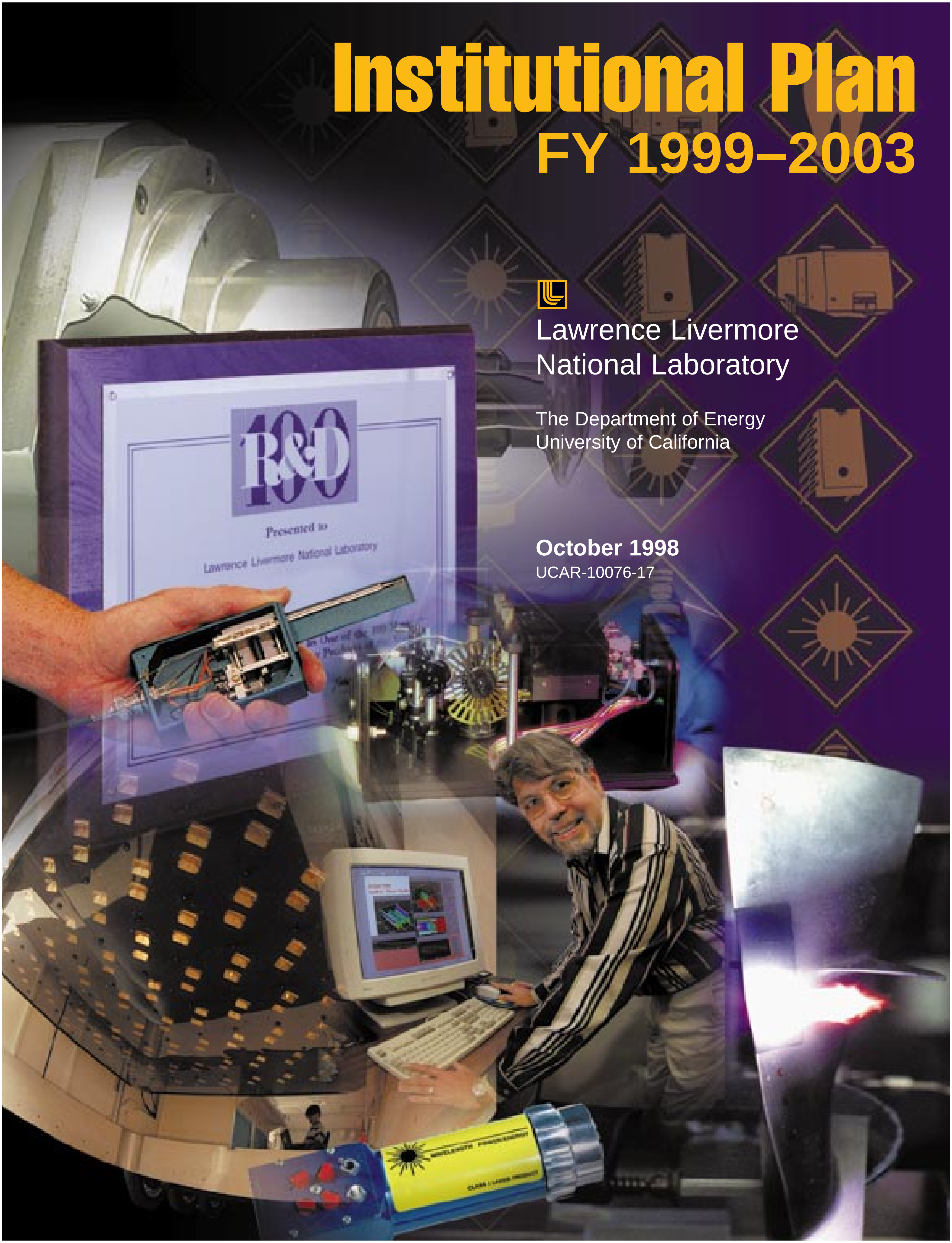
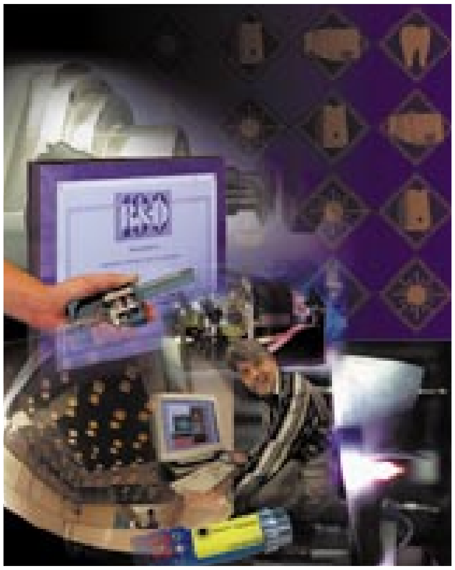
# Institutional Plan
## FY 1999–2003

Lawrence Livermore
National Laboratory

The Department of Energy
University of California

**October 1998**
UCAR-10076-17





**Cover Images:** A mobile radar system for inspecting bridges. Laser pulses to strengthen metal. A new kind of key that uses lasers. An imaging system that reveals the insides of teeth. A novel method to measure temperature. Computer software that boosts semiconductor production. And a detector to aid optics manufacturing efficiency. Images of these R&D 100 award winners are shown on the cover and section dividers of this year's Institutional Plan.

Lawrence Livermore researchers and their industrial partners were recently honored by *R&D Magazine* for seven of the top 100 technological achievements of the past year. Every year, the magazine honors the breakthrough products and processes that promise to improve people's lives. Livermore's awards for 1998 will impact the construction, metalworking, semiconductor, security, medical, and optics industries.

Livermore's seven awards match our previous best set in 1987, 1988, and 1997 and brings to 75 the number of R&D 100 Awards won by Livermore researchers since 1978.

We are particularly proud of the list of outside agencies and companies that are award co-recipients and contributors. These organizations include the Federal Highway Administration, Metal Improvement Co. Inc., University of Connecticut Health Center, OptiPro Systems Inc., Center for Optics Manufacturing, and American Precision Optics Manufacturers Association.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# Preface



## Navigating the Institutional Plan

This year, the *Institutional Plan* is divided into the following sections:

### Section 1. Laboratory Overview

Livermore's mission, roles, and responsibilities as a DOE national laboratory and the foundation for decisions about the Laboratory's programs and operations.

### Section 2. Laboratory Science and Technology—National Security

A description of the situations, issues, and planned thrusts of Livermore's national security programs: stockpile stewardship, countering the proliferation and use of weapons of mass destruction, and other defense-related activities.

### Section 3. Laboratory Science and Technology—Enduring National Needs

A description of the situations, issues, and planned thrusts of Livermore's programs of enduring national need: energy, earth and environmental sciences, bioscience and biotechnology, and fundamental science and applied technology.

### Section 4. Program Initiatives

Proposed significant additions to existing programs or new directions within our mission and a link to the major program that provides the foundation for the initiative.

### Section 5. Laboratory Operations and Facilities

Facilities and human resources information, including Laboratory staff composition and diversity and status of facilities with links to Contract 48 management and the 1998 LLNL Comprehensive Site Plan.

### Section 6. Appendices

- Program Resource Requirement Projections: Resource data for FY 1997-2003.
- LLNL organization chart.
- References for this Institutional Plan.

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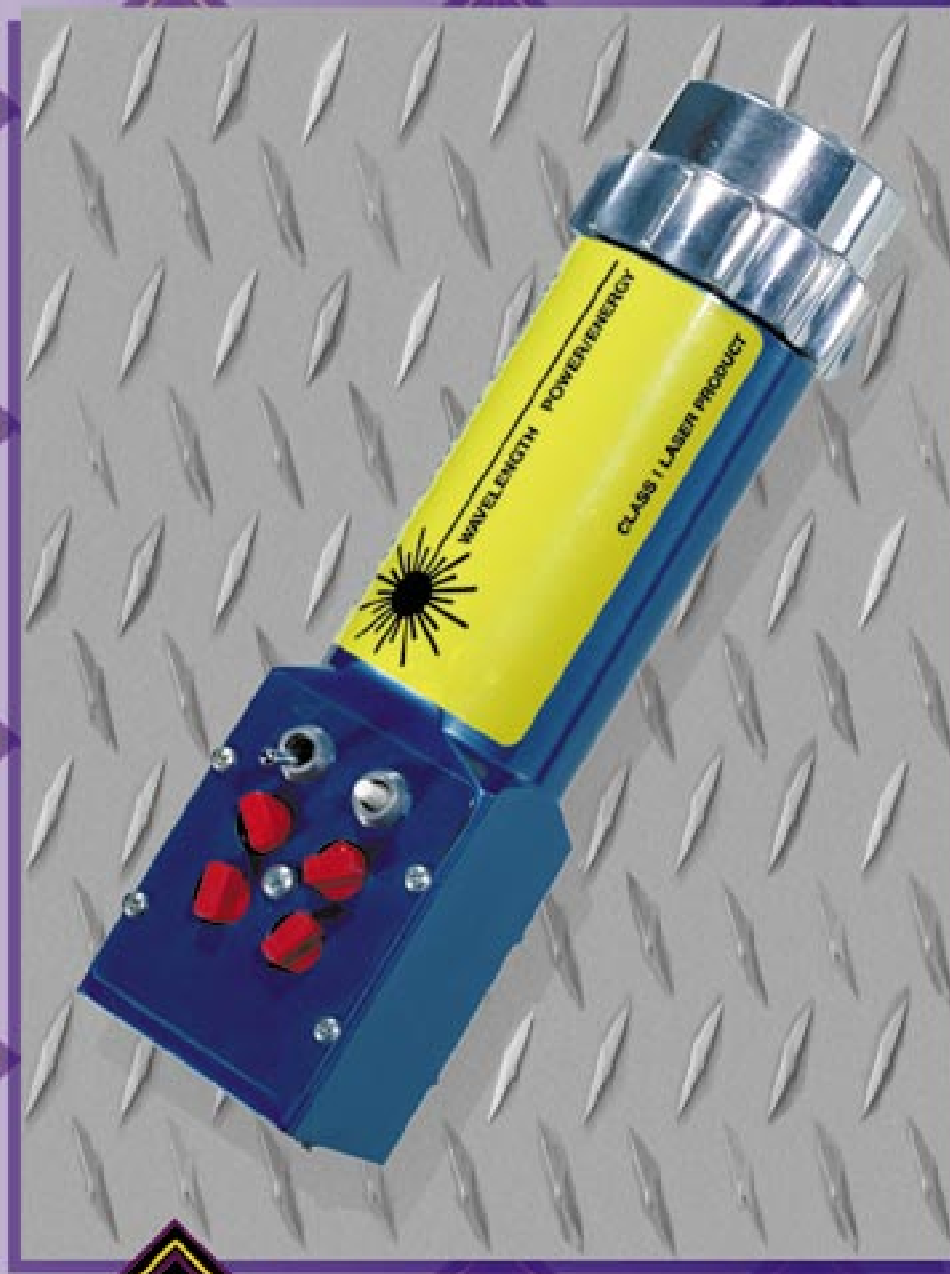
## Institutional Plan FY 1999–2003

**Department of Energy**
**Lawrence Livermore National Laboratory**

# Contents

# Director's Statement





R&D 100 AWARD

# Light Lock Optical Security System



**Light Lock Optical Security System, a laser-mediated electronic–mechanical lock with a reprogrammable code to activate the locking device.**

*Defense and Nuclear Technologies Directorate.*

# Director's Statement

***C. Bruce Tarter***
*Director*

The Lawrence Livermore National Laboratory's Institutional Plan FY1999-2003 highlights that this is a time of outstanding technical accomplishments and tremendous challenges at the Laboratory.

Our accomplishments and ongoing activities make clear our role as a Department of Energy (DOE) national laboratory. The challenges we face arise from the need for major scientific and technical advances to attain DOE's goals in national security, energy resources, environmental quality, and science and technology. Livermore's activities during this institutional planning period will help the Department to achieve success in its missions, and in the process, set the course for the Laboratory's programs in the early part of the 21st century.

The mission of Livermore is clear. National security is our defining responsibility. We are a vital part of the DOE's extraordinarily demanding program to maintain a safe and reliable U.S. nuclear weapons stockpile in the absence of nuclear testing—a supreme national interest. As one of the laboratories that designed the weapons in the stockpile, Livermore is a principal participant in the Stockpile Stewardship Program. It is our responsibility, together with Los Alamos and Sandia national laboratories, to provide accurate assessments of safety, security, and reliability of each weapon system. These assessments support a process of annual certification of the stockpile to the President by the Secretaries of Defense and Energy. The third annual certification was completed in December 1998.

Livermore's national security responsibilities extend beyond stockpile stewardship. The proliferation of weapons of mass destruction (WMD)—nuclear, chemical, and biological—is a serious threat to national security. There are concerns about Russia's ability to keep secure the weapons-usable nuclear materials and WMD know-how. Also, various nation-states in unstable regions of the world have or are seeking to acquire WMD, and the possibility of WMD terrorism cannot be dismissed.

Through a spectrum of activities, the DOE and its national security laboratories are supporting U.S. arms control and nonproliferation policy, analyzing weapons activities worldwide, and providing improved capabilities to thwart WMD threats. Livermore is making significant progress in technologies to secure weapons-usable fissile materials, to detect proliferation-related activities, and to combat WMD terrorism. Our future programs and plans are further described in this Institutional Plan.

Both major aspects of our national security mission—stockpile stewardship and nonproliferation—are very demanding. In particular, to meet the challenge of maintaining and refurbishing ever-aging U.S. nuclear weapons, the Stockpile Stewardship Program calls for major investments in vastly improved tools. Livermore is bringing into operation advanced scientific capabilities that our experienced nuclear designers need for responding to stockpile issues and training the next generation of stockpile stewards.

The National Ignition Facility (NIF) is a major investment that is under construction at the Laboratory. The NIF, a $1.2-billion, 192-beam laser facility, will provide the means for investigating the thermonuclear physics of primaries and secondaries in nuclear weapons. The facility will be a keystone of the Stockpile Stewardship Program. Advanced computer systems being developed for stockpile stewardship must be tested in the physical conditions that only the NIF can provide. NIF construction continues on schedule, with initial capability anticipated by the end of 2001 and project completion by the end of 2003.

Through our work in the DOE's collaborative Accelerated Strategic Computing Initiative, we are taking delivery of successively more powerful computers to improve our ability to simulate the performance of the aging stockpile and conditions affecting weapon safety. Performance increases by factors of thousands are needed to include the necessarily detailed physics models and carry out three-dimensional simulations. We expect to acquire a 10-teraOPS IBM supercomputer in 2001 and will be preparing for delivery of a much more powerful system in 2004. These acquisitions are accompanied by efforts to improve simulation models and develop tools to manage and visualize the vast amount of data generated.

These major investments shape the Laboratory's future. Together with an exceptional staff and other state-of-the-art research facilities, they enable the Laboratory to respond to a broad range of vital national needs. Livermore will have scientific computing capabilities that offer the potential of leading to unprecedented levels of understanding in climate and weather modeling, environmental studies, the design of new materials, molecular biology, astrophysics, and many other areas. And, with the NIF, we expect to create—for the first time ever in a laboratory setting—bursts of self-sustained fusion reactions. This accomplishment will be an important milestone on the road to developing fusion as a viable, clean source of energy.

As these research interests demonstrate, our focus is on the enduring missions of the DOE and program areas that build on and reinforce our national security work. In the areas of energy and environment, we will be pursuing fusion energy research, applying our extraordinary computational capabilities to modeling the global climate, and seeking further development and application of novel groundwater technologies. In addition, we will be extending our efforts in nuclear materials management—a long-term mission of DOE—including program integration and work in specific areas, such as Yucca Mountain. In biosciences and biotechnology, we will build on the successes of the Joint Genome Institute to develop programs in functional and structural genomics, as well as other areas of interest, such as healthcare technologies.

