization or prepares an environmental assessment or an environmental impact statement as appropriate.

For health and safety requirements, the software produces a primary hazard screening that identifies hazards, the sections of the ES&H Manual dealing with those hazards, and required training. The primary hazard screening is sufficient to control the hazards associated with office and standard industrial operations. For other low-hazard operations, the software prompts the user for more information to produce a hazards analysis. For nuclear, moderate-hazard nonnuclear operations, and accelerators, the software identifies the safety documentation (safety assessment, safety analysis report, and safety assessment documents) required for authorization. However, the software does not produce complete safety assessments, safety analysis reports, or safety assessment documents.

8.5.2.2.3 Develop and Implement Hazard Controls

The third safety management function identifies standards and requirements, generates authorization basis documents and agreements, identifies and establishes controls to prevent or mitigate hazards, and trains and qualifies personnel. To identify standards and requirements and tailor them to specific operations, Sandia has formalized a directives flow to Sandia's ES&H Manual from the Legal Division, from the Contract Management Department, and from the Laboratory Standards Department work control documents.

Procedures vary with the hazard level of an operation. For operations involving office and standard industrial hazards, the primary hazard screening of the Integrated Safety Management System software is the only required authorization basis document. The primary hazard screening, the approved Integrated Safety Management System description, and the existing management and operating contract constitute the authorization agreement. Controls identified in the hazards analysis or the ES&H Manual are linked to work activities by work control documents. Most Sandia operations involve office, standard industrial, and low-level nonnuclear hazards.

For low-hazard nonnuclear operations, completing the primary hazard screening and hazards analysis generates the authorization basis. After Sandia conducts a prestart readiness review, the primary hazard screening, the hazards analysis, the approved integrated safety management system description, and the existing management and operating contract constitute the authorization agreement. Greater hazards require more extensive authorization basis documents, more careful review, and explicit authorization agreements on a case-by-case basis.

For Sandia's nuclear facilities (all category 2 or 3), the list of applicable requirements, the safety analysis report, the technical safety requirements, and the unreviewed safety questions process constitute the authorization basis. The DOE reviews and approves the authorization basis documents by issuing a safety evaluation report that serves as the authorization agreement. After satisfactory completion of an operational readiness review to assure that controls identified in the authorization agreement are in place and effective, the DOE approval authority authorizes facility startup.

For moderate-hazard nonnuclear operations, the applicable list of standards and requirements, the safety assessment, and the operational safety requirements constitute the authorization basis. The DOE reviews and approves the authorization basis documents via a memorandum that serves as the authorization agreement.

For accelerator facilities, the applicable list of standards and requirements, the safety analysis document, and the unreviewed safety issues process constitute the authorization basis. After performing an accelerator readiness review, the DOE authorizes operation via a memorandum, which serves as the authorization agreement.

Managers ensure that all Sandia employees, onsite contractors, and visitors are trained in compliance with the ES&H Manual and the authorization basis documents applicable to their work.

8.5.2.2.4 Do the Work Safely

The fourth safety management function concerns readiness and safe performance. For less hazardous operations, Sandia conducts a readiness review and determines when to start or restart operations unless a DOE directive requires DOE involvement. For more hazardous operations, the DOE participates in the appropriate readiness review. Reports of these reviews usually become part of the authorization agreement.

8.5.2.2.5 Collect Feedback to Improve Safety Management

The fifth safety management function involves collecting feedback to evaluate performance and identify improvements. ES&H feedback includes such indicators as radiation exposures, reportable releases to the environment, and injury and illness rates. The corporation negotiates an annual performance agreement with the DOE and evaluates its performance every quarter. Line organizations conduct self-assessments of their operations and Lockheed Martin conducts corporate appraisals of ES&H, as do the DOE, Department of Transportation, California Environmental Protection Agency, and New Mexico Environment Department.

Additionally, several mechanisms provide ongoing feedback and identify improvement opportunities. Various ES&H councils and committees meet regularly to review and improve performance. DOE facility representatives provide daily, independent oversight of Sandia facilities. The ES&H concerns program allows any employee, onsite contractor, or visitor to report concerns or complaints. The occurrence management program captures both DOE-reportable and nonreportable occurrences, and the lessons learned program uses experience at Sandia and other DOE sites to improve Sandia's ES&H performance.

After analyzing the feedback, Sandia staff and management may correct minor problems immediately. For major findings, corrective action plans are developed and monitored.

8.5.2.3 Sandia-Wide Cleanup Operations

Sandia's Integrated Safety Management System focuses on individual line operations in support of current missions. In addition, we close out operations from past years. These include restoring sites, disposing of legacy waste, and decontaminating and decommissioning outdated facilities.

8.5.2.4 Sandia Site-Wide Environmental Impact Statement

The DOE issued a record of decision for the Sandia National Laboratories Site-Wide Environmental Impact Statement (SWEIS) in January 2000. The DOE selected the alternative under which Sandia could increase operations to the highest reasonable levels set forth in the SWEIS that can be supported by current facilities and the future expansion and construction of new facilities as specifically identified in the SWEIS. The SWEIS provides DOE, other agencies, and the public with

- a description of the affected environment, current operations, and potential impacts associated with continued operation of the Sandia New Mexico site;
- sufficient information to facilitate routine decisions by the DOE consistent with current operation status;
- a document for prioritizing National Environmental Policy Act analyses for future proposed actions, eliminating repetitive discussions of similar issues, and focusing on issues ready for decision; and
- an understanding of Sandia's contribution to cumulative environmental impacts created by the Sandia New Mexico site, Kirtland Air Force Base, and other onsite DOE facilities.

The SWEIS documents the environmental impacts of ongoing and proposed activities at the Sandia New Mexico site through FY 2008. However, the DOE will evaluate the SWEIS at least every five years in accordance with 10 CFR 1021.330 by preparing a "supplement analysis" to determine whether the SWEIS remains valid, or preparing a supplemental SWEIS, or preparing a new SWEIS.

We expect the DOE to continue suggesting new programs, projects, and facilities for Sandia. As appropriate, subsequent National Environmental Policy Act reviews for projects and activities at Sandia will reference the SWEIS.

SUPPORTING DATA

Sections 9.1 through 9.5 are Sandia's funding summary table, funding table by assistant secretarial office, funding tables by program within each secretarial office, funding table for work for non-DOE sponsors, and personnel summary table by major sponsor.

The funding tables cover five years (previous fiscal year, present fiscal year, and three years projected). Budget authority dollars are in millions and personnel are in annual average full-time equivalents (FTEs). Amounts for operating, capital equipment, and general plant projects and construction for FY 2000 and FY 2001 are expressed in the actual dollars of those respective years. For FY 2002 and beyond, operating, capital equipment, and general plant project estimates are expressed in then-year dollars. Estimates for major construction projects are expressed in dollars of the year of project commencement

The FY 2002 projection reflects our best estimate of the Defense Programs budget pending congressional action.

Section 9.6 is the Sandia executive management organization chart. Section 9.7 lists documents referenced in the text and provides other information relevant to specific sections of the text.

9.1 Sandia Funding Summary

Sandia Funding Summary
(Fiscal Year Budget Authority in Millions of Dollars)

	2000	2001	2002	2003	2004
DOE Effort	989.5	1,084.6	1,147.4	1,297.8	1,331.5
Work for Non-DOE Sponsors	386.8	413.3	474.1	485.5	506.5
Total Operating	1,376.3	1,497.9	1,621.5	1,783.3	1,838.0
Capital	46.2	55.7	58.8	65.2	67.1
General Plant Projects	8.0	4.2	6.1	8.6	8.9
Line Item Construction	33.0	41.1	125.1	70.0	377.8
Total Funding	1,463.5	1,598.9	1,811.5	1,927.1	2,291.8

9.2 Sandia Funding by Assistant Secretarial Office

Sandia Funding by Assistant Secretarial Office
(Fiscal Year Budget Authority in Millions of Dollars)

	2000	2001	2002	2003	2004
Weapons and Waste Cleanup Programs					
Total Assistant Secretary for Defense Programs					
Operating	677.5	782.9	876.9	1,017.6	1,048.1
Capital Equipment	42.8	52.2	56.8	63.2	65.1
General Plant Projects	7.9	4.1	5.9	8.4	8.7
Major Construction	33.0	41.1	120.1	70.0	347.8
Total Funding	761.2	880.3	1,059.7	1,159.2	1,469.7
Total Office of Fissile Materials Disposition					
Operating	1.1	0.0	0.0	0.0	0.0
Total Office of Nonproliferation and National Security					
Operating	161.9	147.7	125.0	138.0	138.0
Capital Equipment	1.2	1.3	0.0	0.0	0.0
Total Funding	163.1	149.0	125.0	138.0	138.0
Total Assistant Secretary for Environmental Management					
Operating	59.4	61.4	50.8	45.4	44.8
Total Funding	59.4	61.4	50.8	45.4	44.8
Energy Programs					
Total Assistant Secretary for Energy Efficiency and Renewable Energy					
Operating	46.7	47.5	48.7	50.3	51.9
Capital Equipment	0.1	0.0	0.0	0.0	0.0
Total Funding	46.8	47.5	48.7	50.3	51.9
Total Office of Nuclear Energy					
Operating	1.8	3.0	2.4	0.4	0.4
Capital Equipment	0.2	0.0	0.0	0.0	0.0
Total Funding	2.0	3.0	2.4	0.4	0.4

Sandia Funding by Assistant Secretarial Office (continued)
(Fiscal Year Budget Authority in Millions of Dollars)

	2000	2001	2002	2003	2004
Total Assistant Secretary for Fossil Energy					
Operating	6.1	8.0	8.5	8.8	9.1
Total Funding	6.1	8.0	8.5	8.8	9.1
Science and Technology Programs					
Total Office of Energy Research					
Operating	35.0	34.0	35.6	37.3	39.2
Capital Equipment	1.9	2.3	2.0	2.0	2.0
General Plant Projects	0.1	0.1	0.2	0.2	0.2
Major Construction	0.0	0.0	5.0	0.0	30.0
Total Funding	37.0	36.4	42.8	39.5	71.4
Total DOE Programs					
Operating	989.5	1,084.5	1,147.4	1,297.8	1,331.5
Capital Equipment	46.2	55.7	58.8	65.2	67.1
General Plant Projects	8.0	4.2	6.1	8.6	8.9
Major Construction	33.0	41.1	125.1	70.0	377.8
Total Funding	1,076.7	1,185.5	1,337.4	1,441.6	1,785.3

9.3 Sandia Funding by Program within Each Secretarial Office

Assistant Secretary for Defense Programs
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Directed Stockpile Work					
Operating	239.4	291.8	315.1	406.1	418.3
Direct Personnel	754	806	806	826	826
Campaigns					
Operating	240.9	280.3	287.2	304.9	314.0
Direct Personnel	771	866	866	882	882
Readiness in Technical Base and Facilities					
Operating	192.3	165.9	187.6	211.8	218.2
Capital Equipment	41.7	52.2	56.8	63.2	66.3
General Plant Projects	7.9	4.1	5.9	8.4	8.7
Major Construction	33.0	41.1	120.6	70.0	347.8
Direct Personnel	443	511	511	524	524
Facilities and Infrastructure					
Operating	0.0	0.0	24.8	24.8	25.0
Direct Personnel	0	0	0	1	1
Program Direction					
Operating	0.2	0.5	0.4	0.4	0.4
Direct Personnel	1	2	2	2	2
Safeguards and Security (SO/Emergency Response/NEST)					
Operating	4.7	4.5	4.6	4.9	5.0
Capital Equipment	1.1	0.0	0.0	0.0	0.0
Direct Personnel	16	16	16	16	16
Safeguards and Security (Physical, Personnel, and Cyber)					
Operating	0.0	39.8	56.7	65.1	67.1
Direct Personnel	0	273	273	273	273
Total Assistant Secretary for Defense Programs					
Operating	677.5	782.9	876.9	1,017.6	1,048.1
Capital Equipment	42.8	52.2	56.8	63.2	66.3
General Plant Projects	7.9	4.1	5.9	8.4	8.7
Major Construction	33.0	41.1	120.1	70.0	347.8
Total Funding	761.2	880.3	1,059.7	1,159.2	1,469.7
Total Direct Personnel	1,984	2,474	2,474	2,524	2,524