Increasingly, our major program activities are executed in partnerships with other laboratories, U.S. industry, and universities. The Joint Genome Institute is one such important partnership, uniting the efforts Lawrence Livermore, Lawrence Berkeley, and Los Alamos national laboratories. We have entered into "production mode" for sequencing DNA and achieved our FY 1998 goal by sequencing over 20 million base pairs.

Our partnerships with industry are many and varied: development of Atomic Vapor Laser Isotope Separation (AVLIS) technology with the U.S. Enrichment Corporation for uranium enrichment of reactor fuel; field demonstration of remarkably effective new groundwater cleanup technologies at an industrial site in Visalia, California; and work as part of a consortium of industry and laboratories to develop extreme ultraviolet lithography (EUVL) technologies for manufacturing the next generation of computer chips. Other activities in the areas of precision manufacturing and healthcare, as well as those based on R&D 100 award-winning technologies, demonstrate innovation in problem-solving. Our industrial partnerships—which bring with them a new set of technical, programmatic, and management challenges—are resulting in many exciting success stories.

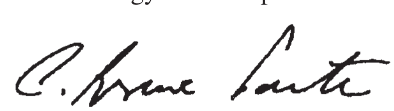
Success also demands that we meet the high operational expectations of the outside world—we aim to set a standard of excellence in performance and safety among high-technology R&D institutions. The Laboratory is taking steps to improve safety and create a work environment that ensures that safety stays a top priority. In 1998, we created a Safety Improvement Task Force to analyze our safety culture and processes and to perform extensive benchmarking of our performance. Their results provide the basis for high-priority actions we are taking this year, most notably the implementation of the Integrated Safety Management System (ISMS) at Livermore. The principles of ISMS are just right: make safety a conscious process for all, and create a responsibility and accountability system that trains everyone in both safety skills and roles.

Planning in the area of Laboratory operations includes the preparation for DOE a Comprehensive Site Plan (covering future facility development and land use) and a Site Safeguards and Security Plan that details the physical and procedural measures we are taking. We take the issue of protecting sensitive information extremely seriously and are employing increasingly sophisticated measures to do so. In response to DOE's evolving security requirements, the Laboratory is adding capabilities to provide even greater protection of critical assets. We are also enhancing our counterintelligence program and working with DOE to help strengthen counterintelligence throughout the Department.

Overall, we have greatly increased the efficiency and cost effectiveness of Laboratory operations, and we continue working to improve productivity and business practices. This Institutional Plan also describes actions we are taking in the human resources area to enhance opportunities for all members of an increasingly diverse workforce. The Laboratory's principal asset is its quality workforce.

This Institutional Plan describes our strategic plans and ongoing planning efforts, our current program accomplishments, and our new initiatives. Overall, our tasks are clear. We must deliver on our challenging programmatic commitments; we must keep our commitment to safe, efficient Laboratory operations; and we must assure alignment of our programs and critical competencies to meet the important, emerging needs of the nation.

At Livermore, we are ensuring national security and applying science and technology to the important



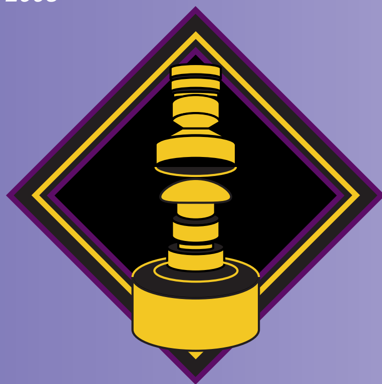
# Section 1



## Laboratory Overview

# R&D 100 AWARD

## OptiPro AED Proximity Sensor



**The OptiPro-AED Proximity Sensor, a product substantially improving the efficiency of precision optics manufacturing by sensing the separation between fine abrasive grinding tools and optical glass parts.**

*A collaboration of the Energy, Engineering, and Laser Programs of Livermore and OptiPro Systems Inc. of New York.*

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security continues to be Livermore's defining mission. The Laboratory has been administered since its inception by the University of California, first for the Atomic Energy Commission and now for the U.S. Department of Energy. Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and to establish an atmosphere of intellectual freedom and innovation, both of which are essential to sustained scientific and technical excellence. As a Department of Energy laboratory, Livermore has an essential and compelling core mission and the capabilities to solve important, difficult, real-world problems.

At Lawrence Livermore National Laboratory, we are ensuring national security and applying science and technology to the important problems of our time.

## 1.1 Mission, Vision, and Goals

### 1.1.1 Mission

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory.

Our primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide.

This mission enables our programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply Livermore's unique capabilities and to enhance the competencies needed for our national security mission.

The Laboratory serves as a resource to U.S. government and a partner with industry and academia. (See Figure 1-1.)

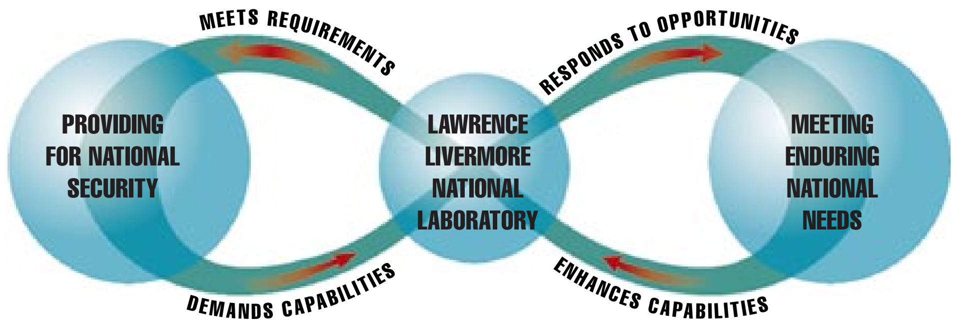



**Figure 1-1. The Laboratory's mission. We meet requirements to provide for national security. This mission demands capabilities at the Laboratory that are used to respond to opportunities to meet enduring national needs through projects that enhance our capabilities.**

### 1.1.2 Vision and Goals

Our goal is to apply the very best science and technology to enhance the security and well-being of the nation and to make the world a safer place.

#### *A Focus on National Security*

National security is the defining responsibility of Lawrence Livermore National Laboratory. We are focusing the Laboratory's efforts on two of the nation's top priorities: ensuring the safety, security, and reliability of the U.S. nuclear stockpile and preventing and countering the proliferation of weapons of mass destruction. We will provide the world-class scientific and engineering capabilities that have made it possible for the U.S. to maintain the national deterrent while taking major steps in international arms control and arms reduction.

The realization of a world without nuclear testing—but with remaining dangers that keep nuclear deterrence and nonproliferation central elements of U.S. security strategy—presents new challenges. As part of an integrated national effort, we must make significant advances in science and technology to maintain confidence in the U.S. nuclear stockpile under a Comprehensive Test Ban Treaty. Drawing on these advances and the special expertise of the Laboratory, we will also work with various U.S. government agencies to improve international nuclear safety and halt and prevent the use of nuclear, chemical, and biological weapons by developing needed technologies and analysis tools. In addition, Livermore will continue to apply its scientific and engineering capabilities to develop advanced defense technologies to increase the effectiveness of U.S. military forces.

#### *Major Investments at Livermore*

Investments are being made at the Laboratory in cutting-edge computational and experimental tools needed to help ensure that the U.S. nuclear weapons stockpile remains safe and reliable. Livermore will have scientific computing capabilities that offer the potential for revolutionary advances in many areas of science and technology as we make necessary improvements to simulation models of nuclear weapon performance. Livermore is also the site for the National Ignition Facility, which will be the world's largest laser system and will provide the means for investigating the thermonuclear physics of weapons in the absence of nuclear testing and for exploring the promise of fusion energy. These major investments shape the future of the Laboratory.

#### *Meeting Enduring National Needs*

An exceptional staff with state-of-the art research capabilities will enable the Laboratory to respond to a broad range of vital national needs. With Livermore's emphasis on high-payoff results, many projects will entail significant scientific and technical risk. We seek such challenges and will contribute where Laboratory efforts can lead to dramatic benefits for the nation.

Our special focus will remain on the critical, enduring missions of the Department of Energy and the program areas that positively reinforce our national security work. Livermore will pursue projects aimed at significant, large-scale innovations in energy production to ensure abundant and affordable energy for the future. Environmental efforts will be directed at demonstrating effective remediation technologies, advancing the science base for environmental regulation, improving the stewardship of nuclear materials in the U.S., and modeling more accurately regional weather and global climate conditions. We will also serve as an effective national technical resource in the stewardship of nuclear materials. The Laboratory's bioscience research will advance human health through efforts focused on genomics, disease susceptibility and prevention, and improved healthcare and medical biotechnology. In other fields, Livermore researchers will pursue science and technology initiatives that have the potential for major advances and that bolster the Laboratory's scientific and technological strengths.

#### *Supportive Operations and Internal Investments*

The foundation for Livermore's diverse set of research and development activities—now and in the future—is the Laboratory's science and technology base, which we will sustain through effectively managed internal investments. Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges. Livermore's scientific and technological achievements will be made possible by safe and efficient operations and sound business practices. Increasingly, accomplishments will be achieved through effective partnerships with others.

## 1.2 Critical Capabilities

The Laboratory is a national resource of science and technology with an extensive science and technology base and many specialized centers of excellence. Livermore provides leadership in several broad research areas that are central to the Laboratory's missions.

### 1.2.1 An Extensive Science and Technology Base

Livermore programs are supported by a large technical base consisting of more than 1,200 Ph.D. scientists and

## The Livermore Approach to Problem Solving

**Multidisciplinary Research Teams.** We form multidisciplinary teams tailored to meet the demands of each challenging problem. The teams combine scientific and engineering talent, and they draw from a diverse mixture of knowledge, skills, and experience to generate innovative solutions. Increasingly, research efforts entail partnerships with others outside the Laboratory as well.

**An Integrated Approach to Research and Development.** Research and development activities at Livermore range from fundamental science to production engineering of complex systems. We often carry concepts all the way from scientific discovery to fully developed prototype products.

**Large-Scale Experimental Science and Engineering Development.** We design and develop both products for our customers and large-scale experimental facilities, which we then use as tools to achieve program goals.

**Computer Simulation of Complex Systems.** Computer simulation is often the most cost-effective means for "conducting" a large number of complex experiments. Confidence in modeling results depends on careful validation through actual experiments. The use of simulations and experiments is mutually reinforcing.

engineers. A significant portion of the scientific staff is organized into "discipline" directorates—Chemistry and Materials Science, Computations, Engineering, and Physics—and many of these people are matrixed, or assigned, to specific programs. Use of the matrix system fosters efficient transfer of technical knowledge among programs, enables staff members to develop a wide-ranging set of skills and knowledge, and infuses projects with diverse ideas for solutions. As a result, the Laboratory has the ability to seize program opportunities, the agility to react quickly to technical surprises, and the flexibility to respond to programmatic changes.

### 1.2.2 Leadership in Research Areas Central to our Missions

The Laboratory's many research and development accomplishments demonstrate Livermore's leadership in several broad research areas:

- **High-Energy-Density Physics and Nuclear Science and Technology.** For over 45 years, the Laboratory has demonstrated excellence in science and technology directed at the development of nuclear weapons and the harnessing of thermonuclear and fission energy for civilian power. We have broad expertise in nuclear science and technology as well as exceptional capabilities for investigating the properties of matter at extreme conditions (up to stellar temperatures and pressures) and interaction of matter with intense radiation. This expertise will remain crucial for our national security programs. It will also be applied to develop innovative techniques for environmental cleanup, assist the Department of Energy in the stewardship of nuclear materials, and advance fundamental science in many areas.
- **Advanced Lasers and Electro-Optics.** Livermore is the pre-eminent laser science and technology laboratory in the world. We are strongly focused on two high-priority efforts—meeting design and construction goals for the National Ignition Facility and successfully completing the transfer of uranium atomic vapor laser isotope separation to the private sector. We are also applying the Laboratory's expertise in lasers and electro-optics to meet other national needs, contribute to the competitiveness of U.S. industry, and address issues in basic science. (See Figure 1-2.)
- **High-Performance Scientific Computing.** Over the 1994–2004 decade, we are acquiring successively more powerful computers with the goal of achieving increases in computational speed and data capacity by a factor of 100,000. By spring 2000, we expect to have a 10-teraOPS computer (10 million megaOPS), capable of performing calculations in 5 minutes that would have taken 40 days to complete in 1997. While meeting the Laboratory's commitments to national security programs, we are making internal investments to ensure that all major programs at the Laboratory have access to these advanced computing capabilities. They offer the potential of revolutionizing scientific discovery and leading to unprecedented levels of understanding in climate and weather modeling, environmental studies, the design of new materials, and many areas of physics.
- **Materials Science.** In support of Laboratory programs, we have developed wide-ranging expertise about materials. In addition to conducting fundamental research on the properties of materials, we engineer novel materials at the atomic or near-atomic levels. Livermore's stockpile stewardship responsibilities require researchers to understand in great detail the properties of very complex materials—ranging from plutonium to organic materials, such as high explosives—and how materials age in the presence of radiation and other toxic materials. Expertise in chemistry and materials science also provides critical support to many other program areas at the Laboratory, such as environmental cleanup, nuclear waste disposal, and atmospheric modeling programs. In addition, we develop nano-engineered multilayer materials and other exotic materials, such as aerogels. These advances meet programmatic needs for highly efficient energy-storage components; ultralight structural


**Figure 1-2. Expertise in advanced lasers and associated technologies, necessary for the National Ignition Facility and other major projects for national security, provides program opportunities in laser isotope separation, inertial confinement fusion, advanced lithography, and other diverse applications.**

materials; tailored coatings; and novel electronic, magnetic, and optical materials.

### 1.2.3 Specialized Centers of Excellence

Many specialized centers of excellence exist at Livermore. Because of our overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified, much of the necessary expertise to support programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have significant expertise to support innovative applied-science efforts in advanced materials; precision engineering; microfabrication; nondestructive evaluation; complex-system control and automation; and chemical, biological, and photon processes.

## 1.3 Strategy Development and Alignment

### 1.3.1 Development of a Strategy—The DOE Strategic Plan

*The U.S. Department of Energy Strategic Plan* (September 1997) articulates the Department's mission, vision for the future, core values, and strategic goals in its four businesses: National Security, Energy Resources, Environmental Quality, and Science and

## Principal Research Centers and Facilities at Livermore

**Atomic Vapor Laser Isotope Separation Facility**—advanced capability for industrial-scale research on uranium processing.
**Center for Accelerator Mass Spectrometry**—most versatile spectrometry capability in the world.
**Chemistry and Materials Science Environmental Services Laboratory**—wide-ranging capability to provide chemical and radiochemical characterization of environmental samples.
**Conflict Simulation Laboratory**—state-of-the-art, interactive, entity-level conflict simulation.
**Electron Beam Ion Trap Facility**—first achievement of totally ionized uranium not using a high-energy accelerator.
**Flash X-Ray Facility**—currently the most capable hydrodynamic testing facility in the world.
**Forensic Science Center**—world leadership in development of new forensic capabilities and instrumentation.
**Genome Center**—home of world's largest collection of cloned genes and the most detailed map of a human chromosome.
**Hardened Test Facility**—provides capability for mechanical testing of weapons components.
**High Explosives Applications Facility**—world's most modern high-explosives research facility.
**International Assessments Center**—national resource for evaluations of foreign weapons programs.
**Large Optics Diamond Turning Machine**—world's most accurate machine tool for fabricating large metal optical parts.
**Microtechnology Center**—world leader in laser-based microtechnology development.
**National Atmospheric Release Advisory Center**—for real-time emergency predictions for hazardous substance releases.
**Nova Laser**—world's primary research tool for inertial confinement fusion.
**4-MeV Pelletron**—versatile particle accelerator for materials analysis and radiation effects studies.
**Plutonium Facility**—modern facility for nuclear materials research and testing.
**Positron Microscope**—world's most intense pulsed proton beam for studying material defects.
**Secure and Open Computing Facilities**—the Laboratory's supercomputers and testbed for hardware and software development.
**Superconducting Magnet Test Facility**—unique development testing facility for large superconducting magnets.
**300-keV Transmission Electron Microscope**—provides important chemical and structural information about materials at the near-atomic level.
**Tritium Facility**—supports ICF target fabrication and decommissioning and recycling activities.
**Two-Stage Gas Guns**—first achievement of metallic hydrogen.
**Ultra-Short Pulse Laser**—for equation-of-state, opacity, and other stockpile stewardship experiments.
**Uranium Manufacturing and Process Development Facility**—supports research on casting and forming processes.

Technology. The strategic goals identified in the plan are:

- **National Security.** Support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction.
- **Energy Resources.** The Department of Energy and its partners promote secure, competitive, and environmentally responsible energy systems that serve the needs of the public.
- **Environmental Quality.** Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear R&D programs, minimize future waste generation, safely manage nuclear materials, and permanently dispose of the Nation's radioactive wastes.
- **Science and Technology.** Deliver the scientific understanding and technological innovations that are critical to the success of DOE's mission and the Nation's science base.

### 1.3.2 Development of a Strategy—*Creating the Laboratory's Future*

The Laboratory's strategy document, *Creating the Laboratory's Future*, provides the basis for this *Institutional Plan*. Published in September 1997, *Creating the Laboratory's Future* reflects our view of Livermore's responsibilities in meeting the strategic goals of DOE. The Laboratory's strategy was developed through the efforts of the five Strategic Councils at the Laboratory and the Policy, Planning, and Special Studies Office, which took the lead in synthesizing the work of the councils for senior management review.

The five Strategic Councils were created by the Laboratory Director 1996 to provide Laboratory-wide strategic direction in their domain of responsibility. Three councils focus along major business lines of the Laboratory: the Council on National Security, the Council on Energy and Environmental Systems, and the Council on Bioscience and Biotechnology. The Council on Strategic Science and Technology focuses its attention on issues pertaining to the scientific and engineering base at the Laboratory. In addition, there is a Council on Strategic Operations. (See Figure 1-3.)

The Laboratory's five councils, consisting of a senior-management chairperson and a select group of Associate Directors (or their representatives), are responsible for both tactical planning and formulating a strategy for long-range program and resource development in their areas. The councils provide guidance and are part of the review process for Laboratory-Directed Research and Development. They were also tasked with developing planning materials as input into *Creating the Laboratory's Future* and for ensuring that the strategic direction of planned actions and initiatives align with the strategic plans of the Department of Energy (and other sponsors of work). Many of the councils have published materials that describe their strategic direction in more detail than *Creating the Laboratory's Future*.

*Creating the Laboratory's Future* describes Livermore's roles and responsibilities as a DOE national

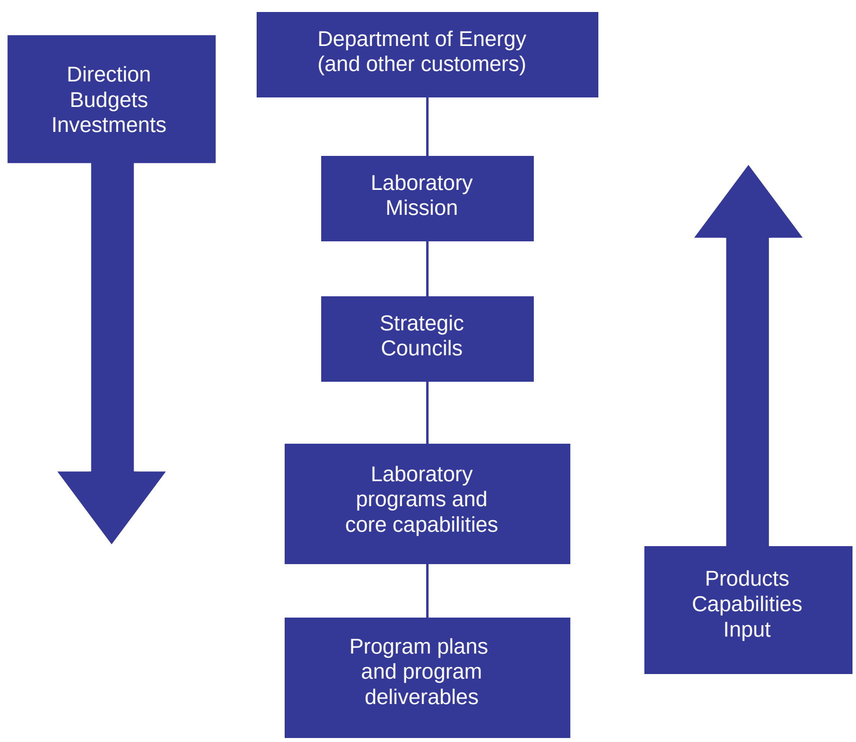



**Figure 1-3. Development and alignment of Livermore's strategic plans are highly interactive processes involving the Department of Energy (as well as other customers) and the Laboratory's programs and strategic councils. Strategic direction and major new investments at Livermore, which flow down from the Department of Energy, are based on recognition of the Laboratory's capabilities, responsibilities, and current deliverables.**

laboratory and sets the foundation for decisions about Laboratory programs and operations. It presents the Laboratory's mission, vision, and goals (Section 1.1 above); work projects and initiatives in support of them; the science and technology strengths of the Laboratory that support our missions (Section 1.2 above); the management of operations at the Laboratory (and operations initiatives); and steps we are taking to prepare for the future.

One of the steps the Laboratory has taken is the formation of the Long Range Strategy Project to explore science and technology opportunities and national program needs in the 2010-to-2020 time frame. The project was launched with the recognition that Livermore's prospects 10 to 25 years in the future are uncertain. Technology is evolving very rapidly, and programmatic uncertainties arise from the fact that post–Cold War national research and development priorities remain the subject of a national debate. The Long-Range Strategy Project entails the efforts of 20 younger leaders at the Laboratory—spanning disciplines and programs—guided by the Director and the Deputy Director for Science and Technology and supported by a resource group of selected senior Laboratory leaders.

Project participants are meeting with an array of leaders from diverse fields and enterprises and are having in-depth discussions with each of the Associate Directors and other senior Livermore scientists/engineers. They are focusing their efforts on selected topics, which are being pursued through topical subgroups that will meet for three to six months. The first set of topics being considered includes: nuclear deterrence in the 21st century, computations and

## From *Creating the Laboratory's Future...*

**PROVIDING FOR NATIONAL SECURITY**
"National security is the defining responsibility of the Laboratory."

**MEETING ENDURING NATIONAL NEEDS**
"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."

**MISSION-DIRECTED SCIENCE AND TECHNOLOGY**
"Livermore's strengths are well matched to DOE's needs . . . We pursue major projects where we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths."

**AN OUTSTANDING WORKFORCE**
"Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce."

**INVESTING IN THE FUTURE**
"Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges."

**MANAGING OPERATIONS EFFECTIVELY**
"Safe and efficient operations, sound business practices, and attention to the Laboratory's valuable resources make possible Livermore's technical achievements."

**PARTNERSHIPS THAT CREATE CAPABILITIES**
"We are involved in collaborations as a means to accomplish our goals, an expansion of the original E. O. Lawrence model of team science."

communications, bioscience and biotechnology, and the future of public and private R&D. The results of these and future studies will be documented, eventually to form part of the overall project report recommendations. The Long-Range Strategy Project will be active for about 18 months, concluding in Fall of 1999, with a synthesis report to be completed by January 2000.

### 1.3.3 Alignment with DOE Strategy and Needs

The Laboratory's mission statement—and essentially all the supporting material in *Creating the Laboratory's Future*—highlights the important interaction among LLNL's primary mission (national security), the scientific and technical capabilities at the Laboratory, and programs to meet enduring national needs (other than national security). The direction of the Laboratory's national programs is discussed in Section 2 of this Institutional Plan. In providing for national security, Livermore's principal responsibilities are:

- **Stewardship of the U.S. nuclear weapon stockpile.**
- **Stemming the proliferation of weapons of mass destruction.**
- **Responding to other important national security needs through application of Livermore's science and technology.**

Requirements to provide for national security demand unique capabilities at the Laboratory, which are also used to respond to opportunities to meet broader national needs. As discussed in Section 3 of this Institutional Plan, our focus is on the critical, enduring missions of the DOE and program areas that reinforce our national security work. Where we are able to make unique and valuable contributions, Livermore pursues major projects directed at:

- **Energy security and long-term energy needs.**
- **Environmental assessment and management.**
- **Bioscience advances to improve human health.**
- **Breakthroughs in fundamental science and technology.**

We are able to make selected advances in many of DOE's mission areas because our approach to research and development is multidisciplinary, integrating many disciplines with cutting-edge capabilities in multiple areas of science and technology. For example, Livermore's Biology and Biotechnology Research Program is at the forefront of genomics research in part because of the Laboratory's capabilities and success at engineering development of technologies for high-speed sorting of individual chromosomes and for measuring distances between DNA markers. Bioscience expertise, in turn, is contributing to the development of novel bioremediation technologies for groundwater cleanup and portable minisensors for rapid, accurate detection and characterization of biological warfare agents in the field. Opportunities to meet a broad range of national needs are created by our other special capabilities, such as in advanced lasers (Figure 1-2) and advanced scientific computing (Figure 1-4).

The nearly continual interactions of Livermore programs with DOE sponsors and frequent interactions of senior Laboratory managers with DOE Program Secretarial Officers (PSOs) greatly contribute to alignment of the Laboratory's strategic direction with the *U.S. Department of Energy Strategic Plan* (September 1997) and the commitments made in the Secretary of Energy's Performance Agreement with the President for FY 1998. Moreover, as exemplified by the Stockpile Stewardship Program, key Laboratory program leaders and staff work with and provide information to assist DOE PSOs in formulating DOE's strategic plans and direction. These activities feed back into the Laboratory's strategic planning process and assure that Livermore programs and strategies align with those of the DOE (Figure 1-5).

In our self-assessment of Laboratory planning for DOE and the University of California (Section 1.4, below), we evaluate success and alignment with DOE's strategic direction and plans through consideration of four factors:

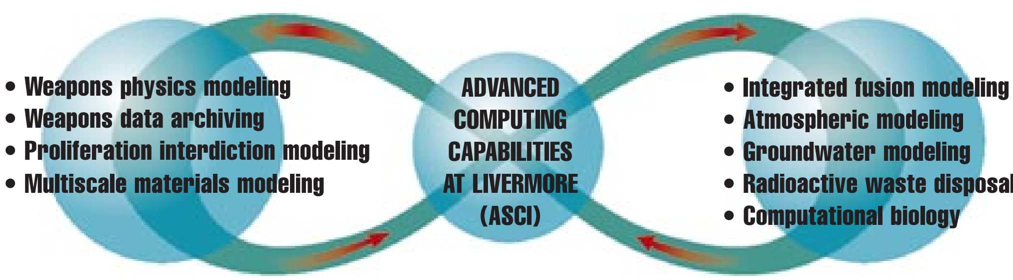



**Figure 1-4. The Accelerated Strategic Computing Initiative (ASCI), required for stockpile stewardship, enables the Laboratory to respond to other program opportunities.**

• **Successful Programs and Partnerships.** Sustained support for program activities at the Laboratory are indicative of our efforts to align with the DOE's plans and goals and of executive branch and congressional recognition of the importance of the work and the progress being made. Increasingly, Livermore's programs are being pursued in partnership with other laboratories, academia, and industry. The formation and successful management of these partnerships also reflect on effective planning.

• **Major Investments at the Laboratory.** Successful planning is evident in the fact that major investments in capabilities and facilities are being made at Livermore. In addition, our special capabilities are being effectively used in programs sponsored by DOE and others.

• **New Initiatives with DOE.** Livermore is at the forefront of planning and execution of several new DOE initiatives, indicating that the Laboratory's plans are well aligned with those of the Department.

• **Awards and Honors.** The awards and honors we receive demonstrate the quality of science and technology at the Laboratory. A strong science and technology base at Livermore makes it possible for the Laboratory to be very responsive to and stay aligned with the changing needs of DOE.

**Department of Energy Strategic Plan**

**National Security**
Support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction.

**Energy Security**
Promote secure, competitive, and environmentally responsible energy systems that serve the needs of the public.

**Environmental Quality**
Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs, minimize future waste generation, safely manage nuclear materials, and permanently dispose of the nation's radioactive wastes.

**Science Leadership**
Deliver the scientific understanding and technological innovations that are critical to the success of DOE's mission and the nation's science base.

**Creating the Laboratory's Future**

- **Providing for National Security**
  - — Stewardship of the U.S. nuclear stockpile
  - — Stemming the proliferation of weapons of mass destruction
  - — Meeting new military requirements

*"National security is the defining responsibility of the Laboratory."*

*"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."*

- **Meeting Enduring National Needs**
  - — Energy security and long-term energy needs
  - — Environmental assessment and management
  - — Nuclear materials stewardship
  - — Advancing biosciences to improve human health
  - — Pursuing breakthroughs in fundamental sciences and applied technologies

**Figure 1-5. The missions and goals identified in the Laboratory's strategy document, *Creating the Laboratory's Future*, closely align with the strategic goals identified in the *U.S. Department of Energy's Strategic Plan* (September 1997).**

### 1.3.4 Anticipating and Responding to Future Needs

In addition to its programmatic responsibilities, Livermore—as a national laboratory—serves as a technical resource for the federal government to use in the development of effective public policy. To meet this responsibility, the Laboratory must maintain its vitality by anticipating and changing to meet evolving national needs. We work with DOE and other sponsors to anticipate the future needs of the nation, keep them apprised of emerging technical opportunities, and identify areas where science and technology can enhance security and national well-being. To be effective, we must continue to be an integral and active part of the nation's science and technology infrastructure, by participating in the national dialogue on important science issues and being broadly recognized as a scientific leader.