Office of Nonproliferation and National Security
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Nonproliferation and Verification Research and Development					
Operating	70.9	64.8	67.0	70.0	70.0
Capital Equipment	1.0	0.0	0.0	0.0	0.0
Direct Personnel	161	197	176	176	176
Nuclear Safeguards and Security					
Operating	9.8	11.2	12.0	12.0	12.0
Capital Equipment	0.2	0.0	0.0	0.0	0.0
Direct Personnel	22	30	28	28	28
Arms Control and Nonproliferation					
Operating	71.7	65.3	40.0	50.0	50.0
Direct Personnel	163	221	246	246	246
Intelligence/Counter Intelligence					
Operating	9.5	5.8	6.0	6.0	6.0
Direct Personnel	22	21	19	19	19
Total Office of Nonproliferation and National Security					
Operating	161.9	147.1	125.0	138.0	138.0
Capital Equipment	1.2	0.0	0.0	0.0	0.0
Total Funding	163.1	147.1	125.0	138.0	138.0
Total Direct Personnel	368	469	469	469	469

Office of Fissile Materials Disposition
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Fissile Materials Disposition					
Total Operating	1.1	0.0	0.0	0.0	0.0
Total Direct Personnel	3	0	0	0	0

Assistant Secretary for Environmental Management
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Environmental Management (Defense)					
Operating	58.8	61.4	50.8	45.4	44.8
Direct Personnel	140	167	167	167	167
Environmental Management (Nondefense)					
Operating	0.6	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0
Total Assistant Secretary for Environmental Management					
Total Operating	59.4	61.4	50.8	45.4	44.8
Total Direct Personnel	141	167	167	167	167

Assistant Secretary for Energy Efficiency and Renewable Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Solar Energy					
Operating	33.8	34.2	34.8	35.5	36.3
Direct Personnel	84	83	83	83	83
Energy Conservation					
Operating	12.9	12.4	13.2	14.3	14.9
Capital Equipment	0.1	0.0	0.0	0.0	0.0
Direct Personnel	39	41	41	41	41
Other Energy					
Operating	0.0	0.9	0.7	0.5	0.7
Total Assistant Secretary for Energy Efficiency and Renewable Energy					
Operating	46.7	47.5	48.7	50.3	51.9
Capital Equipment	0.1	0.0	0.0	0.0	0.0
Total Funding	46.8	47.5	48.7	50.3	51.9
Total Direct Personnel	123	124	124	124	124

Assistant Secretary for Fossil Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Coal					
Operating	1.5	1.5	1.7	1.8	1.9
Direct Personnel	6	6	6	6	6
Gas					
Operating	0.3	1.1	0.9	0.9	1.0
Direct Personnel	1	1	1	1	1
Petroleum					
Operating	2.4	2.9	3.4	3.5	3.6
Direct Personnel	5	6	6	6	6
Strategic Petroleum Reserve					
Operating	1.9	2.5	2.5	2.6	2.6
Direct Personnel	9	11	11	11	11
Total Assistant Secretary for Fossil Energy					
Total Operating	6.1	8.0	8.5	8.8	9.1
Total Direct Personnel	21	24	24	24	24

Office of Nuclear Energy
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Nuclear Energy Research and Development					
Operating	0.9	1.1	0.7	0.4	0.4
Direct Personnel	2	3	3	3	3
Isotope Production and Distribution Program					
Operating	0.9	1.9	1.7	0.0	0.0
Capital Equipment	0.2	0.0	0.0	0.0	0.0
Direct Personnel	3	6	6	6	6
Total Office of Nuclear Energy					
Operating	1.8	3.0	2.4	0.4	0.4
Capital Equipment	0.2	0.0	0.0	0.0	0.0
Total Funding	2.0	3.0	2.4	0.4	0.4
Total Direct Personnel	5	9	9	9	9

Office of Science Programs
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Magnetic Fusion Energy					
Operating	3.4	3.2	3.2	3.3	3.8
Direct Personnel	13	12	12	12	12
Basic Energy Sciences					
Operating	23.2	22.6	22.0	22.5	23.0
Capital Equipment	1.8	2.0	2.0	2.0	2.0
General Plant Projects	0.1	0.1	0.2	0.2	0.2
Major Construction	0.0	0.0	5.0	0.0	30.0
Direct Personnel	59	59	59	59	59
Computational and Technology Research					
Operating	5.4	4.6	6.6	6.9	7.3
Capital Equipment	0.1	0.0	0.0	0.0	0.0
Direct Personnel	14	14	14	16	15
Biological and Environmental Research					
Operating	3.0	3.4	3.7	4.5	5.0
Direct Personnel	7	8	8	10	9
Total Office of Science Programs					
Operating	35.0	33.8	35.5	37.2	39.1
Capital Equipment	1.9	2.0	2.0	2.0	2.0
General Plant Projects	0.1	0.1	0.2	0.2	0.2
Major Construction	0.0	0.0	5.0	0.0	30.0
Total Funding	37.0	35.9	42.7	39.4	71.3
Total Direct Personnel	93	93	93	97	95

Total All DOE Programs
Resources by Major Program
(Fiscal Year Budget Authority in Millions of Dollars; Personnel in FTEs)

	2000	2001	2002	2003	2004
Operating	989.5	1,084.7	1,147.4	1,297.8	1,331.5
Capital Equipment	46.2	55.7	58.8	65.2	67.1
General Plant Projects	8.0	4.1	6.1	8.6	8.9
Major Construction	33.0	41.1	125.1	70.0	377.8
Total Funding	1,076.7	1,185.6	1,337.4	1,441.6	1,785.3
Total Direct Personnel	2,737	3,360	3,360	3,414	3,412

9.4 Sandia Funding for Work for Non-DOE Sponsors

Resources by Major Program
(Fiscal Year Budget Authority in Millions; Personnel in FTEs)

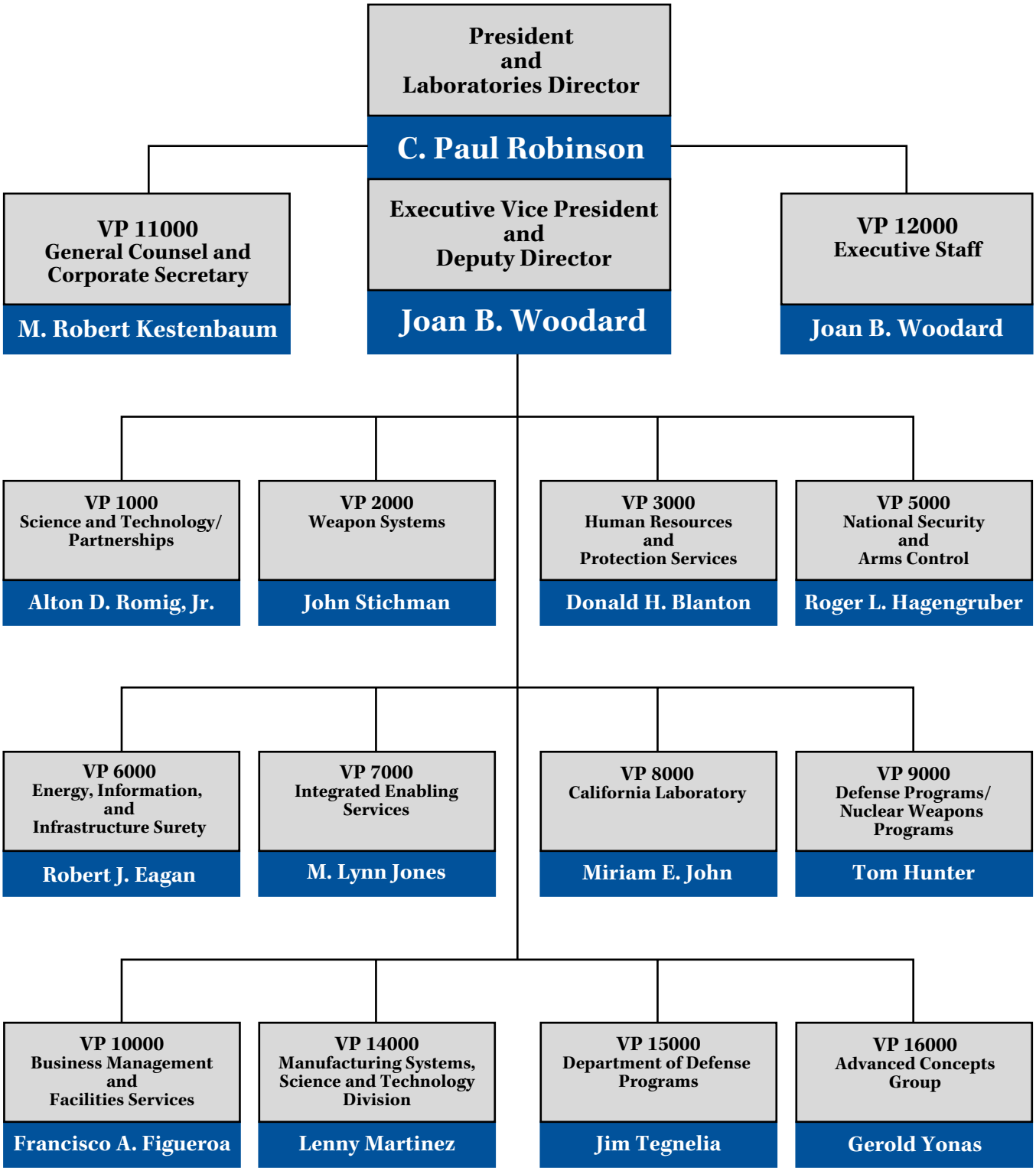
	2000	2001	2002	2003	2004
Department of Defense					
Operating	209.7	224.1	257.0	262.2	273.5
FTEs	669	726	726	726	726
Nuclear Regulatory Commission					
Operating	7.9	8.6	8.4	9.9	10.3
FTEs	37	32	32	32	32
All Other Federal Agencies					
Operating	33.0	35.1	40.4	41.4	43.2
FTEs	108	117	117	117	117
Total Other Federal Entities					
Total Operating	250.6	267.8	305.8	313.5	327.0
Total FTEs	814	875	875	875	875
Nonfederal Entities					
Operating	30.0	32.1	36.8	38.9	40.5
FTEs	90	81	81	81	81
CRADA Partners/Royalties and Licensing					
Operating	42.2	45.1	51.7	52.9	55.3
FTEs	116	105	105	105	105
Other DOE Locations/M&O Contractors					
Operating	63.9	68.3	78.3	80.2	83.7
FTEs	195	181	181	181	181
Total Work for Other than DOE					
Total Operating	386.8	413.3	472.6	485.5	506.5
Total FTEs	1,215	1,242	1,242	1,242	1,242

9.5 Personnel Summary by Major Sponsor

Personnel Summary by Major Sponsor
(FTEs)

	2000	2001	2002	2003	2004
DOE Programs					
Weapons and Waste Cleanup					
Defense Programs	1,984	2,474	2,474	2,524	2,524
Nonproliferation and National Security	368	469	469	469	469
Fissile Materials Disposition	3	0	0	0	0
Environmental Management	141	167	167	167	167
Energy Programs					
Energy Efficiency and Renewable Energy	123	124	124	124	124
Fossil Energy	21	24	24	24	24
Nuclear Energy	5	9	9	9	9
Science and Technology					
Energy Research	93	93	93	97	95
DOE Programs (Subtotal)	2,738	3,360	3,360	3,414	3,412
Programs Other than DOE					
Department of Defense	669	726	726	726	726
Nuclear Regulatory Commission	37	32	32	32	32
All Other Federal Agencies	108	117	117	117	117
Non Federal Entities	90	81	81	81	81
CRADA Partners/Royalties and Licensing	116	105	105	105	105
Other DOE Locations/M&O Contractors	195	181	181	181	181
Work For Other Federal Entities (Subtotal)	1,215	1,242	1,242	1,242	1,242
Direct Programs Total	3,953	4,602	4,602	4,656	4,654
Laboratory Directed Research andDevelopment (Subtotal)	266	325	327	375	384
Direct Support(Subtotal)	1,533	1,509	1,523	1,523	1,523
Indirect (Subtotal)	1,689	1,164	1,201	1,240	1,306
Laboratories Total	7,441	7,600	7,653	7,794	7,867