We also must continue to make internal investments that develop the skills and capabilities needed to meet customers' future needs. The present strengths of Livermore are, in large part, a product of investment choices in the past. An important source of internal investment is Livermore's Laboratory Directed Research and Development (LDRD) Program. LDRD is an important tool we have for supporting research and development projects that will enhance the Laboratory's core strengths, nurture research efforts that expand the Laboratory's scientific and technical horizons, and create important new capabilities so that the Laboratory can

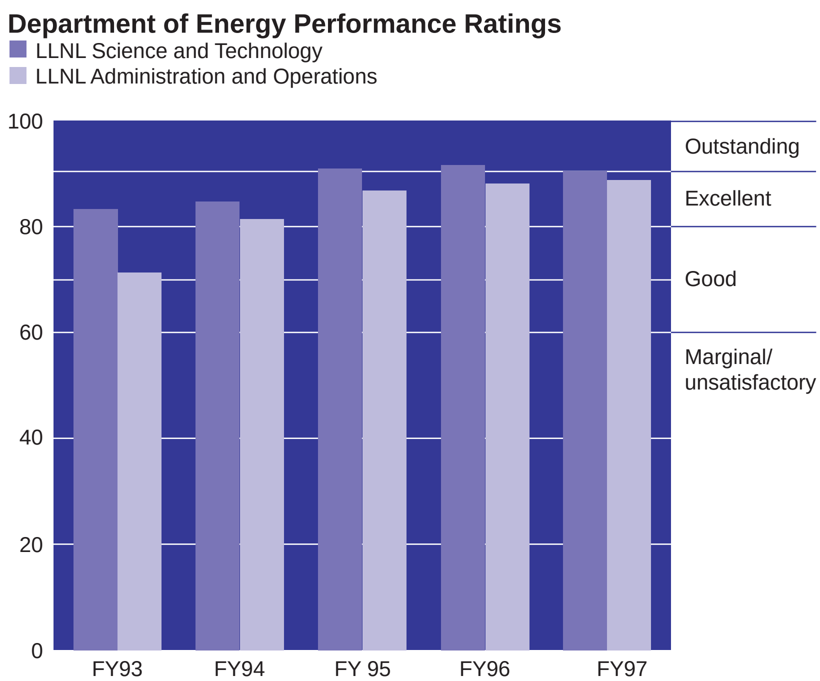



**Figure 1-6. Livermore's Science and Technology (S&T) and Administration and Operations (A&O) "excellent" as measured by performance criteria defined in the performance-based management contract between the Department of Energy and the University of California.**

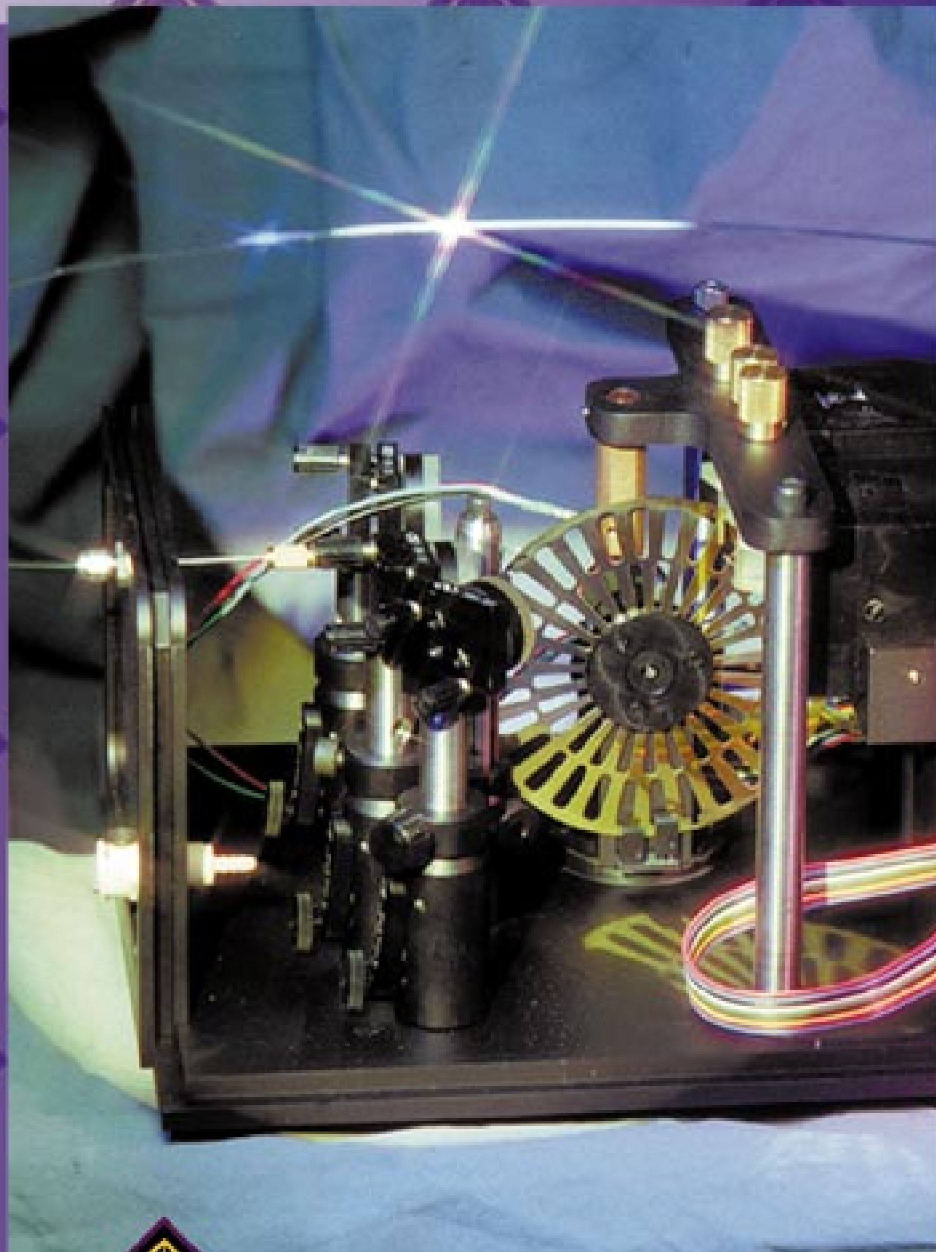
respond promptly and effectively to new missions and national priorities. Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. Program accomplishments (highlighted in Section 3.3) are more fully described in Livermore's LDRD Annual Reports.

## 1.4 Evaluation of Performance

Livermore is one of three national laboratories managed and operated under a contract between the Department of Energy and University of California (UC). When the DOE–UC contract was revised and extended in 1992, DOE and UC pioneered performance-based contracting as applied to government-owned, contractor-operated (GOCO) institutions. In 1997, DOE and UC agreed to extend the contract for five years. The new contract extension preserves and strengthens the performance-based management system introduced in 1992.

Appendix F of the DOE/UC management and operating contract contains over 100 performance measures that provide the basis for the performance management system. Performance is measured in two areas: (1) science and technology and (2) administration and operations, which includes such items as environmental, safety, and health (ES&H), business operations, facilities management, and human resources. Each year, Livermore provides to UC the Science and Technology Assessment Report, prepared by the Laboratory Science and Technology Office, and the Appendix F Self-Assessment Report, coordinated by the Laboratory Office of Contract Administration, which covers administrative and operations. UC reviews and uses these self-assessments to prepare an overall report that it submits to DOE, and DOE publishes an annual appraisal of the Laboratory's performance.

As shown in Figure 1-6, since the inception of performance assessment system in FY 1993, the Laboratory has achieved very high ratings in science and technology and has steadily improved ratings in administration and operations. Livermore's performance evaluation in FY 1997 was "outstanding" in science and technology and "excellent" in administration and operations.



# Laboratory Science and Technology– National Security

**Two-Color Fiber-Optic Infrared Sensor, for measuring temperature and emissivity in medical and industrial applications.**

*Livermore's Medical Technology Program.*

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security remains Livermore's defining mission. The world has undergone significant changes since then, and, like the world, our mission has become more dynamic and complex.

National security rests on the twin pillars of deterring aggression against the U.S.—through diplomacy, treaties, and military strength—and reducing the threats posed by others—by stemming and countering the spread of weapons of mass destruction. The Laboratory's national security programs, conducted in the context of the overall national and global security environment, provide science and technology to underpin and support U.S. national security policy.

Livermore's national security programs align directly with the major goal in DOE's Strategic Plan to "support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction."

### *Stockpile Stewardship*

As stated by the President and Congress, nuclear deterrence will remain a key component of U.S. national security policy for the foreseeable future. The maintenance of a safe and reliable nuclear stockpile is a supreme national interest of the U.S. As one of DOE's three national security laboratories, Livermore plays a key role in the Stockpile Stewardship Program for maintaining the nation's nuclear weapons stockpile in the absence of nuclear testing. The accelerated and expanded use of strategic computing and simulation tools is fundamental to the success of the effort.

### *Countering the Proliferation and Use of Weapons of Mass Destruction*

National security is threatened by the spread and potential use of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD). At least 20 countries, some of them hostile to U.S. interests, are suspected of or known to be developing WMD. In addition, WMD materials and technical know-how make terrorist use of such weapons a grave concern. Livermore is addressing the problem of WMD proliferation through a wide spectrum of analysis and technology development activities.

### *Meeting Other Important National Security Needs*

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and nonproliferation missions, Livermore develops advanced defense technologies for the Department of Defense to enhance the effectiveness of U.S. military forces. Livermore's technologies are also increasingly being applied to domestic national security issues—critical infrastructure protection and law enforcement. National laboratories like Livermore can make valuable contributions as DoD and law-enforcement agencies tackle the difficult task of anticipating and responding to shifting threats to U.S. national security.

Our work takes place within the context of the national security community—the three DOE national security laboratories, the production plants and the Nevada Test Site, the DoD, and the U.S. intelligence community. With the growing recognition of the vulnerability of the nation's critical infrastructure, Livermore is beginning to address the needs of the Justice Department and other law-enforcement agencies. Many projects involve extensive collaborations with other national laboratories, government agencies, universities, and U.S. industry. We coordinate and integrate our efforts with others to provide the best scientific and technical capabilities to the nation as cost effectively possible. For a full explanation of our current Laboratory initiatives, see Section 4, below.

We also target Laboratory Directed Research and Development (LDRD) investments to enhance our ability to meet national security mission objectives. The investments reinforce our core strengths, expand the Laboratory's scientific and technical horizons, and create new capabilities, such as laser cutting for stockpile refurbishment and field-portable biological agent detectors. More generally, LDRD investments help Livermore to explore advanced technologies to meet very challenging, long-term national security needs and to respond promptly to national priorities as they change. Over 90% of the Laboratory's LDRD projects contribute to our national security mission. Livermore's overall LDRD Program is discussed in more detail in Section 3.3.1.

## 2.1 Stockpile Stewardship

The future course for the nation's nuclear weapons program was set in 1995, when President Clinton announced that the U.S. would pursue a comprehensive nuclear test ban. In making that decision, he reaffirmed the importance of maintaining a safe and reliable U.S. nuclear stockpile. Subsequently, the President directed necessary programmatic activities to ensure stockpile safety and reliability in the absence of nuclear testing. The Stockpile Stewardship Program was developed in response to this directive, and, in 1996, the President signed the Comprehensive Test Ban Treaty.

The DOE Assistant Secretary for Defense Programs (DP) is leading the Department, its three national security laboratories, and others in the weapons complex in the formulation and execution of the Stockpile Stewardship Program. It is a program designed to ensure the safety and reliability of the U.S. nuclear weapon stockpile in an era of no nuclear testing, no new weapon development, an aging stockpile of fewer weapons and fewer types of weapons, and a reduced production capacity to refurbish nuclear weapons. The *Stockpile Stewardship Plan: Second Annual Update (FY 1999)*, issued by the DOE Office of Defense Programs, April 1998, provides an executive overview of the Stockpile Stewardship Program.

Significant challenges lie ahead because the demands on the program will grow as weapons in the enduring stockpile continue to age. Weapons in the U.S. nuclear stockpile are now older on average than they have ever been. Stockpile problems must be anticipated or detected and then evaluated and resolved without nuclear testing. Existing warheads and weapon systems will have to be refurbished to extend stockpile lifetimes and to meet future military requirements. At the same time, the reservoir of nuclear test and design experience at the laboratories continues to diminish. This experience base—and the tools needed to resolve stockpile issues—must be passed on to the next generation of stockpile stewards.

Livermore's efforts support the five major Stockpile Stewardship Program strategies:

- **Integrated management of the Stockpile Stewardship Program**—to ensure that both the major program elements and the activities at the laboratories and plants are tightly interconnected and focused on program goals.
- **Surveillance of the stockpile**—including efforts to better predict aging phenomena sufficiently far in advance that refurbishment of components can be managed in a production complex having limited capacity.
- **Assessment of stockpile issues and certification of required changes to the stockpile**—using detailed component-level experiments and sophisticated computational simulations.
- **Refurbishment of stockpile components**—in a flexible, cost-efficient, and environmentally sound fashion.
- **Production of tritium**—on a time scale consistent with stockpile needs.

Successful execution of Livermore's program responsibilities presents many technical and management challenges. The technical demands of the program are significant—many aspects of the required science and technology are at the leading edge of what is possible. We must proceed expeditiously with the program so that enhanced capabilities will be available to deal with difficult stockpile issues, which could arise at any time. These enhanced capabilities will be developed by scientists and engineers with nuclear weapons design and testing experience working with and training the next generation of stockpile stewards. Management challenges stem from tight budget constraints and the need to both integrate and balance the many elements of the program. Managers are also responsible for ensuring that expertise in all aspects of nuclear weapon science and engineering remains high, with particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel. Workforce recruiting benefits from the Laboratory's LDRD Program (Section 3.3.1) and the Science and Technology Education Program (Section 3.3.4.2), which help to attract high-caliber scientists and engineers and develop a future workforce to work on challenging national security problems.

## 2.1.1 Integrated Program Management and Implementation

### *Situation and Issues*

Integrated program management and implementation are critical to the success of the Stockpile Stewardship Program. The major program elements are tightly interconnected, as are the activities of the three laboratories, the production plants, and the Nevada Test Site. A detailed implementation plan, referred to as the "Green Book" and summarized in DOE's *Stockpile Stewardship Plan: Second Annual Update (FY 1999)*, specifies roles and responsibilities within the program and defines the capabilities needed for stockpile stewardship without nuclear testing. The plan integrates surveillance, assessment, and life-extension design and manufacturing activities for each weapon system, and (to the extent possible) time-phases all activities to balance the workload. Program integration efforts also include formal processes with the Department of Defense (DoD) for validating assessments of stockpile performance and modification actions.

### *Program Thrusts*

Livermore is a key participant in formal review processes for certification of weapon safety and reliability—Annual Certification of the stockpile for the President and Dual Revalidation. Annual certification is based on technical evaluations made by the laboratories and on advice from the three laboratory directors, the Commander in Chief of the Strategic Command, and the Nuclear Weapons Council. To prepare for certification, we collect and analyze all available information about each stockpile weapon system, including physics, engineering, and chemistry and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review.

In addition to annual certification, we have developed in consultation with DoD a Dual Revalidation process to examine in detail over a two- to three-year period each warhead design in the stockpile. The W76 is the first system undergoing Dual Revalidation. We are also establishing with DoD new procedures for recertifying weapons after life-extension refurbishment activities.

Livermore is also a key contributor to updating and improving the Green Book as the laboratories and plants continue to refine comprehensive life-extension plans for weapon systems in the stockpile. Priorities for stockpile stewardship activities at the Laboratory are established through consideration of integrated program goals—both Green Book priorities and risks to the overall program if specific activities are less than fully supported. Livermore's integrated priorities, highest first, are:

- To keep the current stockpile safe, secure, and reliable. This involves projects such as the W87 Life Extension Program, surveillance, and baselining of the current stockpile systems to support Annual Certification and Dual Revalidation. In general, these activities require full support of the core computing program, physical databases, experiments (including no-nuclear-yield tests using plutonium), and Livermore's current suite of facilities.
- To accelerate development of the advanced experimental and computational capabilities needed to resolve complex stockpile issues. Major activities include laboratory, industry, and university efforts to develop high-performance computing platforms and applications (the Accelerated Strategic Computing Initiative program), construction of the National Ignition Facility, and development of the Advanced Hydrodynamic Facility (AHF) for primary high-explosive experiments.
- To further develop the underlying science and technology critical to future stockpile certification. To understand the performance and aging characteristics of nuclear weapons, we need state-of-the-art theory, modeling, and experiments on materials and detailed atomic and nuclear processes.
- To develop production technologies that could be employed when the current stockpiled systems must be replaced.

## 2.1.2 Stockpile Surveillance

### *Situation and Issues*

With fewer types of weapons in the stockpile and reduced capabilities and capacity in the production complex, we must become more proficient at early detection and identification of precursors of potential problems so that we have adequate time for thorough evaluation and action before problems affect stockpile safety or reliability.