9.6 Sandia Organization Chart at the Vice Presidential Level



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INDEX

A

A Guide to Defending SNM Facilities Against Chemical Attacks, 5-4
Accelerated Paths to Closure, 6-22
Accelerated Strategic Computing Initiative (ASCI), 2-2, 2-5, 2-7, 5-11, 6-8, 6-13, 8-21, 8-24
Accelerated Strategic Computing Initiative Research Internship Program, 6-13
Accident Response Group, 6-14
accomplishments
- Energy and Critical Infrastructure strategic objective, 5-5 to 5-7
- Emerging Threats strategic objective, 5-7 to 5-8
- Infrastructure strategic objective, 5-14 to 5-15
- Nonproliferation and Materials Control strategic objective, 5-3 to 5-5
- Nuclear Weapons strategic objective, 5-1 to 5-3
- Partnerships strategic objective, 5-15 to 5-18
- People strategic objective, 5-8 to 5-9
- Science and Technology research foundations
  - computational and information sciences, 5-11
  - engineering sciences, 5-12
  - materials and process science, 5-9 to 5-11
  - microelectronics and photonics sciences, 5-11 to 5-12
  - pulsed power sciences, 5-12 to 5-14

Achieving Results Through People, 8-8
Acorn (W76 warhead component), 6-10
Adaptive 3-D Sensing for Human-Machine Cooperation, 6-44, 6-45
adhesion research, 6-30
Advanced Atmospheric Research Equipment, 4-2
Advanced Batteries Engineering Facility, 8-14
Advanced Batteries Research, Engineering, and Evaluation designated capability, 8-11
Advanced Design and Production Technologies (ADAPT) Campaign, 6-5, 6-9 to 6-10
advanced failure analysis techniques, 5-18
Advanced Firing and Detonation Systems project, 5-3
advanced industrial materials research, 6-24
Advanced Information Systems Laboratory, 5-6
Advanced Manufacturing Automatic Design of Practical Fixtures project, 4-3
Advanced Manufacturing for Education Program, 6-14
Advanced Materials Laboratory, 8-15
Advanced Modular Tag, 5-4
Advanced Monitoring Technologies Center, 6-39
Advanced Radiography Campaign, 6-13
Advanced Radiography Program, 5-14
Advanced Technology Academy, 8-10
Advanced Ultraviolet Remote-Sensing Applications (AURA) Program, 4-2, 5-4
Aeronautical Systems Center, 6-34
aerospace vehicle remote-sensing applications, 4-2, 5-4
Affirmative Action Program, 8-8
Agent-Based Evolutionary Computing Methods for Microsimulation designated capability, 8-11
Agile MEMS Prototyping, Layout Tools, Education, and Services (SAMPLES) model, 5-17
AIM-9X guidance sector, 6-44
Airworthiness Assurance Nondestructive Inspection Validation Center, 6-38, 7-10
Albuquerque Full-Scale Experimental Complex, 6-11
Altus Unmanned Aerospace Vehicle, 5-4, 6-33
aluminum gallium indium nitride devices, 5-12
American Indian Outreach Committee, 7-12
American Wind Energy Association, 6-24
Ames Research Center, 6-38
Annual Certification to the President, 6-5
Annular Core Research Reactor (ACRR), 5-12, 6-8, 6-12, 6-26
Apache helicopter, 5-7
Apatite Reactive Zone project, 7-14

Archimedes software, 6-43 to 6-45, 8-11
Argonne National Laboratory, 6-28
arms control, 6-16, 6-36 to 6-40. *See also* nonproliferation and materials control; terrorism, countering
Arms Control Technology Development Office, 6-37
Army Battle Laboratories, 6-35
Army Research Laboratory, 6-35
Arnold Engineering Development Center, 5-14
ASCI. *See* Accelerated Strategic Computing Initiative (ASCI)
ASCI Red teraflop supercomputer, 5-11, 6-8
Assembly Test Chips designated capability, 8-11
Atmospheric Radiation Measurement Program, 6-32, 6-33
Atomic Energy Act, 6-41
Atomic Weapons Establishment, Aldermaston, England, 5-14
Atoms for Peace, 7-4, 7-11
Aviation Safety Critical Elements and Necessary Tasks Program, 7-10
awards, 8-5
- Air Force's Ronald Yates Award for Team Excellence, 5-14
- American Society of Mechanical Engineers Fellow, 6-42
- DOE Managing and Operating Contractor of the Year, 8-10
- DOE Nuclear Weapons Program Award of Excellence, 5-12
- DOE Office of Basic Energy Sciences awards for outstanding scientific accomplishment, 6-42
- DOE Office of Solar Energy Technologies Recognition of Exceptional Service, 6-42
- DOE Program and Project Management Award 2000, 5-15
- DOE Weapons Award of Excellence, 5-2
- Gordon Bell Prize, 6-28
- *Industry Week* magazine award, 5-12
- Lockheed Martin NOVA award, 5-12
- National Association of Purchasing Management's Charles J. McDonald Minority Business Advocate Award, 8-11
- New Mexico State Environment Department Green Zia awards, 5-15
- Performance Excellence Award (Silver Medal), 5-3
- *R&D* magazine R&D100 award, 5-12
- Rio Grande Minority Purchasing Council awards, 8-11
- Sandia Employee Recognition Award, 8-5
- Sandia President's Gold Quality Award, 5-12
- Sandia President's Quality Award, 8-5
- Sandia President's Quality Award program, 5-9
- Sandia service awards program, 8-5
- Small Business Administration Dwight D. Eisenhower Award for Excellence, 8-10
- Small Business Administration Frances Perkins Vanguard Award, 8-11
- US Hispanic Chamber of Commerce Southwest Region Business Advocate of the Year, 8-11

B

B61, 6-9, 6-44
- components, 6-5
- microcontroller redesign, 5-2
- Type 3E Trainer, 6-5

B61 Alt 349, 5-2
B61 Life Extension Program, 6-5, 6-9
B61-7/11, 5-2
B83, 6-5
badge, DOE/Sandia, 5-14
Ballistic Missile Defense Organization, 6-36
Bechtel G2 model, 7-14
benefits, employee, 5-9, 8-3 to 8-5
biotechnology, 2-2, 2-4, 3-4, 6-43
Blocks 1 and 2 refurbishment schedules, 6-9
bomb disablement technology transfer program, 4-2
bomb disabling technologies, 5-4
Border Research and Technology Center, 6-40
Bragg reflector, 5-11
brazing technologies, 5-10
Bureau of Reclamation, 6-40

C

cafeteria renovation, 5-9, 8-4
California Environmental Protection Agency, 6-19, 8-29
Campus Executive Program, 8-7
Capability Maturity Model, 8-24, 8-25
carbon sequestration technologies, 6-26
Carlsbad Environmental Monitoring and Research Center, 6-21
Carlsbad Irrigation District, 7-15
catalysis and separations science and engineering, 6-25
Center for Civil Force Protection, 6-40
Center for Integrated Nanotechnologies (CINT), 4-3, 6-32 to 6-33, 7-8, 7-9
Center for Security Systems Evaluation, 8-14
Center for System Reliability, 8-11
Central Steam Plant, 5-15
ceramics materials research, 5-10, 6-29 to 6-30
Certification in Hostile Environments Campaign, 6-13
Chemical and Biological National Security Program, 6-17
Chemical Defense Assessment Team, 5-4
Chemical Waste Landfill, 6-19
chemical/biological threat reduction, 2-4, 5-4, 5-6, 5-8, 6-17
Chief Information Officer, 8-23
Chief Technology Officer, 6-45
Chiles Commission, 6-13
ChileSPICE circuit simulator
Citizens Advisory Board, 8-18, 8-19
Classified Network, 5-11
Clean Air Act Amendments, 6-35.
cleanup operations, Sandia-wide, 8-29. *See also* environmental remediation
cloud and radiation testbed sites, 6-33
coal and biomass combustion research, 6-26
coil gun, 5-14
Cold Spray, 5-16
College Cyber Defenders Program, 6-13
combustion chemistry research, 6-19, 6-20
Combustion Research Facility, 6-24, 6-26, 6-28, 6-29, 8-11, 8-14
Communications Electronics Command, 6-35
community involvement, 8-9 to 8-11
Community Resources Information Office, 8-19
Compensation Increase Plan, 8-3
Component Modeling and Characterization Laboratory, 8-14
Compound Semiconductor Research Laboratory, 6-11, 7-2, 7-4
computational and information sciences. *See also* computing; modeling and simulation; software; supercomputers
- accomplishments, FY 2001, 5-11
- Classified network enhancements, 5-11
- computer graphics rendering system, 5-11
- Cougar operating system extension, 5-11
- Cplant, 2-5, 5-11, 6-28
- desktop computing support, 5-11
- research foundation, 2-5 to 2-6, 5-11
- restricted network reliability, 5-11
- videoconferencing, 5-11
- Web Fileshare, 5-11

Computational Materials Science Network, 6-31
Computational Plant. *See* CPlant
computational sciences program, 6-28
computer security, 5-6
computer simulation. *See* computing; modeling and simulation

computing. *See also* computational and information sciences; modeling and simulation; software; supercomputers
distributed, 2-5, 6-28, 6-29
massively parallel computation, 2-6, 5-11, 5-12, 6-28, 6-29, 6-32
model validation, 2-7, 4-2, 5-1
structural dynamics code, three-dimensional, 5-11
supercomputing, 2-5 to 2-6, 5-11, 5-12, 6-8
Concentrating Solar Power Program, 6-23
Concurrent Design and Manufacturing Program, 5-2, 6-5
Condition Assessment Survey, 8-19
Congressional Issues Document, 5-8
Congressional Nuclear Caucus, 7-6
construction plan, 8-20
construction projects, 8-17, 8-18, 8-20 to 8-23
containment vessel model, 5-5, 6-26
Contract Management Department, 8-28
Convention on the Physical Protection of Nuclear Material, 6-16
conversion of weapons-grade plutonium from weapons, 6-14
Cooperative Monitoring Center (CMC), 5-4, 6-16, 6-37, 7-7 to 7-8, 7-15, 8-23
cooperative research and development agreements (CRADAS), 5-3, 5-16 to 5-17, 6-25, 6-29, 6-31, 6-40
Cooperative Threat Reduction Office, 6-36
Cooperative Threat Reduction program, 6-37
core values, 2-1 to 2-2
alignment with DOE and Lockheed Martin, 2-2, 2-3
Corporate Archives and History, 8-25
Corporate Business Development and Partnerships Center, 5-18
Corporate Diversity Team, 8-7
Corporate Integrating Initiatives, 4-3
Corporate Ombuds Office, 8-8
Corporate Process Requirement on Software Quality, 8-24
Corporate Quality Assurance Program, 8-24
Corporate Sites Planning, 8-17
Corporate Sites Planning Council, 8-18, 8-20
Corporate Training, Development, and Education organization, 8-6
corporate values, 2-1, 2-3. *See also* core values
Cougar operating system, 5-11
counterintelligence, 8-27
counterproliferation. *See also* nonproliferation and materials control, 4-3, 6-37, 7-7, 7-10
Coyote Test Field, 8-21
Cplant, 2-5, 5-11, 6-28
Creating a Woman-Friendly Culture at Sandia conference, 5-9
crime-fighting technologies, 6-40. *See also* terrorism, countering
bomb disabling devices, 5-4
critical infrastructure programs. *See also* Energy and Critical Infrastructure strategic objective
accomplishments, FY 2001, 5-6 to 5-9
chemical/biological threat reduction, 5-6
computer security, 5-6
consequence-based methodology, 7-9 to 7-10
Domestic Demonstration and Application Program, 5-6
infrastructure interdependencies, 7-9 to 7-10
Internet security, 5-6, 7-10
nuclear power revitalization, 7-11 to 7-12
nuclear power safety, 5-6, 6-37, 7-10
radioactive waste processing, 5-6
surety, 7-9 to 7-10
systems and policy analysis, 7-10 to 7-11
transportation of radioactive materials, 5-7
transportation surety, 7-10
transuranic waste disposal site assessment, 5-7
Crosslinks, 8-10
Cruise Missile, 5-7
CTH Software designated capability, 8-11
Current Waste Management Project, 6-12