Our stockpile surveillance efforts focus on Livermore designs in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. These efforts include building the scientific base and developing monitoring capabilities to better understand aging effects in all stockpiled weapons. Aging affects the physical characteristics of materials, and we must determine how these changes impact weapon safety and performance. With a better understanding of aging, our stockpile surveillance can be more predictive, making possible systematic refurbishment and preventative maintenance activities to correct developing problems.

### *Program Thrusts*

Major efforts are under way to enhance surveillance capabilities. We are preparing detailed archives of existing test data, and we are using very modern instrumentation to obtain even more precise physical data on stockpiled weapons. The accumulated information serves as a baseline to identify anomalies in aging weapons as they occur. We are also improving the sensors and techniques for inspecting stockpiled weapons. Furthermore, we are developing a better understanding of how aging alters the physical characteristics of weapon materials and components.

For example, we are making significant progress on improving detection capabilities and computer models of corrosion in nuclear weapons. Understanding the evolution of the gases and materials in a weapon and extrapolating the long-term consequences present challenges to our materials scientists. Working with the production plants, we are using a newly developed technique for sampling evolved gases within stockpile weapons that is extremely efficient and does not require collecting a large gas sample. Livermore researchers also are developing a computer model of the generation, transport, and reaction of materials in aging canned secondary assemblies (CSAs) in weapons. We will be able to use the simulation tool, when thoroughly tested and validated, to predict the effective life of CSAs.

In addition, we are greatly improving our understanding of the properties of plutonium. This is a very important issue—we need to understand aging in plutonium and its effect on the performance of an imploding pit of a stockpiled weapon. We are obtaining this information through advances in theoretical modeling and non-nuclear research tools, just recently becoming feasible and increasingly made available through Stockpile Stewardship Program investments. Efforts include various types of laboratory experiments to study the microstructure of plutonium, computer simulations of plutonium at the atomic and molecular scales, and subcritical experiments at the Nevada Test Site. Working with colleagues at Los Alamos, we have also devised a means for carrying out accelerated aging tests that will help us assess the performance of plutonium pits much older than those now in the stockpile.

#### Laboratory Initiative

- Enhanced Surveillance (DP), p. 55.

### 2.1.3 Stockpile Assessment

#### Situation and Issues

Assessments provide the foundation for formal certification of stockpile performance and refurbishment decisions. The Stockpile Stewardship Program includes a comprehensive set of activities to address issues that arise from stockpile surveillance and to evaluate the significance of observed and predicted aging processes. When modifications are deemed necessary, we must assess options for refurbishing or replacing specific warhead components as well as for new production and fabrication processes and materials. Modification actions must then be certified.

Assessments must be based on scientific and engineering demonstrations to be credible. In the absence of nuclear testing, we rely on data from past nuclear tests as a benchmark, component-level experiments and demonstrations, and advanced simulations for an integrated assessment of weapon performance and safety. This approach has enabled us to successfully address stockpile issues that have emerged to date. However, as the stockpile ages, we anticipate that more difficult assessment issues will arise. In addition, it is possible that, as in past cases, design and production flaws will be discovered in systems that have been in the stockpile for some time.

#### Program Thrusts

We are engaged in a balanced and integrated program of computational simulation, fundamental scientific research, and experiments. Non-nuclear experiments are used to assess weapon component performance. Together with past nuclear test results, they also are used to validate computer simulations, which rely heavily on fundamental scientific research as a source of data and a basis for the detailed physics models in the codes. Once validated to the extent possible, weapon physics simulations guide our judgment about integral stockpile issues.

In many ongoing stockpile stewardship activities, we combine past nuclear test data and non-nuclear experimental results with our most sophisticated computer models and advances in theory to attain a solid scientific foundation for our assessments. These activities include Annual Certification of the stockpile and Dual Revalidation of the Los Alamos W76 warhead, the first system being examined in a very thorough multiyear evaluation of each weapon in the enduring stockpile. Demonstration-based assessments also underpin Livermore's W87 stockpile life-extension work.

The expectation that more challenging stockpile issues will arise as weapons continue to age is driving the program's investments in more capable experimental facilities. They include the National Ignition Facility (NIF) and the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT). We are also developing greatly enhanced numerical simulation tools through the Accelerated Strategic Computing Initiative (ASCI). Livermore has major responsibilities in the execution of the ASCI program and the construction of the NIF.

- **The Accelerated Strategic Computing Initiative (ASCI).** ASCI is a program to dramatically advance our ability to computationally simulate the performance of an aging stockpile and the conditions affecting weapon safety. The initiative is designed to deliver significant new capabilities at a steady pace in support of stockpile stewardship. To make the needed major advances in weapons science and weapons simulation code technology, Livermore, Los Alamos, and Sandia national laboratories are obtaining from U.S. industry dramatic increases in computer performance and information management. The ASCI program is integrating the development of computer platforms, simulation applications, and data management technologies.

Livermore took delivery of the first elements of the ASCI Blue Pacific computer from IBM in 1996. The 512-node "Initial Delivery System" nearly tripled Livermore's computing capability. The supercomputer has since been upgraded with faster processors, new software, and additional storage capability, which increase the computing capability to 0.9 trillion operations per second (0.9 teraOPS). The machine has been used, for example, to perform very detailed calculations of 3-D phenomena that simply could not be addressed prior to the ASCI program. We are on schedule to obtain at Livermore the next step in greatly enhanced computing capabilities—the Sustained Stewardship TeraOPS (SST) machine will arrive in the first quarter of 1999. SST will perform at 3.9 teraOPS and surpass ASCI Red at Sandia as the fastest and most capable machine in the world. In addition, our contract with IBM has been extended to acquire the 10-teraOPS "Option White" supercomputer by spring 2000.

Expansion of Livermore's computing power beyond "Option White" will necessitate investment in the Terascale Simulation Facility (TSF) to accommodate a 100-teraOPS capability. A Conceptual Design Report for this facility is in the final stages of approval. If approved, construction could begin in FY 2000. The TSF would provide two spacious computer rooms with adequate power and cooling for the huge heat loads and would include office space for the growing staff of computer scientists who support the computers and perform related research and development.

ASCI's goal of a 100-teraOPS computer by 2004 requires further increases in capability and major efforts by industry to develop the technology to interconnect tens of thousands of advanced microprocessors. Announced by President Clinton in February 1998, PathForward provides contracts worth over $50 million over the next four years to Digital Equipment Corporation, IBM, Silicon Graphics Computer Systems (SGI/Cray), and Sun Microsystems to make the necessary advances. Through the Academic Strategic Alliances Program (ASAP), which is part of ASCI, academic participants are accelerating advances in large-scale computational simulation. In July 1997, ASAP awarded funds to establish major centers at five universities, and now proposals for lesser-scale partnerships (Level-II alliances) are under review. Livermore scientists interact with these centers and apply lessons learned from advanced physics and engineering simulations developed at the universities to important stockpile issues. More generally, we will benefit from a strengthening of U.S. academic programs in high-performance scientific computing and closer ties with universities, which provide a major source of new talent for the Laboratory and the Stockpile Stewardship Program.

**•The National Ignition Facility.** Construction is under way at Livermore for the National Ignition Facility (NIF), a $1.2-billion facility housing a 192-beam laser and associated experimental capabilities. The NIF is a cornerstone of the Stockpile Stewardship Program. It will be the only facility capable of well-diagnosed experiments to study the thermonuclear properties of primaries and secondaries in nuclear weapons. Advanced computer models being developed for stockpile stewardship need to be tested in the physical conditions that only the NIF will provide in the absence of nuclear testing.

A major goal of Laboratory researchers is to use the NIF to achieve fusion ignition and burn in a controlled laboratory setting. To succeed will be both a remarkable achievement and meaningful indicator that stockpile stewardship is working. Like the design of a nuclear weapon, fusion in the laboratory is an integral experiment that tests the skills and resourcefulness of the physicists and engineers who will be the nation's stockpile stewards in the future. Success in fusion experiments will also greatly boost the value of the NIF as tool for laboratory experiments to address real stockpile problems and study the physics of nuclear weapon primaries as well as secondaries.

All of the major conventional facility construction contracts have been awarded. Procurement of special equipment has begun, building on critically important partnerships formed with U.S. industries to ensure that the special equipment and advanced technologies needed for the NIF can be delivered on budget and on time. The NIF schedule calls for an initial capability by the end of FY 2001 consisting of the first bundle of 8 beams installed, which will provide a capability equivalent to approximately twice that of Nova. Half of the 192 beams will be available for use at the end of FY 2002; project completion is scheduled for the end of FY 2003.

#### *Laboratory Initiatives*

• National Ignition Facility (DP), p. 51.
• Contained Firing Facility (DP), p. 51.
• Accelerated Strategic Computing Initiative (DP), p. 52.
• Terascale Simulation Facility (DP), p. 53.
• Two-Stage Light-Gas Gun—JASPER Facility (DP), p. 55.
• Advanced Hydrotest Facility (DP), p. 56.

### 2.1.4 Stockpile Refurbishment

#### *Situation and Issues*

Livermore is the design laboratory for four nuclear weapon systems in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. They are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 already has done so. Weapon refurbishment—needed because weapon components degrade over time—is a particularly demanding challenge because we cannot rebuild many weapons components exactly as they were manufactured. In many cases, the materials or the manufacturing processes originally used are no longer available or are environmentally unacceptable. Production quality assurance must be provided by new assessment and certification processes that do not include nuclear testing.

We are working closely with the production plants to integrate the development of replacement components with the development of new materials and manufacturing processes. To lower costs and environmental impact, refurbishment can make use of modern production technologies and incorporate major technical advances that have occurred since the weapons were first manufactured. We focus on technologies that are flexible and high quality (to provide defect-free production in a capacity-limited complex) and that use modern commercial methods wherever possible.

### Program Thrusts

Our principal program thrusts are the W87 Life Extension Program (LEP) and our development of advanced manufacturing technologies as part of the Advanced Design and Production Technologies (ADaPT) initiative. We are also developing comprehensive plans to extend the stockpile life of other Livermore-designed systems. To this end, significant effort is being expended on their surveillance, maintenance, and selective refurbishment.

The objective of the LEP is to enhance the structural integrity of the warhead so that it can remain part of the enduring stockpile beyond the year 2025 and will meet anticipated future requirements for the system. We are well along in development activities, which have included flight testing, ground testing, and physics and engineering analyses. While the production agencies are readying for the stockpile refurbishment, final assessment testing and analysis of the design will be completed. We will also be certifying product processes in 1998. The first production unit is scheduled to be completed in February 1999 and the final production unit in 2003.

As part of ADaPT, the Laboratory is teaming with the plants to develop and provide greatly improved manufacturing technologies for stockpile refurbishment and life extension of weapon systems. We have signed cooperative agreements with Savannah River and Pantex to develop and transfer technologies more efficiently in areas of mutual interest. We are also forging partnerships on production projects with the Y-12 and Kansas City plants, and we are working with TA-55 at Los Alamos on plutonium part-production technologies that reduce cost, hazardous waste generation, and radiation exposure to workers. Livermore is an important part of efforts to develop a coordinated plan to supply new weapons pits as needed for warhead refurbishment.

One area of continuing interest is the use of an ultrashort-pulsed laser for precision cutting, a technology that earned an R&D 100 Award in 1997. For the Y-12 plant, we have built a production-worthy Laser Cutting Workstation, which will have general applicability to several stockpile systems and refurbishment programs. We also demonstrated the laser system as a safe and precise tool for cutting high-explosive materials. Pantex is very interested in further development of laser cutting for high-explosive applications. In addition, we are working with the Pantex Plant to establish a pilot production capability for TATB, the explosive ingredient that, over time, will have to be replaced in stockpiled weapons. Developed by Laboratory researchers, the production process is based on an entirely new synthesis route that avoids producing chlorinated compounds dangerous to Earth's ozone layer.

In addition, to foster greater integration of work throughout the weapons complex, we are developing a complex-wide, secure, high-speed digital network. In effect, it will be a "Secure Internet" with classified information shared on a need-to-know basis. Initial implementation of the system will allow Livermore engineers and designers to have access to "as-built" production, disassembly, and surveillance data from Y-12 and Pantex during W87 life extension program refurbishment activities.

### Laboratory Initiative

- Advanced Design and Production Technologies Initiative (DP), p. 54.

## 2.1.5 Production of Tritium

### Situation and Issues

No tritium has been produced for the U.S. nuclear weapons stockpile since 1988. At present, DOE is meeting stockpile needs by recycling tritium from dismantled weapons. Because tritium decays at a rate of 5.5% per year, the total tritium inventory available without further production will decline to a level where, in the year 2007 or so, the inventory will be insufficient to maintain the current stockpile.

The DOE is pursuing a dual-track production strategy for the most promising tritium supply alternatives. One option for producing tritium is the purchase of an existing commercial reactor or the use of irradiation services (with an option to purchase the reactor for conversion to a defense facility). A second option is to design and build an accelerator system for the production of tritium. In late 1998, the DOE selected the two Tennessee Valley Authority reactors as the preferred facilities for producing a future supply of tritium. The linear accelerator option has been designated a "backup" technology.

### Program Thrusts

Livermore partnered with Los Alamos, Brookhaven, Sandia, and Savannah River National Laboratories on the Accelerator Production of Tritium

(APT) project. The design of the accelerator and the target region represented substantial technical challenges for the multilaboratory team, led by Los Alamos. Livermore has contributed to the accelerator design and made important contributions in technical areas such as beam handling and computer modeling. Our efforts in the APT project have built on the Laboratory's strengths in accelerator design and performance, computer simulation, systems design, and target design and performance. These strengths are being applied to other new initiatives in advanced accelerators.

### Laboratory Initiative

• Accelerator Technology Development (Multiple Offices), p. 67.

## 2.2 Countering the Proliferation and Use of Weapons of Mass Destruction

We apply Livermore expertise in nuclear weapons, developed over time through the Laboratory's weapons program and continuing stockpile responsibilities, to the challenge of nuclear nonproliferation. Because the threat of proliferation is not restricted to nuclear weapons, we also build on Livermore's large investment in chemical and biological science to develop technologies and expertise to stem the spread of chemical and biological weapons.

This threat is extremely complex. There are myriad routes to weapons of mass destruction—many different starting materials, material sources, production processes, and deployed weapons. There are also many possible proliferators—threshold countries, rogue states, state-sponsored terrorist groups, domestic terrorists, and even internationally organized criminals and narcotics traffickers. Motives for acquiring and using weapons of mass destruction are similarly wide ranging—from a desire to change the regional military balance, deny access to a strategic area, or alter international policy to extortion, revenge, or hate.

Our principal sponsor is the Department of Energy's Office of Nonproliferation and National Security (NN). Other sponsors include the Department of Defense, various U.S. intelligence agencies, and the Department of Energy's Office of Defense Programs. Our activities are coordinated with and complement the work of other government laboratories and agencies.

We address the problem of weapons proliferation at all stages—prevention, reversal, response, and avoiding surprise. In addition, our Center for Global Security Research provides a bridge between the technology and policy communities, exploring ways in which technology can enhance national and international security.

### 2.2.1 Proliferation Prevention and Arms Control

#### Situation and Issues

The best way to stop weapons proliferation is at the source. Of particular importance to preventing the spread of nuclear weapons are the protection, control, and accounting of nuclear materials worldwide. We also participate in programs to improve international nuclear safety. Of particular concern are the security of nuclear materials at research and manufacturing facilities in the former Soviet Union and the large quantities of surplus nuclear material resulting from Russia's retirement of thousand of nuclear weapons. In contrast, chemical and biological weapons proliferation is much more difficult to control at the source because the materials and technologies for such weapons are ubiquitous and often have legitimate uses.

For all types of weapons of mass destruction, arms control agreements—and verified compliance with the agreements—are key components to preventing proliferation and enhancing regional, national, and international security. Livermore has provided technical and analytical support to U.S. arms control efforts for more than 40 years. We have contributed to the SALT treaties; the Limited, Threshold, and Comprehensive Test Ban treaties; the START agreements; and the Chemical and Biological Weapons conventions.