D

DAKOTA. *See* Design Analysis Kit for Optimization (DAKOTA) software
Deans' Day, 8-7
DECADE radiation effects testbed, 6-37
decontaminating and decommissioning, Sandia facilities, 8-29
Decontamination and Demolition Program, 8-20
Defence Evaluation and Research Agency facility, Porton Down, England, 5-7
Defense Advanced Research Projects Agency, 5-7, 5-8, 5-12, 6-37
Defense Applications and Modeling Campaign, 2-7, 6-5, 6-8, 6-13
Defense Intelligence Agency, 6-40
Defense Nuclear Facilities Safety Board, 6-22, 8-24
Defense Nuclear Materials Stewardship project, 6-12
Defense Nuclear Security Office, 4-2
Defense Threat Reduction Agency, 4-2, 5-6, 6-36 to 6-37
demilitarization, 4-3
Department of Agriculture, 7-14
Department of Commerce, 6-40
Department of Defense, 6-2, 6-37
emerging threats technologies, 5-7
fuzing options, 5-3
nonproliferation and verification programs, 6-15
Office of the Secretary of Defense, 6-37
security requirements, 5-2
Singapore naval port, 4-4
training responsibilities for, 6-5
Department of Energy. *See* DOE
Department of Interior, 6-40
Department of Justice, 6-40
Department of State, 6-14, 6-38 to 6-39
Department of Transportation, 6-38, 8-29
Office of Pipeline Safety, 6-38
Design Analysis Kit for Optimization (DAKOTA) software, 5-11
Design, Evaluation, and Test Technology designated capability, 8-11
Design, Evaluation and Test Technology Facility, 8-14
Design Review and Acceptance Group, 5-2
designated capabilities, 8-11 to 8-14
Advanced Batteries Research, Engineering, and Evaluation, 8-11
Agent-Based Evolutionary Computing Methods for Microsimulation, 8-11
Archimedes software tool, 8-11
Assembly Test Chips, 8-11
Center for System Reliability, 8-11
CTH Software Package 8-11
Design, Evaluation, and Test Technology, 8-11
Engine Combustion Issues, 8-11
Environmental Technology Verification Testing, 8-12
Explosive Components Facility, 8-12
Geomechanics Research, Development, and Applications, 8-12
Geoscience Center Flow Visualization and Processes Laboratory, 8-12
High-Temperature Drilling/Logging Instrumentation, 8-12
Manufacturing and Industrial Capabilities, 8-12
Materials and Process Science, 8-12
National Solar Thermal Test Facility, 8-12
Photovoltaic Systems Support, 8-13
Physical and Chemical Sciences, 8-13
Plasma Materials Testing, 8-13
Primary Standards Laboratory, 8-13
Sandia Pulsed Reactor Capabilities, 8-13
Software Quality Engineering Support, 8-13
Soil and Sediment Transport, 8-13
Subsurface Environment, 8-13
Switch Tube Technology, 8-14
Underground Storage Technology, 8-14
Unique Sandia Systems Applicable to Specific Environmental Problems, 8-14
VxInsight, 5-18, 8-14

desktop computing support, 5-11
Dinero, 8-8
Directed Stockpile Work, 2-7, 5-14, 6-1 to 6-10, 6-11, 6-12
Directors' Council on Software Improvement, 8-24
DisCom². *See* Distance Computing and Distributed Computing Program (DisCom²)
dish/Stirling solar power generation system, 5-5, 6-23
Distance Computing and Distributed Computing Program (DisCom²), 2-5, 2-6
distributed computing, 2-5, 6-28, 6-29
Distributed Information Systems Laboratory, 5-15, 8-21 to 8-22
diversity, 8-7 to 8-8
Diversity Leadership Council, 8-7
Diversity Program, 8-7
Doctoral Study Program, 8-5
DOD. *See* Department of Defense
DOD Headquarters, 6-36
DOD/DOE Munitions Technology Development Program, 6-37
DOE
  Assistant Secretary for Energy Efficiency and Renewable Energy, 6-29
  Assistant Secretary for Environmental Management, 6-18
  Assistant Secretary for Fossil Energy, 6-26 to 6-27, 6-29
  Assistant Secretary for Renewable Energy, 6-22
  Atmospheric Radiation Measurement Program, 6-33
  Basic Energy Sciences, 6-28 to 6-32
  Business Management Oversight Program, 8-23
  Campaigns, 2-7, 6-3, 6-4, 6-5 to 6-11
  Center of Excellence in Synthesis and Processing of Advanced Materials, 6-31
  Defense Programs, 2-5, 3-1, 5-16, 5-17, 6-1 to 6-10, 6-11, 6-23, 6-31, 6-34, 7-1, 7-4, 8-20
  Division of Materials Sciences, Office of Basic Energy, 6-31
  Land and Facility Use policy, 8-18
  Nuclear Energy Research Initiative, 6-25
  Office of Basic Energy Sciences, 7-8
  Office of Civilian Radioactive Waste Management, 5-17, 6-25
  Office of Defense Nuclear Nonproliferation, 6-38
  Office of Energy Efficiency and Renewable Energy, 6-24, 6-25
  Office of Engineering and Construction Management, 5-15
  Office of Environmental Management
    Nonactinide Isotope and Sealed Sources (NISS) Management Group, 6-22
    Nuclear Material Focus Area (NMFA), 6-22
  Office of Fossil Energy, 6-26
  Office of Industrial Technologies, 6-24
  Office of Power Technologies, 6-22
  Office of River Protection at Hanford, 7-14
  Office of Science, 6-25, 8-11, 8-23
  Office of Science and Technology, 6-22
  Office of Science and Technology/Environmental Management Program, 5-17
  Office of Science Programs, 6-27 to 6-33
    Basic Energy Sciences, 8-23
  Office of Scientific and Technical Information, 8-26
  Office of Solar Energy Technologies, 6-42
  Seamless Safety Process, 5-1
  Strategic Petroleum Reserve, 6-27
  Strategic Plan, 6-44
  Superfund Innovative Treatment Evaluation Program, 6-39
  Work for Others Program, 8-11, 8-14
DOE Albuquerque Operations Office, 3-1, 5-3
DOE appraisal agreement, 4-4
DOE Carlsbad Field Office, 6-21, 6-22
DOE Headquarters, 3-1, 5-11, 6-34, 8-18, 8-19
DOE Laboratory Appraisal, 4-1, 8-2
DOE/DOD Design Review Acceptance Committee, 4-2
Domenici, Pete (Senator), 7-6
Domestic Demonstration and Application Program, 5-6
Dual-Axis Radiographic Hydrotest Facility, 6-5
Dugway Proving Ground, 5-4
Dugway Proving Grounds, 4-2
Dynamic Materials Properties Campaign, 2-7, 6-6, 6-7 to 6-10, 6-13

E

Eisenhower, Dwight D. (President), 7-11
electric vehicle battery technologies, 6-25
Electronics Quality/Reliability Center, 8-14
Electronics Technology Facility (Microelectronics Development Laboratory), 8-14
emergency response teams, 6-12, 6-14
emerging threats programs. *See also* Emerging Threats strategic objective
  adversary models, 5-8
  explosives destruction, 5-7 to 5-8
  foam, decontamination, 5-8
  laser dynamic range imager sensor, 5-8
  robotics, 5-7
  Short-Pulse Laser Program, 5-8
  telemetry, high-explosive radio, 5-7
  terrain-mapping radar, 5-7
  weapons systems maintenance, 5-7
Emerging Threats strategic objective, 3-4, 4-3
  accomplishments, FY 2001, 5-7 to 5-8
  goals, intermediate, 3-4
  LDRD support for, 6-41, 6-43
  milestones, FY 2002, 4-3
EMPHASIS computational tools, 5-12, 5-14
Employee Assistance Program, 8-4
Employee Preferences Survey, 8-2
employees. *See also* work force; Human Resources
  affirmative action, 8-8
  benefits, 5-9, 8-3 to 8-5
  compensation, 8-3
  diversity, 8-7 to 8-8
  education programs, 8-5 to 8-6
  equal employment opportunity, 8-8
  hiring program, 4-2
  labor relations, 8-1, 8-7
  recruiting, 6-13, 8-6
  staff composition, 8-1
  staffing, 4-3, 8-6
Endeavor space shuttle, 5-8
energetic particle synthesis research, 6-30
Energy and Critical Infrastructure strategic objective, 3-4, 4-2
  accomplishments, FY 2001, 5-5 to 5-7
  goals, intermediate, 3-4
  LDRD support for, 6-41, 6-43
  milestones, FY 2002, 4-2 to 4-3
Energy Management Plan, 8-19
Energy Management Program, 8-19
energy programs. *See also* Energy and Critical Infrastructure strategic objective; fossil energy research; nuclear power; solar energy
  accomplishments, FY 2001, 5-5 to 5-6
  basic energy sciences, 6-28 to 6-32
  dish/Stirling solar power generation system, 5-5
  electric power grid reliability, 6-22
  energy portfolio, 7-9
  energy storage systems, 6-22 to 6-24
  fossil fuel combustion emissions detection, 5-5
  fusion energy sciences, 6-27 to 6-28
  gas leak detection technologies, 5-6
  lithium-ion batteries, 5-5

energy programs (continued)
nuclear reactor containment vessel model, 5-5
oil well integrity, 5-5
photovoltaics, 5-5
portfolio analysis, 6-22
renewable energy, 5-5, 6-22
Energy Research and Development Administration (ERDA), 6-41
Engine Combustion Issues designated capability, 8-11
Engineering Sciences Experimental Facility, 8-14
engineering sciences
accomplishments, FY 2001, 5-12
ChileSPICE circuit simulator, 5-12
electromagnetics and plasma physics models, 5-12
GOMA multiphysics code, 5-12
microstructure-property material model, 5-12
polymer viscoelasticity, 5-12
research foundation, 2-7, 5-12
Enhanced Surveillance Campaign, 6-5, 6-9, 8-22
environment, safety, and health (ES&H), 8-18, 8-20, 8-27 to 8-29
Environment, Safety, and Health (ES&H) Manual, 6-19, 8-28
Environmental Education Outreach, 8-10
environmental impact statement, 8-29
environmental remediation, 6-21, 8-14
environmental restoration activities, 6-19, 8-17, 8-18, 8-20, 8-29
thics Office, 8-8
Expanding Your Horizons in Math and Science for Young Women Conference, 8-10
Explosive Components Facility, 8-12
explosives
destruction technologies, 5-7 to 5-8
detection technologies, 5-4
high-explosive radio telemetry system, 5-7
transportation of, 6-18
export control training program, 5-9
Exterior Communications Infrastructure Modernization, 8-22
extreme ultraviolet light technologies, 5-15
Extreme Ultraviolet Limited Liability Company (EUV LLC), 5-15

F

F-16, 5-7
F-22, 5-7
Facilities Engineering Command, 6-35
Facilities Investment Strategy, 8-20 to 8-22
facilities maintenance, Sandia, 8-19 to 8-20
Facilities Management and Operations Center, 5-14, 8-18
facilities plans, 8-19 to 8-20
Facility for Acceptance Calibration and Testing, 8-14
Family Science Nights, 8-10
Federal Aviation Administration, 2-7, 5-4, 5-17, 6-38, 7-10
Federal Emergency Management Agency (FEMA), 6-40
fire environments research, 8-16
fissile materials disposition, 6-14 to 6-15
fission technology, 6-26
Five-Year Plan for Waste Management Operations and Environmental Restoration, 8-20
foam, decontamination, 4-3, 5-8, 5-18, 6-37
Foreign Interactions Office, 8-27
Foreign Visits and Assignments Program, 8-27
Fossil Energy Program, 6-26 to 6-27
fossil energy research
downstream processing, 6-26
fossil fuel combustion technologies, 5-5 to 5-6
oil and gas technologies, 5-15 to 5-16, 5-18, 6-26 to 6-27
upstream exploration, production, and storage, 6-27
Freedom of Information Act, 8-25
fuel cells, 5-5, 6-23, 6-26
funding
All Other Federal Agencies, 9-13, 9-14
Arms Control and Nonproliferation, 9-6
Assistant Secretary for Defense Programs, 9-3, 9-5
Assistant Secretary for Energy Efficiency and Renewable Energy, 9-3, 9-8
Assistant Secretary for Environmental Management, 9-3, 9-7
Assistant Secretary for Fossil Energy, 9-4, 9-9
Basic Energy Sciences, 9-11
Biological and Environmental Research, 9-11
Coal, 9-9
Computational and Technology Research, 9-11
CRADA Partners/Royalties and Licensing, 9-13, 9-14
Department of Defense, 9-13, 9-14
Direct Support, 9-14
Directed Stockpile Work, 9-5
DOE Programs, All, 9-4, 9-12
Energy Conservation, 9-8
Energy Programs, 9-3, 9-14
Environmental Management (Defense), 9-7
Environmental Management (Nondefense), 9-7
Facilities and Infrastructure, 9-5
Fissile Materials Disposition, 9-7
Gas, 9-9
Indirect, 9-14
Intelligence/Counter Intelligence, 9-6
Isotope Production and Distribution Program, 9-10
Laboratories Total, 9-14
Laboratory Directed Research and Development, 9-14
Magnetic Fusion Energy, 9-11
Nonfederal Entities, 9-13, 9-14
Nonproliferation and Verification Research and Development, 9-6
Nuclear Energy Research and Development, 9-10
Nuclear Regulatory Commission, 9-13, 9-14
Nuclear Safeguards and Security, 9-6
Office of Energy Research, 9-4
Office of Fissile Materials Disposition, 9-3, 9-7
Office of Nonproliferation and National Security, 9-3, 9-6
Office of Nuclear Energy, 9-3, 9-10
Office of Science Programs, 9-11
Other DOE Locations/M&O Contractors, 9-13, 9-14
Other Energy, 9-8
Petroleum, 9-9
Program Direction, 9-5
Readiness in Technical Base and Facilities, 9-5
Safeguards and Security (Physical, Personnel, and Cyber), 9-5
Safeguards and Security (SO/Emergency Response/NEST), 9-5
Science and Technology Programs, 9-4, 9-14
Solar Energy, 9-8
Strategic Petroleum Reserve, 9-9
summary, 9-2
Weapons and Waste Cleanup Programs, 9-3, 9-14
Work for Non-DOE Sponsors, 9-13
funds-in agreements, 4-4, 5-17, 6-40
Fusion Energy Sciences Program, 6-27 to 6-28
fusion research
fusion energy sciences, 6-27 to 6-28
inertial confinement, 5-12 to 5-13, 6-6, 6-7
plasma materials testing, 8-13
Future Combat System, 5-7
Future Use Project Office, 8-18

G

Gamma Irradiation Facility (GIF), 6-8, 6-12, 8-13
gas leak detection technologies, 5-6
gas technologies, 5-15 to 5-16, 5-18

Gas Technology Institute, 6-26
gel capacitor, 5-2
General Accounting Office, 7-6
General Plant Projects Program, 8-18, 8-19 to 8-20
General Services Administration, 5-14, 6-40
Generation IV Nuclear Energy Systems Initiative, 6-26
Generator Interface Program, 6-18
Geomechanics Laboratory, 8-14
Geomechanics Research, Development, and Applications designated capability, 8-12
Geoscience Center Flow Visualization and Processes Laboratory, 8-12
geosciences research, 6-32, 8-12
geothermal systems, 6-23
Gesellschaft für Schwerionenforschung, Darmstadt, Germany, 5-14
Gioconda, Thomas (Air Force Brigadier General), 5-12
global climate change research, 6-32 to 6-33
Global Nuclear Futures model, 4-2
Global Nuclear Materials Management Initiative, 6-18, 7-5, 7-6, 7-11
Global Positioning System (GPS) satellites, 5-5, 6-15
Go Figure contest, 6-14
Goddard Space Flight Center, 6-38
GOMA code, 5-12
Government Performance and Results Act, 2-2
Grand Challenge, 6-43
Greater Confinement Disposal, 5-7

H

Habiger, Eugene (General), 5-4
Hands-On/Minds-On, 8-9
Hanford Site, 4-2, 6-20, 7-13, 7-14
HERMES III. *See* High-Energy Radiation Megavolt Electron Source (HERMES) III
heterojunction bipolar transistors (HBTs), 5-17
High Energy Density Physics Program, 2-7
High-Energy Radiation Megavolt Electron Source (HERMES) III, 6-8, 6-11
High-Temperature Drilling/Logging Instrumentation, 8-12
Highly Enriched Uranium Transparency Program, 6-17
History Program, 8-25
HoldFast, 8-12
Hot Cell Facility, 6-26
Hound sampling/preconcentration system, 5-4
HR Queries, 8-8
Hubble telescope, 6-44
Human Resources, 8-2, 8-3 to 8-8
Human Resources Customer Satisfaction Survey, 8-2
Human Resources Strategies and Services function, 8-2
hybrid electric vehicles, 5-5
hydrogen reduction technologies, 5-3
hydrogen storage and utilization research, 6-23

I

Idaho National Engineering and Environmental Laboratory (INEL), 6-27
Immune Buildings teams, 6-37
In-Ground Storage Vault, 5-14
Inertial Confinement Fusion Ignition and High Yield Campaign, 2-7, 6-5, 6-7 to 6-10, 6-11, 6-36
INet, 7-12
Information Design Assurance Red Team, 5-8
information resources management, 8-23
information sciences, 5-11
Information Technology/Computer Science Retraining, 5-9, 8-5
Infrastructure Council, 8-18
Infrastructure strategic objective, 3-5, 4-4
  accomplishments, FY 2001, 5-14 to 5-15
  goals, intermediate, 3-5
  milestones, FY 2002, 4-4
Initiatives for Proliferation Prevention Program, 6-16 to 6-17, 6-39, 7-7
Innovative Treatment and Remediation Demonstration, 6-20
Institute for Scientific Information (ISI), 6-42
Institute of Physics and Power Engineering (Obninsk, Russia), 6-16, 7-6
integrated circuits, 2-2, 2-6, 5-2, 5-9, 5-11, 5-18, 6-7, 6-11, 7-1
Integrated Information Services, 8-23
Integrated Intrusion Detection and Access Control, 7-10
integrated microsystems, 2-2, 2-6, 6-6, 6-9, 6-44 to 6-45, 7-1 to 7-4. *See also* microelectronics and photonics sciences
Integrated Microtechnologies Laboratory, 8-22
Integrated Nuclear Materials Monitoring System, 7-10
integrated nuclear materials stewardship plan, 6-10
Integrated Safeguards and Security Management Program, 8-27
Integrated Safety and Security Management Program, 8-25
Integrated Safety Management System, 8-27 to 8-29
Intelligent Systems and Robotics Center, 6-15, 8-15
International Arms Control Conference, 6-40
International Atomic Energy Agency (IAEA), 6-16, 6-37, 6-38, 6-38 to 6-39, 7-4, 7-5
International Center for Excellence in Regulatory Science, 6-21
International Energy Agency, 6-29
International Programs Building, 7-8
International Science and Technology Center, 6-38, 6-39, 7-7
International Security Program, 6-38
Internet security, 5-6, 7-10
internship programs, 6-13, 8-2, 8-5, 8-6, 8-9, 8-25
Ion Beam Analysis Facility, 5-9, 6-27
Ion Beam Materials Research Laboratory, 8-15
isotope production and distribution program, 6-26

J

Japan Nuclear Cycle Development Institute, 5-17
Japanese Institute of Space and Astronautical Science, 6-41
Jet Propulsion Laboratory, 6-38
Johnson Space Center, 5-8, 6-38
Joint Computational Engineering Laboratory, 8-21 to 8-22
Joint Strike Fighter, 5-7, 6-44
Joint Virtual Battlespace, 5-7

K

Kansas City Plant, 5-1, 5-3, 6-5
Kauai Test Facility, 6-19, 6-36, 8-1, 8-16
Kennedy Space Center, 5-8, 6-38
Kirtland Air Force Base, 5-14, 5-16, 5-18, 8-14, 8-16, 8-18, 8-22, 8-23, 8-29
Kirtland Federal Complex, 8-18
Knowledge Management Program, 6-13, 8-5
Kokole Point launch site, 8-16

L

labor relations, 8-1, 8-7
Laboratories Leadership Team, 8-8
Laboratory Directed Research and Development (LDRD), 6-41 to 6-44, 7-5
  awards, 6-42
  collaborations, 6-43
  emerging national security threats, 4-1
  funds invested, 6-42
  intellectual property performance, 6-42
  Nuclear Weapons Program, 4-1
  patents, 6-42
  process, 6-42
  publications, 6-42
  research projects, 6-43 to 6-44
Laboratory Director, 6-41
Laboratory Leadership Team, 2-2, 3-1
  strategy, 6-41
Laboratory Standards Department, 8-28
laser applications
  ablator materials characterization, 5-13
  beam shaping technology, 5-18
  combustion research, 6-29
  dynamic range imager sensor, 5-8
  gas leak detection, 5-6
  lidar, 5-4
  OMEGA laser, 5-13
  optical bullets, 5-8
  remote detection, 7-5
  ultraviolet vertical-cavity surface-emitting laser (VCSEL), 5-11, 5-12, 5-17
  Z-Beamlet, 5-13 to 5-14, 6-7
LASNEX code, 5-13
Lawrence Berkeley National Laboratory (LBNL), 5-15, 6-27
Lawrence Livermore National Laboratory (LLNL), 2-7, 5-3, 5-13, 5-15, 6-1, 6-28, 7-4, 8-7, 8-20
LDRD funding, 6-41
Leadership Academy for Science Education Reform, 6-40
legacy waste, 6-12, 6-19, 8-29
Legacy Waste Management Project, 6-12
Legal Division, 8-28
licenses, 5-17 to 5-18
lidar technology, 4-2, 5-4, 6-20, 6-33
life-cycle engineering and manufacturing, 2-2, 6-43
LIGA Technologies Facility, 8-22
LIGA technology, 5-3, 5-10, 6-6, 6-10, 8-22
light detection and ranging (lidar) sensor, 4-2, 5-4, 6-20, 6-33
lithium-ion batteries, 5-5
lithography, 5-3, 5-10, 6-6, 6-10
Lockheed Martin/Sandia Shared Vision Program, 4-4
Los Alamos National Laboratory (LANL), 2-7, 5-13, 5-14, 6-1, 6-5, 6-6, 6-15, 6-21, 6-27, 6-32, 6-42, 7-4, 7-5, 7-8, 8-7, 8-20, 8-23
Low Emission Partnership, 6-25
Low-Dose Gamma Irradiation Facility, 8-13
Lurance Canyon Burn Site, 8-16

M

Major Renovation Program, 8-18
Manhattan Project, 6-1
Manufacturing and Industrial Capabilities, 8-12
Manufacturing Development Engineering Program, 5-2 to 5-3
Manufacturing Technologies Center, 8-15
Marshall Space Flight Center, 6-38
Materials and Process Diagnostics Facility (Advanced Materials Laboratory), 8-15
materials and process science
  accomplishments, FY 2001, 5-9 to 5-11
  adhesion research, 6-30
  ceramics, 5-10, 6-29 to 6-30
  dielectric materials, 5-10
  energetic particle synthesis, 6-30
  materials aging and reliability subprogram, 2-5
  materials processing subprogram, 2-5
  scientifically tailored materials subprogram, 2-5
  microsystems, nickel-based, 5-10
  nanofabrication technology, 6-30
  nanomaterials, 6-6
  nanometer-sized clusters, 6-30
  nanoscience, 6-31 to 6-33
  nanostructure fabrication, 5-9
  research foundation, 2-4 to 2-5
  solid state transport processes, 5-10
  structural defects and impurities, 6-30 to 6-31
  superlattices, 6-30
  synthesis and processing, 6-31
  thin films, 5-9, 6-30
  thin-surface layers, 6-30
Materials and Process Science designated capability, 8-12
materials control, 3-3, 4-2. *See also* nonproliferation and materials control
materials processing programs, 6-24
Materials Protection, Control, and Accounting (MPC&A) Program, 5-4, 6-16, 6-38, 7-6
Materials Readiness Campaign, 6-10 to 6-11
Materials Sciences Program, 6-29 to 6-32
  materials defects and impurities, 6-30 to 6-31
  nanoscience, 6-31 to 6-33
  scientifically tailored materials, 6-29 to 6-30
  synthesis and processing, 6-31
Mayak Production Association, 5-4, 6-16, 7-6
Mechanical Test and Evaluation Facility, 8-15
MELCOR code, 5-6
memoranda of understanding, 5-18, 6-39, 6-40, 7-12
MEMX Inc., 5-17
Microchemlab, 4-2, 5-12, 6-21, 6-26, 6-37, 6-45
microchip technologies, 5-15
microcombustor, 6-44 to 6-45
microelectromechanical systems (MEMS), 2-6, 5-17, 6-7
microelectronics, radiation-hardened, 2-2
microelectronics and photonics sciences
  accomplishments, FY 2001, 5-11 to 5-12
  aluminum gallium indium nitride devices, 5-12
  distributed Bragg reflector, 5-11
  Microchemlab, 4-2, 5-12, 6-21, 6-26, 6-37, 6-45
  semiconductors, 5-11, 5-12, 5-15, 6-7, 6-11, 6-29, 6-30
  photonic crystals, three-dimensional infrared, 5-12
  polychromator, 5-12
  research, 2-6
  research foundation, 2-6, 5-11 to 5-12
  ultraviolet vertical-cavity surface-emitting laser (VCSEL), 5-11, 5-12
Microelectronics Development Laboratory, 4-2, 6-5, 6-11, 7-3, 7-4, 8-14
microprocessors, 5-15
microscopy, 5-10, 5-11
microsystems. *See* integrated microsystems
Microsystems Advanced and Exploratory project, 5-3
Microsystems and Engineering Sciences Applications (MESA), 2-6, 3-3, 4-2, 5-3, 5-11, 6-3, 6-11, 6-13, 6-43, 7-1, 7-4, 8-20, 8-21 to 8-22, 8-23, 8-25
Microsystems Infrastructure Readiness Project, 6-13