#### Program Thrusts

Livermore assesses for the U.S. government the impact of proposed treaty provisions in terms of U.S. ability to monitor other countries and to protect sensitive information during foreign inspections of U.S. facilities. We also develop monitoring and verification technologies and participate in field trials to prepare for inspections in the U.S. and abroad. We are currently involved in preparations for the entry into force of the Comprehensive Test Ban Treaty (CTBT) and for initiation of the START III negotiations, as agreed to by Presidents Clinton and Yeltsin at their March 1997 Helsinki Summit.

We are responding to the critical technical challenge in monitoring compliance with the CTBT. Not only must we be able to detect, identify, and accurately locate small nuclear explosions, but we must also discriminate these nuclear events from the much larger number of small nonnuclear events (e.g., earthquakes, mining explosions). Livermore is playing a key role in the development of reliable seismic monitoring instrumentation, sensor networks, regional discriminants, and data analysis techniques. We are actively calibrating the proposed CTBT monitoring system using well-characterized earthquakes and mining explosions. In addition, we are developing and demonstrating a number of monitoring methods for On-Site Inspections (OSIs), including soil gas sampling and aftershock monitoring. We also sponsor and participate in OSI exercises to prepare for inspections at home and abroad. Parties to the CTBT may request an on-site inspection (OSI) to clarify whether a suspicious event was a nuclear test.

Efforts are under way to improve the security of nuclear materials in the former Soviet Union as part of DOE's Material Protection, Control, and Accounting (MPC&A) program. MPC&A activities are progressing with all 53 known sites in Russia and the other newly independent states. Among the MPC&A projects, Livermore has the lead at ten sites, including the Pulse Research Reactor site at Chelyabinsk-70, one of the former Soviet nuclear weapons design laboratories. We are also assisting the Russian navy and the Murmansk Shipping Company to enhance the protection of fissile fuel for their nuclear-powered vessels.

Large quantities of surplus nuclear materials are resulting from the retirement of thousands of weapons, both in the U.S. and Russia. We are collaborating with the Russians to develop suitable technologies for the management and permanent disposal of excess nuclear materials as well as mutually acceptable detection methods for use in inspections of each other's nuclear facilities and possible measures for increased transparency during the dismantlement process. For the disposition of surplus U.S. plutonium, DOE has recommended a dual-path approach to disposition of excess plutonium: reactor burning and immobilization. Livermore is the lead laboratory for the technical development of the immobilization alternative.

This past year, on the basis of our recommendation, the ceramic waste form was selected over glass, as was our can-in-canister waste package. We are now focusing on characterization, performance testing, and qualification of the ceramic form for repository disposal and on engineering development of the production process and equipment for the future plutonium immobilization plant.

We are also working with our counterparts in Russia on cooperative projects to adapt their weapons-related technologies to civilian and commercial applications. These activities address concerns about a potential "brain drain" of former Soviet weapons scientists and assist those scientists, some of the most highly trained in Russia, in applying their skills in ways that will help improve their country's economy. We are preparing to launch an initiative with Russia's closed nuclear cities to assist their transition to self-sustaining, nonweapons enterprises.

### Laboratory Initiatives


- Activities with Russia and the NIS (NN), p. 56.
- Support of Arms Reduction Treaties (NN), p. 57.
- Environmental Security (NN), p. 58.


## 2.2.2 Proliferation Detection and Defense Systems

### Situation and Issues

In order to reverse weapons proliferation, we must first detect and identify weapons-related activities. Weapons development, testing, and production all have unique indicators that, if measured, can provide clues to the intent and status of a country's weapons program. Because the clues are fragmentary and often ambiguous, we must tap many sources of information—chemical analyses of water, soil, and air; satellite imagery; industrial activity; imported equipment records; material and personnel movement—to assemble a reliable overall picture.

### Program Thrusts

If weapons-related activities are detected, the next step is to evaluate options for reversing proliferation. We provide U.S. policymakers and military planners with the tools and information needed to evaluate the implications of various actions. For example, we have developed a powerful and comprehensive system for analyzing weapons proliferation activities of foreign countries, identifying critical facilities, and evaluating consequences of possible interdiction options.

We are also developing technologies to monitor weapons proliferation activities and to protect critical U.S. facilities and troops from attack. For example, we are developing passive and laser-based remote sensing systems that can identify trace amounts of chemicals released into the atmosphere from weapons production facilities. This extremely difficult problem requires significant advances in remote detection instrumentation and data analysis techniques. Instruments under development include advanced mid-infrared lidar systems for active detection of chemical effluents, an echelle grating spectrometer, and a hyperspectral instrument. Particularly successful this past year were flight tests of our hyperspectral infrared imaging spectrometer (HIRIS). HIRIS provides both spectral and spatial information simultaneously, allowing a single instrument to serve the functions that have previously been tasked to separate instruments.

New, more capable, remote sensing systems would facilitate the monitoring of extremely difficult nonproliferation agreements and would also be valuable tools for monitoring foreign nuclear programs. However, the value of new instruments such as HIRIS depends, in large part, on how well the their data can be incorporated into expert assessments. Livermore is developing prototype tools to assist analysts in interpreting multi- and hyperspectral data in conjunction with other available data sources. Such tools are needed to help analysts interpret "chemical snapshots" of a time varying, spatially distributed WMD process in order to distinguish it from other (legitimate) process that may appear similar in many respects. This effort leverages established Laboratory programs in intelligence analysis, chemical process modeling, and sensor development.

### 2.2.3 Counterterrorism and Incident Response

#### *Situation and Issues*

Despite all attempts to prevent the spread of weapons of mass destruction and to reverse proliferant weapon programs, we must also be prepared to respond to the threatened or actual use of a nuclear, chemical, or biological weapon. We are a key participant in the national Joint Technical Operations Team (the successor to the Nuclear Emergency Search Team), the Accident Response Group, the Radiological Assistance Program, and the Federal Radiological Management Assistance Capability. Our Threat Credibility Assessment Program provides technical, operational, and behavioral evaluations of weapons-of-mass-destruction extortion threats. We also furnish emergency response personnel and equipment for such events as the Atlanta Olympic Games, the Republican and Democratic national conventions, and the Presidential Inauguration.

Terrorist use of weapons of mass destruction is a growing threat, as evidenced by the 1995 nerve-gas attacks on the Tokyo subways by the Aum Shinrikyo cult. Livermore expertise in nuclear detection, explosives, remote sensing, and other technologies is being applied to counter this threat. Working with other U.S. government agencies, we are developing capabilities for threat assessment and effects prediction, techniques for disabling terrorist devices, and technologies for the early detection and identification of nuclear, chemical, and biological weapons agents.

#### *Program Thrusts*

The DOE's Chemical and Biological Weapons Nonproliferation Program was initiated to address the threat posed by chemical and biowarfare agents. We are contributing in the areas of bioinformation, point and standoff detection, transport and fate of weapons agents, and decontamination. In a recent field trial, we demonstrated significant advances in field detection and identification of biological agents with two new detectors, a mini-flow cytometer and a mini-PCR (polymerase chain reaction) instrument. Our most advanced PCR instrument, the Automatic Nucleic Acid Analyzer (ANAA), can analyze multiple samples at a time. The ANAA does all the required sample preparation automatically, eliminating the need for a laboratory technician to prepare samples for analysis. In field tests, the performance of our ANAA far surpassed expectations, providing convincing evidence that PCR is indeed an effective technique for field identification of biological agents.

We are helping to develop the Joint Biological Remote Early Warning System (JBREWS) in a collaborative effort with Los Alamos and the DoD Joint Project Office for Bio-Defense. JBREWS is a network of sensors and communication assets to provide U.S. troops in the field with early warning of a biological attack. The system, which combines a network of commercially available sensors with the military's communications assets, is portable and flexibly deployable to any and all locations where U.S. troops are deployed. JBREWS is scheduled to be demonstrated in an upcoming Advanced Concept Technology Demonstration (ACTD). For this ACTD, Livermore has responsibility for the JBREWS control system, networking, radiofrequency communications, and system operations.

This year, we launched an important new initiative directed at civilian, urban counterterrorism needs. Urban first responders and local emergency managers play a critical role in countering and mitigating acts of WMD terrorism in the U.S. We have made contact with the emergency planning organizations in Los Angeles and New York. We participated in a major exercise in each city and are now a regular member of the Los Angeles emergency planning group. We are working with Los Alamos to understand the gaps in urban first-responder WMD capabilities and to identify capabilities within the national laboratories that could help in urban WMD emergency response. Even in the early stages of this initiative, it is apparent that technology resident at Livermore and Los Alamos can be quickly applied to counter-terrorism problems in an urban environment.

Our Forensic Science Center continues to develop new technologies to detect, characterize, and attribute the source of weapons materials, especially as applied to nuclear smuggling. We are also developing microanalytical forensic techniques, new field instruments, and sample collection techniques for use by federal and local law enforcement agencies (see Section 2.3).

#### Laboratory Initiative

• Counterterrorism (NN), p. 57.

### 2.2.4 International Assessments

#### Situation and Issues

A formal program in international assessments was established at Livermore in 1965 to analyze the Soviet nuclear threat and, shortly thereafter, the Chinese threat for the U.S. intelligence community. Since then, we have expanded our efforts to include nuclear as well as chemical and biological proliferation in smaller nations, rogue states, and terrorist groups. Of particular concern are the activities of threshold states (countries thought to be able to develop or produce nuclear weapons within a few years or less). In addition to assessment activities, we have provided expert personnel for the UN and IAEA inspections of Iraq's covert nuclear program. We also provide advice on and review export license requests for the U.S. Department of Commerce, as well as technical support and assistance to the U.S. intelligence community.

#### Program Thrusts

We assess nuclear proliferation risks in key areas of the world. Some potential proliferators have had antagonistic relations with the U.S. for years, and many are located in politically unstable regions of the world. Nuclear programs in South Asia, Southwest Asia, and North Korea are examples of grave nuclear proliferation concerns.

We also analyze the status of nuclear weapons and weapon materials in the declared nuclear states. Of particular concern are the control and accountability of nuclear weapons, materials, and technology in Russia. Economic instability and the vast quantities of nuclear materials resulting from weapons dismantlement strain the existing and future controls needed to adequately safeguard Russia's nuclear inventory.

Ongoing study efforts also focus on issues affecting the long-term maintenance of foreign nuclear weapons stockpiles. This research helps to elucidate important differences between the specific set of U.S. technical stockpile stewardship issues and the stockpile issues affecting other declared nuclear weapon states. Careful accounting for these differences can promote better understanding of activities observed at foreign test sites. This improved understanding can help resolve questions about these foreign nuclear weapons programs and about their governments' level of commitment to international arms-control initiatives.

In addition, we conduct assessments related to chemical and biological weapons. Nuclear, chemical, and biological weapons activities are often interrelated in the countries of concern. Our assessments of foreign weapons programs provide important input to policy makers and diplomats as they develop strategies for U.S. response to events affecting national and international security.

#### Laboratory Initiative

• Sensitive Compartmented Information Facility (NN), p. 58.

### 2.2.5 Center for Global Security Research

#### Situation and Issues

Technical issues comprise only a portion of the nonproliferation and counterterrorism picture. Our Center for Global Security Research (CGSR) joins technologists and policy people to examine factors that can reduce the threat of weapons of mass destruction and identify ways for technology to enhance the international security framework.

#### Program Thrusts

Areas of current and future efforts focus on four areas of particular interest:

• Managing, controlling, and reducing the threats associated with weapons of mass destruction.
• Evaluating the security implications of emerging technologies.
• Anticipating and managing threats to national and international security.
• Assessing the future role of military forces.

In its inaugural year, CGSR has collaborated with a broad spectrum of organizations and has sponsored workshops and conferences on the role of technology in peacekeeping operations, possible monitoring regimes for the Biological Weapons Convention, and policy and technology implications in critical infrastructure protection. The Center has also supported studies of why countries do or do not choose to develop nuclear weapons and of the political and technical issues in developing a systematic approach to sustainable humanitarian de-mining.

The Center's support to the President's Commission on Critical Infrastructure Protection provides an example of successfully bringing technologists together with the broader policy community to gain fresh insights into national challenges. Together with

Stanford University's Center for International Security and Arms Control, we jointly sponsored a series of three workshops on critical infrastructure protection to assist the Commission in examining the issues of infrastructure vulnerability, potential threats, and possible remedies. The workshops led to a broader and deeper understanding of the issues (see Section 2.3.2). Participants included members and staff of the Presidential Commission, the information technology industry, security specialists at infrastructure organizations, research companies, national laboratories, and the university community.

## 2.3 Meeting Other National Security Needs

Livermore is working with the Department of Defense and other agencies to leverage the Laboratory's capabilities and provide long-term research and development support to meet future security challenges.

### 2.3.1 Department of Defense

#### *Situation and Issues*

The three DOE national security laboratories work with the Department of Defense (DoD) to leverage the laboratories' capabilities and provide long-term research and development support to meet future defense challenges. The focus of future defense efforts has been the subject of a number of recent studies completed by the Joint Chiefs of Staff and the military services in addition to the Congressionally mandated Quadrennial Defense Review and the Alternate Force Structure Assessment. DoD's emerging strategy is for a military of the future that is technologically superior and dominant enough to win quickly, decisively, and with minimum casualties on all sides.

In addition to the Laboratory's proliferation detection and counterproliferation efforts (in part for DoD) discussed in the previous section, Livermore has a history of making technological advances in many relevant areas, such as missile defense, solid-state lasers, armor/anti-armor materials and munitions, conflict simulation modeling, and miniaturized sensors. For over a decade, we have been engaged in a DOE/DoD advanced conventional munitions technologies program with the Services and the Office of the Secretary of Defense. At Livermore, major focuses of this program have been the formulation of new energetic materials and the development of computer tools for design and analysis. For example, the Livermore-developed high explosive, LX-14, is now used in the TOW and Hellfire missiles. Our CHEETAH code is widely used both to predict the performance of propellants and explosives and to evaluate formulations of new energetic materials. Also, in this past year, the Laboratory developed and applied for the first time a first-principles, three-dimensional computer code to evaluate the safety of conventional munitions in a fire accident scenario.

#### *Program Thrusts*

The DOE laboratories are working to establish ways to further increase the effectiveness of the support provided to the DoD and make it even more responsive to critical needs. In particular, in response to FY 1998 Congressional authorization language, we are helping to prepare a pilot proposal for a hard and deeply buried target defeat program that would facilitate effective teaming between the DOE laboratories, DoD, and defense industry to meet important military needs in this area.

More generally, by applying Livermore's special expertise, we will contribute to meeting identified DoD defense needs in four particular areas:

- **Quick and Decisive Military Operations.** The U.S. military's ability to conduct operations quickly and decisively will heavily depend on advanced sensors, information technologies, and predictive meteorology capabilities. Livermore will use its demonstrated strengths and capabilities to pursue innovations in each of these areas.
- **Precision Weapon Systems.** Livermore will contribute its expertise in energetic materials, advanced conventional munitions, laser and electro-optics systems, conflict simulation models, and consequence analyses to the development of precision weapons systems that will allow the U.S. military to destroy adversary targets while minimizing collateral casualties.
- **Effective Protection of U.S. Forces.** The Laboratory will pursue technologies pertinent to theater ballistic missile defense and the detection of chemical and biological agents to protect U.S. forces against chemical and biological weapons.
- **Efficient Operations.** Livermore's conflict simulation capabilities will be applied to logistics issues to investigate means for efficiently supplying equipment to U.S. forces, which can make a decisive difference early in a military operation and dramatically reduce overall costs.