Microsystems Processing Laboratory, 6-13
Ministry for Atomic Energy of the Russian Federation (Minatom), 7-6
Mission Council, 6-45
mission, nuclear weapons, 3-3
Model Validation and System Certification Test Center, 8-21
modeling and simulation
ChileSPICE circuit simulator, 5-12
combustion modeling program, 6-29
critical infrastructures, 7-9, 7-10 to 7-11
electric power grid reliability, 6-22
electromagenetics and plasma physics, 5-12
geophysics research, 6-32
microstructure-property material model, 5-12
model validation, 6-5, 6-6, 6-7, 6-8 to 6-9, 6-11, 6-12, 6-13
nuclear weapons, 2-2, 2-6, 4-1, 5-11, 5-12, 6-6, 6-8, 6-9 to 6-10
structural dynamics of bolted interfaces, 5-12
transuranic waste system, discrete-event modeling, 6-22
W76 arming, fuzing, and firing model, 5-11
Modular Integrated Monitoring System, 7-10
Monitoring Technologies Department, 8-14
Multispectral Thermal Imager (MTI) satellite, 5-5, 6-15, 7-5

N

Nanofabrication and Integration Laboratory, 8-23
nanoscience, 6-31 to 6-33, 7-8 to 7-9, 8-23
Nanoscience Research Center (NSRC), 6-32, 7-8
nanostructures, 5-9, 5-10, 6-6
NASA. *See* National Aeronautics and Space Administration (NASA)
National Academy of Sciences, 6-21
National Aeronautics and Space Administration (NASA), 5-5, 5-8, 6-33, 6-38, 6-44, 7-10
National Association of Colleges and Employers, 8-7
National Atomic Museum, 5-9, 8-9, 8-25
National Center for Photovoltaics, 6-23
National Defense Authorization Act, 6-41
National Defense Electronics Partnership, 7-3
National Energy Strategy, 6-22
National Environmental Policy Act (NEPA), 8-20, 8-28, 8-29
National Historic Preservation Act, 8-25
National Hypersonic Wind Tunnel Program, 6-35
National Ignition Facility, 5-13, 5-14, 6-6, 6-7
National Infrastructure Simulation and Analysis Center, 7-11
National Institute of Justice, 6-40
National Institutes of Health, 6-40
National Museum of Nuclear Science and History, 5-9
National Nuclear Security Administration (NNSA). *See also* DOE Defense Programs
emergency response programs, 6-12, 6-14
Materials Protection, Control, and Accounting (MPC&A) Program, 5-4, 6-16, 6-38, 7-6
Nuclear Materials Stewardship plan, 6-10
Office of Defense Nuclear Nonproliferation, 6-15 to 6-17, 7-4, 7-7, 8-23
Office of Fissile Materials Disposition, 6-14 to 6-15
Office of Nonproliferation and National Security, 5-5, 8-14
Office of the Chief Defense Nuclear Security, 6-17
Office of the Deputy Administrator for Defense Program, 6-1 to 6-10
Office of Transportation Safeguards (OTS), 5-3, 6-18
Second Line of Defense Program, 6-38
Security Systems Engineer, 4-2
Stockpile Management Program, 8-20
Stockpile Stewardship Program, 8-20
National Renewable Energy Laboratory (NREL), 6-23, 6-30
National Science Foundation, 2-7, 6-40
national security. *See also* nonproliferation and materials control
biotechnology, 2-4
chemical/biological threat reduction, 5-6, 6-17
critical infrastructures, 3-4, 4-2 to 4-3, 7-9 to 7-10
electric power grid reliability, 6-22, 7-10
emerging threats, 3-1 to 3-3, 3-4, 4-3
Internet, 5-6, 7-10
materials protection, control, and accounting, 6-16
physical security research and development, 6-17
satellite imaging technologies, 3-3, 5-5, 7-1, 7-5
security systems design, 6-17
transportation, 6-38
water resources protection, 3-4, 6-39, 7-14 to 7-15
National Security Agency, 6-40
National Security Engineering Program, 6-14
National Solar Thermal Test Facility, 6-23, 8-11, 8-12
National Solid State Lighting Initiative, 5-11
National Transuranic Waste Program, 6-22
Navajo Electrification Demonstration Program, 7-12
Navajo Nation, 5-18, 7-12 to 7-13
Navajo Nation Environmental Protection Agency, 7-12
Navajo Tribal Utility Authority partnership, 7-12
Naval Air Systems Command, 6-35
Naval Air Warfare Center, 6-35
Naval Command, Control, and Ocean Surveillance Center, 6-35
Naval Research Laboratory, 5-13
Navy Fuel Storage Sites (Russia), 7-6
Navy Pacific Missile Range, 6-19
Navy Reserve, 6-36
Nellis Air Force Base, 8-16
Network Reliability Task Force, 5-11
Neutron Generator Production Facility, 5-2, 6-12, 8-22
neutron generators, 4-2, 4-3, 5-2, 5-12, 8-22
Nevada Test Site, 5-7, 5-14, 6-5, 6-13, 6-19, 6-25, 8-20
Nevada Test Site U1a Experimental Facility, 6-5, 6-6
New Hire web site, 8-8
New Mexico Environment Department, 8-29
New Mexico Laboratory Partnership with Small Business Tax Credit Act, 5-18
New Mexico Small Business Assistance Program, 5-18
Next Generation Space Telescope, 6-44
Nonactinide Isotopes and Sealed Sources (NISS) Management Group, 6-22
nonactinide isotopes and sealed sources (NISS), 6-22
Nonnuclear Readiness Campaign, 6-5, 6-10
Nonnuclear Reconfiguration Program, 8-22
nonproliferation and materials control, 7-4. *See also* arms control; terrorism, countering
Advanced Modular Tag, 5-4
Advanced Ultraviolet Remote-Sensing Applications (AURA) Program, 5-4 to 5-5
fissile materials, 6-14 to 6-15
Hound explosives detection portal, 5-4
Initiatives for Proliferation Prevention Program, 6-16 to 6-17
international cooperation, 7-6
Materials Protection, Control, and Accounting (MPC&A) Program, 5-4, 6-16, 7-6, 6-38
Nuclear Explosion Monitoring Knowledge Base, 5-4
nonproliferation and verification research and development, 6-15 to 6-16
Operation America Program, 5-4
radioactive materials storage protection, 5-4
radionuclide monitoring in Central Asia, 5-4
satellite imaging technologies, 3-3, 5-5, 7-1, 7-5
treaty verification technologies, 5-4
water quality project, South Asia, 5-4

Nonproliferation and Materials Control strategic objective, 3-3, 4-2
accomplishments, FY 2001, 5-3 to 5-5
LDRD support for, 6-41, 6-43
milestones, FY 2002, 4-2
nonproliferation and verification research and development, 6-15 to 6-16
North Atlantic Treaty Organization, 6-37
Nuclear Cities Initiative, 6-17, 6-39, 7-7
nuclear deterrence, 6-2, 6-9
Nuclear Emergency Search Team/Joint Technical Operations Team, 6-14
Nuclear Energy Initiative, 7-11 to 7-12
Nuclear Energy Plant Optimization Program, 6-25
Nuclear Energy Technologies program, 6-26
Nuclear Explosion Monitoring Knowledge Base, 5-4
Nuclear Facility Maintenance Implementation Plan, 8-19
nuclear fuel cycle, 7-5, 7-7, 7-11
nuclear materials management, 6-22
Nuclear Materials Focus Area, 6-22
nuclear power
Nuclear Energy Initiative, 7-11
research and development, 6-25 to 6-26
safety, 6-37, 7-10
safety research, 5-6
space fission technology, 6-26
nuclear reactors, 8-17
Annular Core Research Reactor (ACRR), 5-12, 6-26
containment vessel model, 5-5
decontamination and decommissioning, 7-13
high-temperature gas-cooled, 7-11
International thermonuclear experimental reactor, 6-28
next generation, 7-5
Pulsed Reactor, 5-14, 8-13
reactor chamber technology, 6-28
safety, 6-25, 6-37
space fission technology, 6-26
tokamak fusion test reactor, 6-28
Underground Reactor Facility, 5-14, 8-21
Nuclear Regulatory Agency, 5-6
Nuclear Regulatory Commission (NRC), 5-5, 5-6, 5-7, 6-37
Nuclear Survivability Campaign, 2-7, 6-5, 6-7 to 6-8
nuclear waste. *See* radioactive waste
nuclear weapons. *See also* stockpile
aging, 6-2, 6-9, 7-2
certification, 6-5 to 6-6, 6-6 to 6-7, 6-9
components, 6-1, 6-43, 7-2
dismantlement, 6-5, 8-17
field support, 6-1 to 6-2
life-cycle engineering and manufacturing, 5-12, 6-2
materials properties research, 6-6
modeling and simulation, 2-2, 2-6, 4-1, 5-11, 5-12, 6-6, 6-8, 6-9 to 6-10
performance, 6-9
pulsed power sciences, 2-7
stewardship. *See* stockpile: stewardship
storage, 6-1, 6-10 to 6-11
surety, 2-2, 6-9
survivability, 6-7 to 6-8
testing, hostile environments, 5-11
transportation, 6-1, 6-18
Nuclear Weapons Engineering and Product Support Complex, 8-22
Nuclear Weapons Information Environment, 4-1
Nuclear Weapons Leadership Council, 4-1, 5-1, 5-2
Nuclear Weapons Program, 4-1, 6-7
structure, 6-3
Nuclear Weapons Strategic Business Unit (SBU), 4-1, 5-1, 5-14, 8-19
Nuclear Weapons strategic objective, 4-1, 6-43
accomplishments, FY 2001, 5-1 to 5-3
LDRD support for, 6-41
milestones, FY 2002, 4-1 to 4-2

O

Oak Ridge National Laboratory, 6-28
occupational medicine programs, 8-3
Office of Aviation Research, 7-10
Office of Naval Research, 6-35, 6-36
Office of Onsite Inspections, 6-37
oil and gas technologies, 5-15 to 5-16, 5-18, 6-26 to 6-27
Ombuds
team, 5-9
Corporate Ombuds Office, 8-8
OMEGA laser, 5-13
One-Year-On-Campus Program, 8-6
Operation America Program, 4-2, 5-4
Operations of Facilities, 6-11 to 6-12
optical bullets, 5-8
optoelectronics, 2-6
Oracle software applications, 8-6
organic hydrogen getters, 5-3
organization chart, 9-15
Orpheus Site, 8-16
outreach programs, 8-8 to 8-11

P

Pacific Fleet Command, 6-35
Pacific Missile Range, 8-16
Pacific Northwest National Laboratory, 7-4
Pacific Rim, 4-4
Pantex Plant, 5-1, 6-5, 6-11, 8-1, 8-22
Partnership for a New Generation of Vehicles, 6-25
partnerships, 2-4, 3-5, 4-4, 6-27, 8-17. *See also* Partnerships strategic objective; technology partnerships
cooperative research and development agreements (CRADAs), 5-3, 5-16 to 5-17, 6-25, 6-29, 6-31, 6-40
designated capabilities, 8-11 to 8-14
funds-in agreements, 4-4, 5-17, 6-40
industry collaborations, 6-24 to 6-25
LDRD Program, 6-42
memoranda of understanding, 5-18, 6-39, 6-40, 7-12
nonfederal entities, 6-40 to 6-41
Partnerships strategic objective, 3-5, 4-4
accomplishments, FY 2001, 5-15 to 5-16
goals, 3-5
milestones, FY 2002, 4-4
People strategic objective, 3-4, 4-3, 8-2
accomplishments, FY 2001, 5-8 to 5-9
goals, 3-4
milestones, FY 2002, 4-3
Performance Assessment Institute, 6-21
performance assessment technologies, 5-7, 6-21 to 6-22, 7-13 to 7-14
Phase One Engineering Team, 6-36
photonic lattice applications, 5-11 to 5-12
Photovoltaic Sciences Facility, 8-15
Photovoltaic Systems Support designated capability, 8-13
photovoltaics, 5-5, 6-23 to 6-24
Physical and Chemical Sciences Center, 8-23

Physical and Chemical Sciences designated capability, 8-13
physical infrastructure, Sandia, 5-14 to 5-15, 8-16 to 8-23
Pit Reuse Project. *See* Submarine-Launched Warhead Protection Program Pit Reuse Project
plasma materials research, 6-27 to 6-28, 8-13
Plasma Materials Test Facility, 6-27, 8-15
Plasma Materials Testing designated capability, 8-13
Plutonium Management and Disposition Agreement, 6-14
Poco Sprytron design, 8-14
polychromator, 5-12
President's Commission on Critical Infrastructure Protection, 6-39
Primary Certification Campaign, 2-7, 6-5 to 6-6
Primary Standards Laboratory, 6-12, 8-13, 8-15
Privacy Act, 8-25
Processing and Environmental Technology Laboratory, 5-15
Production Division, 8-25
Production Workers Metal Trades Council, 8-7
Program Director Leadership Team, 4-1
Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT), 6-17
Program Management and Operations Office for Theater Missile Defense, 6-36
Program Readiness, 6-11, 6-12 to 6-13
Project Alberta, 6-1
Project Roadrunner, 8-10
Project Trinity, 6-1
Pulsed Power and System Validation Diagnostics Facility, 8-15
pulsed power sciences
  ablator material characterization, 5-12
  accomplishments, FY 2001, 5-12 to 5-14
  Advanced Radiography Program, 5-14
  EMPHASIS computational tools, 5-12, 5-14
  radiation symmetry, 5-12
  radiographic accelerator development, 5-14
  segmented rail phased induction motor (SERAPHIM), 5-14
  research foundation, 2-7, 6-7 to 6-10, 6-43
  Z Accelerator, 2-7, 5-13, 6-7, 6-8, 6-12
  Z-Beamlet, 5-13 to 5-14, 6-7
Pulsed Power Technology Project, 6-13
Pulsed Reactor, 5-14, 8-21
Pulsed Reactor Capabilities, 8-13
Pulsed Reactor Facility, 6-8, 8-13

Q

QUICKSILVER code, 5-13

R

Radiant Heat Facility, 8-16
Radiation Detector Analysis Laboratory, 8-15
Radiation Detector Test Facility, 8-15
Radiation Metrology Laboratory (RML), 6-12, 8-13
Radiation Sensors Technology project, 6-14
radiation-hardening technologies, 2-6, 6-7 to 6-8, 6-11
radioactive materials, transportation, 5-3
radioactive waste, 4-4
  disposal, 5-17, 6-21 to 6-22
  handling of, 8-17
  immobilization technologies, 5-10, 7-13
  legacy waste, 6-12, 6-19, 8-29
  processing, 5-6
  sequestration technologies, 7-14
  spent nuclear fuel, 5-7
  transportation safety, 5-3, 5-7
  transuranic waste, 5-7, 6-21 to 6-22
Radiographic Integrated Test Stand (RITS), 5-14
Radiological Assistance Program, 6-14
Rapid Reactivation project, 8-22
Rapid Terrain Visualization Interferometric Synthetic Aperture Radar, 5-7
Readiness in Technical Base and Facilities, 6-3, 6-4, 6-7, 6-11 to 6-15, 8-9, 8-20
Recapitalization of Neutron Generator Facility, 8-22
Recorded Information Management Program, 8-25
records management, 8-25
recycling, 5-14, 5-15, 6-18, 6-19, 6-22
Red Storm 20-teraflops computer, 4-1
Remote Telerobotic Vehicle for Intelligent Remediation (RETRVIR), 8-12
remote-sensing applications. *See also* satellite technologies
  thin-skin deployable mirrors, 6-44 to 6-45
  unmanned aerospace vehicle, 4-2, 5-4
  weapons of mass destruction, detecting, 5-4 to 5-5
renewable energy programs, 6-22
research foundations, 2-2, 2-4 to 2-7, 5-9, 6-22, 6-43
  computational and information sciences, 2-5 to 2-6, 5-11
  engineering sciences, 2-7, 5-12
  materials and process science, 2-4 to 2-5, 5-9 to 5-11
  microelectronics and photonics sciences, 2-6, 5-11 to 5-12
  pulsed power sciences, 2-7, 5-12 to 5-14
Resource Conservation and Recovery Act, 6-19
Resource Conservation and Recovery Act (RCRA), 6-18
Restoration Program, 8-18
Restricted Network, 5-11
RETRVIR. *See* Remote Telerobotic Vehicle for Intelligent Remediation (RETRVIR)
Rio Grande Corridor Initiative, 6-13
risk assessment, 6-20, 6-21, 6-22, 6-39, 7-12, 8-14
River Protection Project, 7-13
robotics, 5-5, 5-7, 6-10, 6-11, 6-14, 6-15, 6-20, 8-12, 8-15, 8-17
Rocket Reader Literacy Program, 8-9
Russian nuclear submarine dismantlement, 5-6
Russian Federation Navy, 6-16
Russian Institute of Automatics, 6-37
Russian Ministry of Atomic Energy (Minatom), 6-16, 6-17
Russian Ministry of Defense, 6-37
Russian Navy, 7-6

S

Safeguards and Security Program, 5-14, 8-26 to 8-27
Safeguards Transporter, 6-18
SALINAS code, 5-11
Sandia facilities investment strategy, 8-20
Sandia infrastructure. *See also* Infrastructure strategic objective
  physical infrastructure, 5-14 to 5-15, 8-16 to 8-23, 8-17 to 8-19
  security, 8-26 to 8-27
Sandia octahedral molecular sieves (SOMS) powder, 5-10
Sandia Orpheus Site, 8-16
Sandia Ultraplanar Multilevel MEMS Technology (SUMMiT), 5-17 to 5-18
Sandia Volunteer Program, 8-10
satellite technologies, 3-3
  Global Positioning System (GPS), 5-5
  Multispectral Thermal Imager (MTI) satellite, 5-5, 7-1, 7-5
Saturn accelerator, 6-11
Saturn x-ray source, 6-8
Savannah River Site, 6-5
SBU. *See* strategic business units (SBUs)
School-to-World Career Fair, 8-10
Science and Technology Center of Ukraine, 6-38, 6-39
Science and Technology Park, 5-18
Science and Technology Strategic Management Unit (SMU), 4-3, 6-45

Science and Technology strategic objective, 3-4, 4-3, 6-43. *See also* research foundations
accomplishments, FY 2001, 5-9 to 5-14
goals, 3-4
milestones, FY 2002, 4-3
Science Bowl, 8-10
Science Education and Outreach Program, 8-9
Science is Everywhere Summer Camp, 8-9
"science with the mission in mind", 2-1, 2-2
science-based stockpile stewardship, 6-2. *See also* stockpile: stewardship
Scientific and Technical Information Management Program, 8-25 to 8-26
Secondary Certification and Nuclear Systems Margin Campaign, 2-7, 6-5, 6-6 to 6-7, 6-7, 6-12, 6-13
Secretary of Energy, 6-25
SecureNet, 5-11
Security Matrix Project, 5-2
Security Police Facility Command Center, 5-14
Security Systems Engineer, 4-2
segmented rail phased induction motor (SERAPHIM), 5-14
semiconductors, 5-11, 5-12, 5-15, 6-7, 6-11, 6-29, 6-30
sensor technologies
drilling applications, 6-23
environmental applications, 6-20, 6-25, 7-15
integrated microsystems, 2-6
laser dynamic range imager sensor, 5-8
microcombustor, 6-44 to 6-45
microsensors, 6-6
nonproliferation activities, 6-15 to 6-16
satellite technologies, 3-3, 5-5, 7-1, 7-5
robotics, 6-44
sulfur dioxide emissions prototype, 5-5 to 5-6
separation technologies, 6-25, 6-26
SERAPHIM. *See* segmented rail phased induction motor (SERAPHIM)
Seventh International School on Disarmament and Research on Conflicts (ISODARCO) Beijing Seminar on Arms Control, 7-5
Sevmash Submarine Building Plant, 7-6
Shock Technology and Applied Research Facility, 8-16
Short-Pulse Laser Program, 5-8
silicon surface micromachining technology, 5-11
Site-Wide Environmental Impact Statement (SWEIS), 8-29
small business, 5-18, 8-10 to 8-11
SMU. *See* strategic management units (SMUs)
Society for Human Resource Management, 8-7
software
Archimedes, 6-43 to 6-45, 8-11
CHT software package, 8-11
component-based architecture, 2-6
Design Analysis Kit for Optimization (DAKOTA) software, 5-11
nonlinear viscoelastic modeling software, 5-16
quality, 8-13, 8-23 to 8-26
software infrastructure research, 6-28
Software Engineering Institute, 8-24
Software Improvement Initiative, 8-24
Software Management Program, 8-23 to 8-24
Software Quality Engineering Support designated capability, 8-13
Software Quality Working Group, 8-24
Software Subcouncil, 8-24
Soil and Sediment Transport designated capability, 8-13
Soil and Sediment Transport Laboratory, 7-14
solar energy, 5-5, 6-23 to 6-24
Soldier and Biological Chemical Command, 6-35
SOMS. *See* Sandia octahedral molecular sieves (SOMS) powder
Soviet Union, former, 5-4, 6-15, 6-16, 6-36, 6-39, 7-6, 7-7, 7-8, 7-11, 7-14
Space and Missile Defense Command, 6-35
Space and Missile Systems Center, 6-34
Space Management Program, 8-18
Space Shuttle, 5-5, 5-8
Special Masters Program, 8-5
special nuclear material (SNM), 5-4, 6-15
special nuclear materials, 6-6, 6-12, 6-18, 6-14, 6-38
Special Projects, 6-13 to 6-14
spent nuclear fuel, 5-7
Sphinx Accelerator, 6-8, 6-11 to 6-12
staff composition, 8-1
staffing, 4-3, 8-6
Staffing Plan, 4-3
Stage Right hazardous material handling vehicle, 8-12
Standard Agent Architecture II "agent-in-a-box", 5-6
Stennis Space Center, 6-38
stockpile, 5-1 to 5-3, 6-45. *See also* Directed Stockpile Work; nuclear weapons
aging of, 6-2, 6-9, 7-2
certification, 2-7
components, 6-1, 7-1 to 7-4
critical needs, 7-3
evaluation, 6-5
field training, 6-5
maintenance, 6-3
mission to maintain, 3-3
production support, 6-5
refurbishment, 5-1, 5-3, 6-7, 6-9 to 6-10, 7-2
research and development, 6-3
sampling and testing, 6-1, 6-2, 6-5
secondary performance, 6-7
stewardship, 6-2, 6-7, 6-8, 6-11, 6-12 to 6-13
surveillance, 6-2, 6-9
Stockpile Life Extension Plan, 3-3
Stockpile Life Extension Program, 2-7, 4-2, 5-1, 5-2, 6-3, 6-7, 6-10, 6-11, 7-3, 8-21
Stockpile Stewardship Program, 2-5, 2-6, 2-7, 5-2
Storm Drain, Sanitary Sewer, and Domestic Water System, 8-21 to 8-22
Strategic Arms Reduction Treaty, 6-5
strategic business units (SBUs), 2-2, 3-5, 4-3, 4-4, 6-28, 6-45, 8-17, 8-23. *See also individual strategic business units*
Strategic Environmental Research and Development Program, 6-35
strategic management units (SMUs), 2-2, 3-5, 4-3, 4-4, 8-17
strategic objectives, 2-1, 2-2, 6-41, 6-45
alignment with DOE, 3-1, 3-2
Energy and Critical Infrastructure, 5-5, 5-6, 5-7
Emerging Threats, 5-7, 5-8
Infrastructure, 5-14, 5-15
Nonproliferation and Materials Control, 5-3, 5-4, 5-5
Nuclear Weapons, 5-1, 5-2, 5-3
Partnerships, 5-15, 5-16, 5-17, 5-18
People, 5-8, 5-9
Science and Technology, 3-4, 4-3, 6-43. *See also* research foundations
Strategic Plan, 2-1, 3-1
Strengthening Quality in Schools Program, 8-9
Submarine-Launched Warhead Protection Program Pit, 5-3
Subsurface Environment designated capability, 8-13
Subsurface Flow and Transport Laboratory, 6-20
Summer Technical Student Intern Program, 8-2
SUMMiT. *See* Sandia Ultraplanar Multilevel MEMS Technology (SUMMiT)
SunLab, 6-23
supercomputers, 5-11, 5-12, 6-8, 6-28, 8-17
ASCI Red teraflop, 5-11, 6-8
Red Storm 20-teraflops, 4-1
supercomputing, 2-5 to 2-6. *See also* computing: massively parallel computation; modeling and simulation
superlattices, 6-30