### 2.3.2 Critical Infrastructure Protection and Law Enforcement

#### *Situation and Issues*

Two recent Presidential Decision Directives (PDDs) address the need to better protect the nation against attacks on its critical infrastructures (PDD-63) and attacks by terrorists using WMD (PDD-62). Livermore's technologies are being applied to such important domestic national security issues as critical infrastructure protection and law enforcement.

At an LLNL-hosted workshop, "Protecting and Assuring Critical National Infrastructures," held in March 1998, Attorney General Janet Reno cited the need for "imaginative solutions" to thwart attacks on the computer-based communications systems and networks vital to the nation's infrastructures. Reno also announced the formation of a Justice Department National Infrastructure Protection Center (NIPC) to detect, protect, and respond to cyber attacks on the U.S. critical infrastructures. She noted that success in this arena will depend on the formation of effective partnerships between law enforcement, private industry, and the technical community, including the DOE laboratories.

The DOE laboratories will also be working with the Departments of Justice, Treasury, and Commerce to provide law-enforcement agencies with cutting-edge, crime-fighting technologies under a newly established "Partnership for a Safer America." In May 1998, the DOE signed memoranda of understanding with the FBI; the Bureau of Alcohol, Tobacco, and Firearms; and the U.S. Customs Service to establish formal working relationships to facilitate the transfer of DOE technology and technical expertise to law enforcement.

### Program Thrusts

The Laboratory's Computer Security Technology Center and Computer Incident Advisory Capability (CIAC) will have an important role to play in partnership with the Justice Department's NIPC. The CIAC was established by the DOE at Livermore in 1989 to help maintain the integrity of the Department's computer systems. It now serves as a national resource for the development of security tools and incident response, provides public information about network security threats through a Web site, and responds to the increasing number of incidents that occur worldwide.

As a component of critical infrastructure protection, we recently initiated a project in information operations to create an analysis tool for understanding and responding to the national security implications of global interconnectivity and the nation's exponentially growing reliance on networked critical infrastructures. The suite of software tools being developed will permit the assessment of a wide variety of systems—computing, communications, command and control, energy and power generation and distribution, transportation, chemical production, manufacturing, and economic and financial.

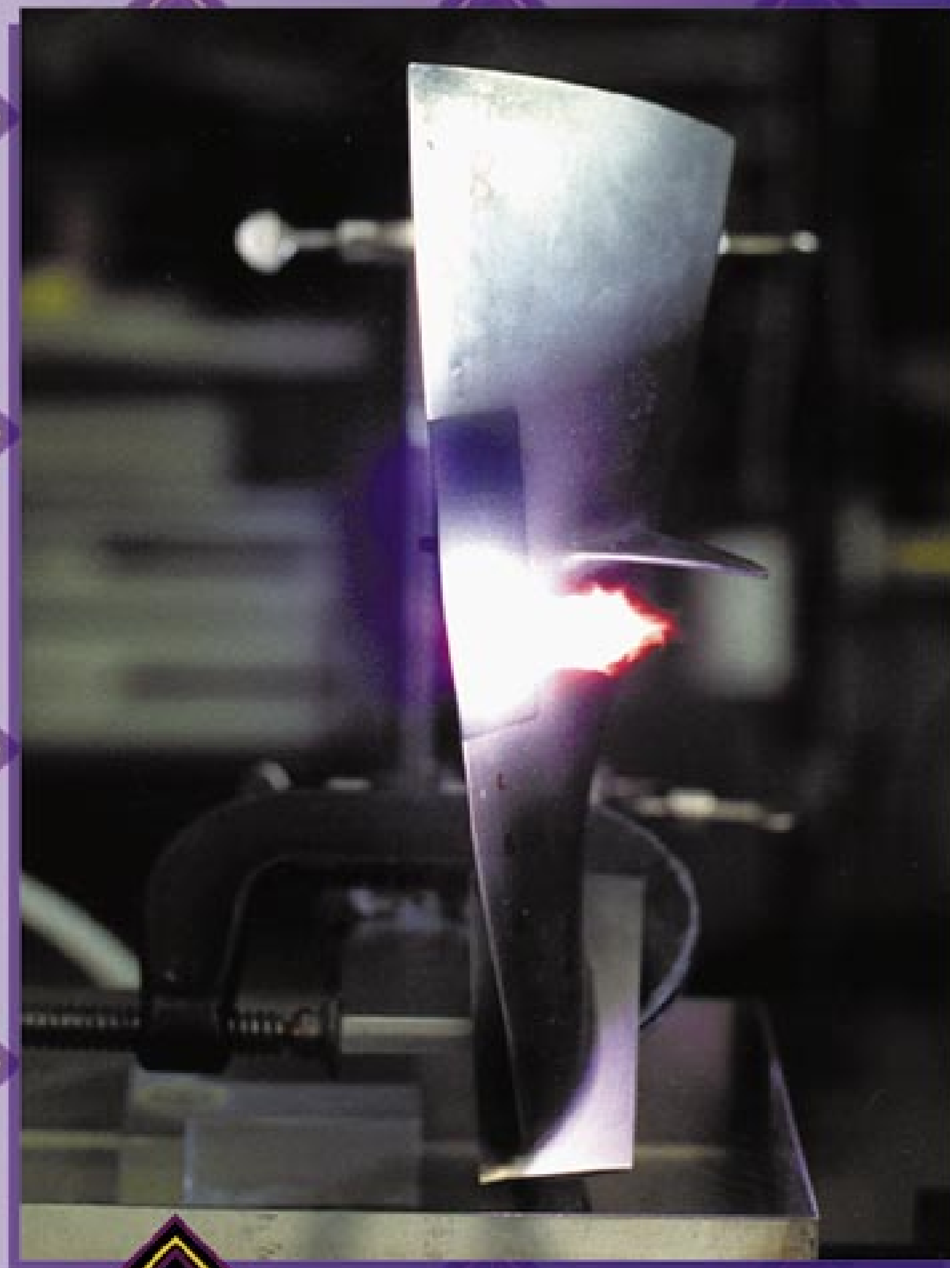
Law enforcement can benefit from Livermore technologies that were developed initially for on-site inspection of arms control treaties and for detection of WMD proliferation activities and response to WMD incidents. An example is the portable gas chromatograph–mass spectrometer (GC–MS), a system for quickly analyzing samples at the scene of a crime or accident. Potential uses for the system, which can identify chemicals to parts-per-billion sensitivity, include on-the-scene analysis of clandestine drug labs or unknown chemical releases, spills, or accidents. Using the GC–MS system, law enforcement agents will be able to identify the substance in question within 15 minutes, greatly facilitating on-scene investigation and evidence collection. Other technologies with potential application to law enforcement include thin-layer chromatography (TLC) and solid-phase microextraction (SPME). Our hand-held thin-layer TLC system can simultaneously analyze 100 samples for high explosives and other chemicals; a new digital camera image-capture system is being added to interpret the TLC results and provide first responders with a simple readout of the chemicals detected. For SPME, we have combined optical fiber technology with ultratrace analysis to create a "chemical dipstick." This technology can be used to detect the presence of illegal drugs or other chemicals of law-enforcement interest.

### Laboratory Initiative

• Critical Infrastructure Protection (NN), p. 58.

# SECTION 3





# Laboratory Science and Technology–Enduring National Needs

# Laser Peening for Metal Protection



**Lasershot$^{SM}$ Peening System, a peening process using lasers to instill deep compressive stress in materials and thereby extend the lifetime of components such as jet-engine fan blades.**

*Laser Programs and Engineering at Livermore and Metal Improvement Co. Inc.*

The Department of Energy has enduring missions that are vital to the national interest. In addition to its national security mission, the Department's priorities include enhancing the nation's energy security, developing and making available clean energy, cleaning up former nuclear weapons sites, finding a more effective and timely approach to nuclear-waste disposal, and leveraging science and technology to advance fundamental knowledge and economic competitiveness. Livermore has four major research areas in science and technology.

### *Energy*

We pursue projects aimed at significant, large-scale innovations in energy production and usage. The availability of abundant, clean, and affordable energy provides the foundation for U.S. prosperity and economic growth.

### *Earth and Environmental Sciences*

Our efforts are directed at demonstrating effective environmental remediation technologies, advancing the science base for environmental regulation, and accurately modeling regional weather and global climate conditions. We also serve as an effective national technical source in the stewardship of nuclear materials.

### *Bioscience and Biotechnology*

Bioscience research at the Laboratory advances human health by leveraging our physical science and engineering capabilities and focusing on genomics, disease susceptibility identification and prevention, and improved healthcare and medical biotechnology.

### *Fundamental Science and Applied Technology*

We also pursue initiatives that bolster Livermore's research strengths, further develop the science and technology areas needed for the Laboratory's national security mission, and contribute to solving important national problems.

Livermore's strengths are well matched to the DOE's needs, particularly in areas with high payoffs that entail significant scientific and technical risk. In addition to our national security efforts, we contribute to the other major programmatic strategic goals specified in DOE's Strategic Plan:

- **Energy Resources—**Promoting secure, competitive, and environmentally responsible energy systems that serve the needs of the public.
- **Environmental Quality—**Aggressively cleaning up the environmental legacy of nuclear weapons and civilian nuclear research and development programs, minimizing future waste generation, safely managing nuclear materials, and permanently disposing of the nation's radioactive wastes.
- **Science and Technology—**Delivering the scientific understanding and technological innovation that are critical to the success of DOE's mission and the nation's science base.

We pursue major projects in which we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths. The nation benefits from the application of Livermore's special skills to a wide range of national problems and from the cross-fertilization of ideas. In turn, program diversity keeps the Laboratory vital and helps to sustain the multidisciplinary base needed for national security work.

Three of the Laboratory's strategic councils set the strategic direction of Livermore's programmatic efforts to meet enduring national needs. The Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, and the Council on Strategic Science and Technology are responsible for tactical planning and formulating a strategy for long-range program and resource development in their areas of interest.

## 3.1 Energy and Environmental Systems

The future security of the U.S. and the world depends on increased access to clean energy and on the preservation of a healthy environment. Many important advances are needed to ensure a prosperous, healthy, and secure future. Livermore's role is to apply its core capabilities to enduring national needs that require innovative science and technology. Our energy and environmental programs reflect the scale, technical reach, demonstration orientation, and expertise needed for Livermore's national security mission. These programs also enrich the Laboratory's capabilities to provide for national security.

Livermore is a leading science and technology laboratory in energy and environment. As a resource to government, in partnership with industry and universities, we develop new energy and environmental capabilities for the nation. Our expertise and accomplishments in these areas enhance the Laboratory's primary mission in national security.

The principal goals of our energy and environmental programs are to provide the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reduce environmental risks to U.S. interests. Reaching these goals will require significant technological advances as well as broad cooperation among institutions. Our efforts are focused on five critical areas in which the Laboratory can make a significant and positive difference.

- **Nuclear Materials Management.** Nuclear materials management is a fundamental, compelling, and enduring responsibility of DOE. Regardless of the future of nuclear weapons or nuclear energy, DOE will be responsible for a vast array of nuclear materials for generations to come. Livermore is a key contributor to nuclear materials stewardship through our stockpile stewardship and nonproliferation activities and the support we provide to DOE's missions in material disposition, waste management, environmental cleanup, and nuclear energy. In partnership with other DOE laboratories, we will work to develop an integrated approach to nuclear materials management to increase efficiency, reduce costs, and provide greater safety in all nuclear-materials-related activities.

• **Advanced Utility (Fixed Energy) Systems.** The Earth's resources are finite, and expanding economies around the world are putting stress on traditional sources of energy and natural systems. Current technologies are not adequate to meet growing demands. Significant, large-scale innovations are needed to provide clean, universally accessible, non-resource-depleting energy production. Livermore will conduct inertial fusion experiments with the National Ignition Facility and pursue advanced magnetic confinement fusion schemes to identify and make progress along the most promising path to full-scale deployment of fusion power. To meet nearer-term needs, we will also pursue research to provide more viable fission energy options for the future. In addition, the Laboratory's strengths in materials, instrumentation, and computational modeling will be applied to develop more efficient coal, energy storage, renewables, and sequestration technologies. Security considerations also warrant new exploration and production methods for hydrocarbon fuels.

• **Advanced Transportation (Mobile Energy) Systems.** Transportation systems, which are a leading contributor to greenhouse gases, increasingly will become targeted for $CO_2$ emission reductions. About 30% of the global $CO_2$ emissions from fossil-fuel stems from the use of oil for transportation. To sustain economic growth and reduce congestion, there is a need to develop transportation systems that are environmentally more benign, economically competitive, and secure from geopolitical instabilities. Livermore's expertise and programs in advanced materials, systems modeling, alternative fuels (e.g., hydrogen), and energy conversion and storage (e.g., fuel cells) provide the basis for expanded work in this area.

• **Atmospheric Prediction of Climate and Weather Processes.** A grand challenge that faces the international scientific community is determining the record of Earth's climate over recent centuries and assessing whether humans significantly impact the global and regional climate. As a major contributor to the international global climate modeling effort, Livermore supports DOE's mission to understand the environmental consequences of fossil-fuel use by capitalizing on the Laboratory's strengths in modeling and atmospheric sciences and the computing capabilities available through DOE's Accelerated Scientific Computing Initiative (ASCI). We are also working to develop more accurate weather forecast modeling at the regional scale. Improving climate and weather models requires a much better understanding of the relationships among the atmosphere, ocean, and land systems. Our goal is to be a leader in DOE's Accelerated Climate Prediction Initiative for developing and integrating predictive atmosphere–ocean models on a global-to-local scale. Use of these models will facilitate responsible environmental management, reliable weather and climate predictions, and anticipation of and effective response to natural and terrorist environmental emergencies.

• **Environmental Risk Reduction.** The DOE has major environmental responsibilities. Dealing with the legacy of Cold War nuclear weapons production is estimated to cost $200 billion to $350 billion. This monumental task would greatly benefit from the use of faster, more cost-efficient cleanup technologies, such as the accelerated remediation techniques that have been developed at Livermore and demonstrated in Visalia, California. Opportunities exist to accelerate cleanup at DOE contractor sites, at DoD property being released for public use, and at Superfund sites throughout the U.S. In addition, the Laboratory has available extremely sensitive techniques for determining the mutagenic and carcinogenic potency of chemical pollutants. We will develop new technologies that reduce the time and cost to achieve specific risk reductions, complete the engineering demonstrations needed to bring these technologies to commercial use, and advance the scientific basis for risk assessment and regulatory reform.

### 3.1.1 Nuclear Materials Management

#### *Situation and Issues*

Nuclear materials management (NMM) is a fundamental, compelling, and enduring responsibility of DOE. Regardless of the future of nuclear weapons or nuclear energy, DOE will be responsible, both internationally and domestically, for a vast array of nuclear materials for generations to come. Because of the importance of proper management of nuclear materials to the strategic objectives of DOE, NMM in one form or another is a major, ongoing responsibility of the Department.

By implementing an integrated strategy for NMM, the DOE will be recognized—at home and abroad–as the pre-eminent U.S. organization for nuclear materials science and technology.

DOE's responsibilities in NMM will be to ensure the safe, secure, and responsible use of nuclear materials throughout their life cycle, both in the U.S. and abroad. Specific objectives of this mission will be to:

- Establish a national nuclear policy framework for implementation of the national security agenda through international cooperation.
- Build on recent steps—such as the Materials Protection, Control, and Accountability (MPC&A) concept—to assure transparency, safety, security, and legitimate use of nuclear materials worldwide.
- Re-establish and assert U.S. influence globally though cooperative cradle-to-grave nuclear energy research and development.
- Ensure the efficient management, use, storage, and disposal of nuclear materials.
- Be an enabler and patron of nuclear science to sustain a national resource of nuclear scientists, engineers, and facilities.