Supervisory Control and Data Acquisition system, 6-22
Supplier Relations Program, 8-10, 8-11
surety. *See also* national security
critical infrastructure, 7-9 to 7-10
nuclear weapons, 6-9
surety science, 2-2 to 2-4
Surety Assessment Center's Software Team, 8-24
surety science, 2-2 to 2-4
Surface Warfare Center, 6-35
Surplus Facilities Inventory Assessment, 8-20
SWEIS. *See* Site-Wide Environmental Impact Statement (SWEIS)
Switch Tube Technology, 8-14
Synthesis and Processing Center, 6-31
Systems Engineering Subcouncil, 8-24

T

Tank-Automotive and Armaments Command, 6-35
Technical Area I, 8-21, 8-22, 8-25
Technical Area II, 8-25
Technical Area III, 6-11, 8-21
Technical Area IV, 6-12
Technical Area V, 6-12, 8-19
Technical Women of the Future, 5-9
technology deployment centers/user facilities, 8-14 to 8-16
technology partnerships
honeycomb structures, bonded repair of, 5-17
chemical/biological threat reduction, 5-6
Cold Spray, 5-16
combustion research, 6-24
energy efficiency, 5-17
energy storage systems technologies, 6-22 to 6-23
heterojunction bipolar transistors (HBTs), 5-17
radioactive waste disposal site characterization, 5-17
hydrogen getter, 5-16
integrated sensing, cutting, and contour-generating technologies, 5-16
memory and logic technologies, 5-17
microprocessor production using extreme ultraviolet, 5-15
microwave system research, 5-16
nanosciences, 6-31
nonlinear viscoelastic modeling software, 5-16
oil and gas technologies, 5-5, 5-15 to 5-16
photovoltaics, 5-5
structural dynamics models, 5-16
transportation cask structural analyses, 5-17
vertical-cavity surface-emitting laser (VCSEL), 5-17
vulnerability assessment methodology of the water supply, 5-17
weapons electronic assembly, 5-16
Technology Readiness Program, 6-36
telemetry technologies, 4-2, 5-2, 5-7, 5-18, 6-23
terrorism, countering, 4-3, 6-38, 6-39, 6-40, 6-41, 6-44
airport and air travel security, 5-6, 6-17, 6-38, 7-10
chemical/biological threat reduction, 5-4, 5-8, 6-17
critical infrastructure surety, 7-9 to 7-10
Operation America Program, 4-2, 5-4
Test and Evaluation Command, 6-35
Test Capabilities Revitalization project, 8-21
Test Capability Renovation, 6-11
Thermal Test Facilities, 8-16
thin films, 5-9, 6-24, 6-30, 6-31
thin-skin deployable mirrors, 6-44 to 6-45
Thunderbird Awards, 8-10
tokamak fusion research, 6-28
Tomahawk missile, 6-36
Tonopah Test Range, 6-11, 6-19, 8-1, 8-16
Top Recruits, 8-6, 8-8
Total Rewards Annual Review booklet, 8-3
Total Rewards Strategy, 8-2, 8-3, 8-5
Trades Training Program, 5-9
Training and Doctrine Command, 6-35
Training Education and Development System (TEDS), 8-8
transparency issues, 6-17, 7-6 to 7-7
transportation
airport and air travel security, 6-38, 7-10
Department of Transportation, 6-38, 8-29
diesel engine soot formation research, 5-6
nuclear materials, 5-3
Office of Transportation Safeguards, 6-18
research, 6-25, 6-38
spent nuclear fuel, 5-7
surety, 7-10
Transportation Appropriations Bill, 5-14
Transportation Safeguards System, 6-18
transuranic waste program, 5-7, 6-21 to 6-22
Treaty on the Nonproliferation of Nuclear Weapons, 6-16, 6-39, 7-4
treaty verification, 5-4, 6-15 to 6-16, 7-4 to 7-5
Trident (United Kingdom), 6-36
Trilateral Initiative of the United States, Russia, Federation, and International Atomic Energy Agency, 5-4, 7-5
Tritium Plasma Experiment, 6-27
Tuition Assistance Program, 8-5
Twin Otter, 6-33

U

ultraviolet vertical-cavity surface-emitting laser (VCSEL), 5-11, 5-12
Under Secretary of Energy, 6-22
Underground Reactor Facility, 5-14, 8-21 to 8-22
Underground Storage Technology, 8-14
Undersea Warfare Center, 6-35
University Collaborations Program, 6-13
University Part-Time Program, 8-5
University Relations, 8-7
unmanned aerospace vehicle, 5-4, 6-33
Unmanned Aerospace Vehicle Program, 6-33
US Advanced Battery Consortium, 6-25
US Agency of International Development, 6-24
US Air Force, 2-7, 5-2, 5-5, 5-7, 5-14, 6-5, 6-34 to 6-35, 6-38, 7-4, 7-5, 8-18
US Air Force Space Warfare Center, 5-4
US Air Force Technical Applications Center, 6-34
US Army, 2-7, 5-7, 6-35
US Army Corps of Engineers, 7-14
US Army Non-Stockpile Chemical Materiél Program, 5-7
US Coast Guard, 6-38
US Environmental Protection Agency (EPA), 5-6, 5-7, 6-19, 6-39 to 6-40, 7-12, 7-14
Environmental Technology Verification Program, 8-12
Office of Research and Development, 6-39
Office of Water, 6-39
Superfund Innovative Treatment Evaluation Program, 6-39
US European Command, 6-37
US Marine Corps, 5-2
US Mint, 6-40
US National Data Center, 5-4
US Navy, 4-4, 5-2, 6-35 to 6-36
US/Russian Plutonium Disposition Development Program, 6-14
US/Russian Security Assessment Training Center, 6-36
US/Russian Steering Committee and Working Group, 6-14

Use Control equipment, 8-24
user facilities, 6-24, 6-28, 6-40, 8-11 to 8-16, 8-14 to 8-16

V

VCSEL. *See* ultraviolet vertical-cavity surface-emitting laser (VCSEL)
videoconferencing, 5-11
Village/Community Integrated System (INet), 7-12
Virtual Node Operating System team, 5-11
vision, 2-1
Visiting Scholars Program, 7-7
volunteer programs, 5-9, 8-7, 8-9, 8-10
VxInsight, 5-18, 8-14

W

W62, 6-5
W76, 6-9, 6-10
  arming, fuzing, and firing model, 5-11
  Type 2F telemetry analyses, 5-2
W76 Arming, Fuzing, and Firing Life Extension Program, 5-1
W76 Life Extension Program, 5-1, 6-5, 6-7, 6-9
W76-0/Mark 4, 5-1
W76-1, 4-2
W76/Mark 4A, 5-1
W78, 6-5
W80, 6-9
W80 Life Extension Program, 5-2, 6-5, 6-9
W80-2,3 Preliminary Weapon Development Report, 4-2
W87, 6-5
Wallops Flight Facility, 6-38
War Reserve, 5-3, 5-9, 6-5, 6-13, 8-16
Warhead Safety and Security Exchange, 6-37
waste. *See also* radioactive waste
  Chemical Waste Landfill, 6-19
  Current Waste Management Project, 6-12
  destruction technologies, 6-19 to 6-20, 6-24
  hazardous, 6-18, 6-20, 6-21, 6-24
  legacy, 6-12, 6-19, 8-29
  management technologies, 6-19 to 6-20
  recycling, 5-14, 5-15, 6-18, 6-19
  separation technologies, 6-19 to 6-20
  transuranic waste, 5-7, 6-21 to 6-22
  Waste Management Program, 6-18 to 6-21
Waste Isolation Pilot Plant (WIPP), 6-21, 7-14, 8-1, 8-25
Waste Isolation Pilot Plant Land Withdrawal Act, 6-21
Waste Management and Environmental Restoration programs, 6-19
Waste Management Program, 6-18 to 6-21
water resources
  groundwater, 6-19, 6-20, 8-13
  infrastructure protection, 3-4, 6-39, 7-14 to 7-15
  management, 4-3
  wastewater reuse, 5-15
Water Surety Initiative, 8-13
Water System Modernization project, 8-21
Weapon Assessment Team, 5-1
Weapon Incident Response, 6-11, 6-14
Weapon System Engineering Certification Campaign, 6-5, 6-9, 6-11
Weapon Systems Quality Director, 8-24
Weapons Evaluation Test Laboratory, 6-5
Weapons Evaluations Testing Laboratory, 8-22
Weapons Intern Program, 8-5, 8-25
weapons of mass destruction, 2-2, 7-4, 7-5, 7-7
  detecting, 5-4 to 5-5
  nonproliferation of, 6-2, 6-15, 6-16
Web Fileshare, 5-11
Weeks Island, 6-27
White Sands Missile Range, 6-35
wind energy technology, 6-24
Work for Others, 6-34, 6-40, 8-11, 8-14
  nonfederal entities, 6-40 to 6-41
  other federal entities, 6-34 to 6-35
work force, 3-4, 4-4. *See also* employees; Human Resources
Workflow Enabled Unsatisfactory Reports System, 5-3

Y

Y-12 Plant, 5-14, 6-10, 6-11
Yucca Mountain, 5-7, 7-13, 8-1
Yucca Mountain Site Characterization Project, 6-25

Z

Z Accelerator, 2-7, 5-13, 6-7, 6-8, 6-12
Z pinches, 5-13, 6-7
Z-Beamlet, 5-13 to 5-14, 6-7
Zoomzone, 8-10

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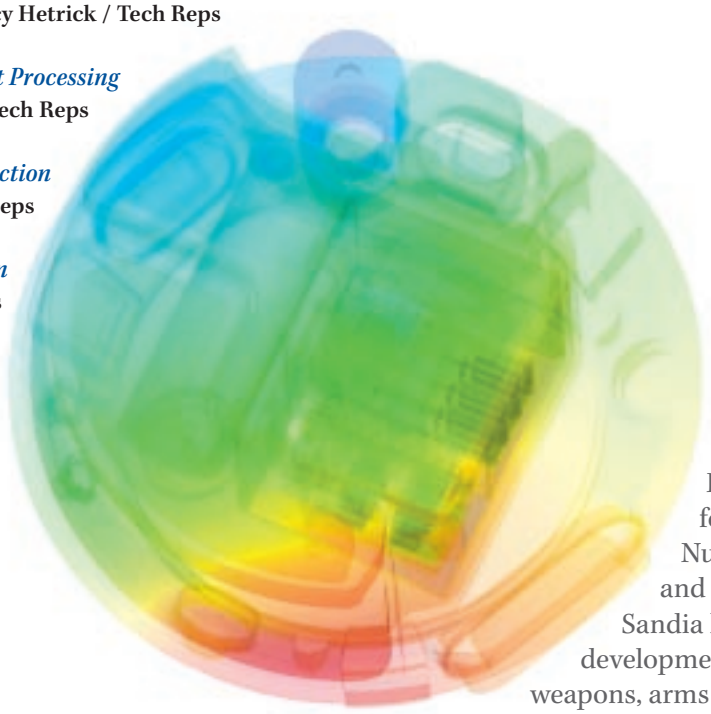

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