The direct benefits of integrated management of nuclear materials will be increased efficiency, reduced costs, and greater safety as the DOE carries out its stockpile stewardship and nonproliferation missions and meets its obligations in nuclear energy, material disposition, waste management, and environmental cleanup. Asset-management decisions should hedge against an undue erosion of our domestic capabilities or a deterioration of our ability to influence international nuclear developments. Rather, to the extent possible, they should help to focus and provide an integrated set of capabilities for the U.S. to engage important nuclear issues in the next century. Success in nuclear materials stewardship will also enhance DOE's technical and management credibility, help preserve the option for nuclear power in the U.S., and maintain U.S. leadership in the international nuclear materials arena.

Livermore is outstanding among U.S. national laboratories in both the scope and focus of its nuclear activities, from weapons materials research and management to nuclear fuel-cycle technology (including disposition of high-level wastes), nuclear systems safety, uranium atomic vapor laser isotope separation, and nuclear-related environmental and public-health assessments. This experience base gives Livermore the expertise and ability to provide key elements of a comprehensive U.S. stewardship program for nuclear materials.

### *Program Thrusts*

We want to be recognized as a major national technical resource for ensuring safe, secure, economic, and environmentally sound conduct of nuclear operations. To this end, we will develop technical solutions for secure, safe, and coordinated management and control of nuclear materials. We have already begun to apply Laboratory expertise to major, identified nuclear materials management issues. Livermore is partnering with other DOE laboratories to develop a comprehensive roadmap for nuclear materials management. We will work with cognizant federal agencies to analyze key segments of U.S. nuclear materials regulations and definitions with respect to nuclear materials types, quantities, values, risks, and origins.

Livermore will also work to resolve issues regarding long-term storage of high-level nuclear waste. For the Yucca Mountain project, we have played a major role in the design of the storage canister and engineered barrier, pioneering the approach of using waste-generated heat to keep the storage environment dry. Work has just begun on developing the integrated repository systems model, including infiltration, thermal effects, and reactive flow. This work will help to optimize the technical performance of the repository.

In addition, the Laboratory supports the U.S. Enrichment Corporation in commercial application of laser-based uranium enrichment technology. Our design, financial analysis, and technical demonstration of laser isotope separation will support production-scale implementation of the technology by the U.S. Enrichment Corporation.

### *Laboratory Initiative*

- Nuclear Materials Management (Multiple Program Offices), p. 66.

## 3.1.2 Advanced Utility (Fixed Energy) Systems

### *Situation and Issues*

To establish the scientific basis of energy production from nuclear fusion is a long-standing goal at Livermore. The synergy of our fusion research and defense programs affords advantages in fusion research not found at other institutions. Through experiments using the Nova laser system, inertial fusion code development, and experience gained from underground thermonuclear testing, we are the leader in the worldwide effort to demonstrate the scientific feasibility of inertial fusion. These activities have established a solid basis for predicting the performance of the National Ignition Facility (NIF), a cornerstone of the Stockpile Stewardship Program that is now under construction at Livermore. NIF is the critical facility for continued worldwide development of inertial fusion technology.

In the area of magnetic fusion research, the tokamak concept has been used to advance the science of high-temperature plasmas. Now attention is being focused on advanced and alternative plasma confinement concepts, such as the spheromak. The spheromak has an internal dynamo to create its confining magnetic field and is therefore a much simpler and more flexible engineering concept than a tokamak. Livermore is analyzing, building, and testing a spheromak.

In both our magnetic and inertial fusion efforts, numerical simulation is crucial to success. Access to the new ASCI computer will increase our computational capability by more than three orders of magnitude in the next few years. An increase in DOE funding allocated to Livermore for magnetic fusion computing will allow us to take much greater advantage of the ASCI capabilities.

Because fusion is a clean energy option that will not be available for decades, security considerations warrant a renewed examination of fission energy alternatives and new exploration and production methods for hydrocarbon fuels and other alternatives.

#### *Program Thrusts*

Livermore is working to establish the scientific basis for demonstrating fusion power. To this end, our goal is to demonstrate for the first time in a laboratory fusion ignition and energy gain using inertial fusion in the National Ignition Facility (NIF). NIF is now under construction at Livermore and is scheduled to be completed in 2003. Demonstration of fusion ignition and energy will be conducted in parallel with a research program on fusion driver concepts (ion-beam accelerators and lasers) to meet the efficiency and repetition-rate requirements of inertial fusion power plants.

Livermore is also initiating a test of a 1-meter spheromak that will allow us to demonstrate modest heat containment in the presence of dynamo action, achieve a significant plasma temperature in the few-hundred-electronvolt range, and begin to examine issues of magneto-hydrodynamic stability. Beyond this experiment, a new facility will be required. In addition, as our resources permit, we will move toward ASCI-compatible integrable code structures for magnetic fusion. In-house ASCI computing capabilities will be used to model fusion physics phenomena and to design and analyze integrated fusion reactions and systems.

We will also explore technologies that can lead to significant, large-scale innovations in energy production and usage. The Laboratory's strengths in materials, instrumentation, and computational modeling will be applied to develop more efficient coal, energy storage, renewables, and sequestration technologies. In addition, we will contribute to basic research efforts that improve the safety and waste management, lower the costs, and increase the proliferation resistance of future fission energy reactor systems. These activities will build on many of the Laboratory's capabilities and activities gained from work in nuclear materials stewardship.

#### *Laboratory Initiatives*

- The National Ignition Facility (DP), p. 51.
- Spheromak Fusion Reactor (AT), p. 60.

### 3.1.3 Advanced Transportation (Mobile Energy) Systems

#### *Situation and Issues*

New technology appears to make feasible the use of hydrogen as a clean, secure transportation fuel. Hydrogen-powered fuel-cell or hybrid electric cars are expected to have fuel costs comparable to today's gasoline cars. The development of a domestic alternative-fuels industry offers the potential for dramatically reducing the use of imported oil, now costing the nation $50 billion annually. In addition, these technologies present an opportunity to reduce the health costs of urban air pollution (as high as $100 billion annually) and the chance to eliminate 25 billion tons of $CO_2$ emissions in the U.S. by 2050. Alternate fuels can be introduced expeditiously into the economy through the development and application of separation and $CO_2$ sequestration technologies, which have been proposed to extend the use of fossil fuels without endangering the environment.

As an example, Livermore has established a leadership role in the DOE hydrogen program (currently $15 million a year). A significant increase in DOE funding for hydrogen power looks imminent. We reinvigorated the concept of using electrolysis and the existing electrical infrastructure as an economic means of initial hydrogen production. We have also developed multilayer, thin-film technology for efficient solid-oxide, hydrogen fuel cells. Our technology innovations provide the conceptual bases for hydrogen-powered vehicles.

#### *Program Thrusts*

We will expand the existing technology base for integrated alternative-fuels production, fueling, and automotive drive systems. In particular, we will develop technologies for very efficient steam electrolysis, for auxiliary energy storage capabilities (flywheel and supercapacitors), and for practical, safe storage of hydrogen fuel onboard a vehicle. We will continue developing an economic analysis code for optimizing the deployment of hydrogen transportation systems, both during the early stages of transition and for their ultimate integration with renewable and nuclear carbonless energy sources.

In addition, Livermore will work in partnership with others to develop a comprehensive plan for implementing alternative-fuels transportation systems using economic analysis tools that incorporate environmental and national–international security considerations. At each stage of implementation, the plan will include technical options that are financially attractive enough to ensure significant market penetration of these fuels.

***Laboratory Initiative***

• Hydrogen as an Alternative Fuel (AR), p. 65.

### 3.1.4 Atmospheric Prediction of Climate and Weather Processes

***Situation and Issues***

With the advent of tera-scale supercomputing (through ASCI), DOE and several of its laboratories are planning the Accelerated Climate Prediction Initiative (ACPI) within a DOE Strategic Simulation Initiative. Livermore is a principal in this planning process. We expect to play key roles in developing both simulation models and the infrastructure needed to support these activities (e.g., code and data standards, data bases and archives, and the computer network). Livermore also has major responsibilities in the Program for Climate Model Diagnosis and Intercomparison, and we are responsible for the development of atmospheric physical and chemical models directed at specific critical issues such as ozone, $CO_2$, and aerosols.

In preparation for an expanded effort in climate and weather prediction modeling, we are focusing on parallelization of our codes to increase their speed and resolution, and we are incorporating better physics simulation models and physics data to improve accuracy. In addition to these improvements, we have recently collaborated with the Naval Research Laboratory at Monterey, California, to adapt their regional weather model for use on highly parallel computers and couple it to our global- and local-scale models. This capability enables us to predict rainfall patterns in California, such as during the recent El Niño season, with encouraging accuracy.

With atmospheric modeling capabilities, ASCI-scale computers, and national security access and responsibility, Livermore is poised to develop the nation's premier capability for atmospheric dispersion prediction and emergency response on all critical time scales and space scales around the globe. We are responsible for the National Atmospheric Release Advisory Center and work closely with customers in the national security arena, who require increased environmental services.

Finally, Livermore is one of the most expert institutions on clathrates—hydrate ices that contain methane and carbon dioxide. We expect the intentional use of clathrates in their natural role to assume greater importance as we learn more about these strange ice forms. Clathrates containing carbon dioxide might provide a method for carbon seabed sequestration, while methane trapped in seabed clathrates might provide future energy sources or could contribute to global warming if released in an uncontrolled way.

***Program Thrusts***

Using coupled atmosphere–ocean simulation codes integrated with data from satellites and other sensor systems, we will achieve unprecedented prediction, speed, and accuracy in our climate, weather, and atmospheric dispersion modeling. This expertise can be applied to military and civilian uses including treaty negotiations and monitoring, energy and environmental policy analysis, and emergency preparedness and response.

Livermore will pursue a long-term relationship with DOE and DoD to provide on-demand operational capability and analysis of continuing national and international issues. This massive effort will require integrating a wide variety of models (from enhanced physics to ecosystem response), transforming the codes to the ASCI environment, and managing vast volumes of data while providing timely, customer-focused results. Our efforts will be structured to deliver an evolving capability in atmosphere–ocean modeling with global to regional predictive capability integrated with new data-assimilation systems. We will provide dependable service for emergency, military, and political management of emerging regional and global environmental situations.

***Laboratory Initiative***

• Accelerated Climate Prediction Initiative (KP), p. 59.

### 3.1.5 Environmental Risk Reduction

***Situation and Issues***

By using Livermore's recent innovations in remediation technology and tools to assess the health risk from low-level exposure to toxic materials, the national mortgage of environmental cleanup can be significantly reduced. In a demonstration of an innovative remediation technology in Visalia, California, the rate of soil and groundwater cleanup was increased by nearly 5,000 times, achieving in six weeks what would have taken 600 years with conventional techniques already in use at that site. The work was executed by Southern California Edison, with consulting assistance from Livermore and the University of California. The technology used at Visalia—a combination of dynamic stripping and hydrous pyrolysis/oxidation—is in the process of commercialization. We would like to assist with its application at Savannah River, Portsmouth, Hanford, and DoD sites, such as Mare Island.

Livermore offers a portfolio of assessment, control, and remediation technologies demonstrated through work with industrial partners. For example, we have shown that we can control and pull back a distal underground plume of contaminants by pump-and-treat techniques. In addition, we are using accelerator mass spectrometry to assess the effects on human health of carcinogens at realistic environmental exposure levels. This science and technology can greatly improve the effectiveness of remediation strategies in reducing health hazards.

#### Program Thrusts

To reduce environmental cleanup costs within DOE and nationwide, we will develop and implement accelerated remediation technologies, which will not only reduce the cost of cleaning up subsurface contamination but will also allow land to return to productive economic uses more quickly. Our strategy will be to target DOE, DoD, and civilian contamination problems as technology development and application opportunities. To validate the performance and the economics of our technologies for other federal and commercial cleanup sites, we will continue building working relationships with industry and regulators on small and large scales and develop the engineering and economic bases for advanced remediation technologies.

Together with industry, university, and regulatory partners, we will form and direct a consortium to apply the extreme sensitivity of accelerator mass spectrometry to understanding mutagenic and carcinogenic mechanisms of chemical pollutants. Our goal is to determine the actual genetic effects—ones that damage and repair—from exposure to environmentally relevant levels of toxic materials, thereby aiding the transition to science-based risk analysis. Problem owners and regulating agencies will then have the basis for planning the most effective risk reduction and remediation expenditures. Inclusion of regulatory agencies in the consortium is essential to ensure support, confidence, and use of the results of the work.

#### Laboratory Initiative

- Center for Fuels Assessment (EE), p. 64.

## 3.2 Bioscience and Biotechnology

Working with academia, industry, and government, we are leveraging the Laboratory's capabilities in the physical and engineering sciences to conduct biosciences and biotechnology research of national importance. Livermore is part of an accelerating revolution in biology and biotechnology. The groundwork for this revolution was laid in the 1980s with a shift of the national research strategy toward large-scale, complex projects, notably the Human Genome Project. This project, in which Livermore is a significant participant, is creating material resources, technologies, and information to set the stage for dramatic advances in the next century.

Livermore's bioscience program grew out of a long-standing biomedical research mission to identify and characterize the effects of ionizing radiation on human health, which led to the development of sensitive instrumentation for genomics research. Today and in the future, research activities in biology, biotechnology, and healthcare fit well in a technology-rich, multidisciplinary, broad-based national laboratory. The core program in biosciences is multidisciplinary, drawing upon Livermore's matrix organization in physical sciences and engineering. Many of bioscience program staff are physicists, chemists, engineers, mathematicians, and computer scientists who are brought in from the diverse laboratory infrastructure and who work side-by-side with the core biologists and biochemists.

A hybrid vigor results from the cross fertilization of talents and, moreover, provides our bioscientists access to the latest technologies in physical sciences and engineering inherent in the parent discipline organizations. Conversely, bioscientists at Livermore make significant contributions to national security activities and other major programs at the Laboratory. For example, we are developing detection technologies to monitor and characterize biological weapon proliferation activities and to respond in the event of an emergency. This very important "spinback" to the Laboratory's defining mission increases the benefits to the nation of sustaining a strong bioscience and biotechnology program at Livermore.

Many grand challenges are associated with the biosciences. We identify three that align with DOE's and the Laboratory's missions and draw upon our existing personnel talents and core competencies.

- **Genomics:** How living systems function; how we use that information to enhance our nation's security, preserve our environment, and ensure a better quality of life.
- **Disease Susceptibility—Identification and Prevention:** What causes disease; why some people are more susceptible than others; what we can learn to prevent it.
- **Healthcare and Medical Biotechnology:** What tools we can provide for cost-effective, high-quality healthcare for our nation.

Bioscience and biotechnology research at Livermore is supported by diverse sources. For many years, most of the funding for Livermore's bioscience program came from the DOE Office of Health and Environmental Research (OHER). More recently, OHER support has hovered around 50% of the overall budget. That office supports major research efforts at Livermore, including the Joint Genome Institute activities. Our focus remains on serving the needs of DOE OHER and developing with them new program opportunities. Additional support comes from other sources such as the National Institutes of Health (NIH), other government sources, and industry. The NIH is the major funding source for biosciences research in the U.S., and funding from this agency is expected to continue growing. NIH and peer-reviewed funding is essential for LLNL bioscientists to maintain credibility with their peers. Moreover, with funding from multiple sources, the Laboratory enriches the biosciences research program for DOE, and we are able to apply the Laboratory's special science and engineering skills to meet the important needs of a variety of sponsors.

***Laboratory Initiative***

- Office Space for Biology and Biotechnology Research Program Staff (KP), p. 63.

### 3.2.1 Genomics

***Situation and Issues***

Genomics is a multidisciplinary science whose goals are to characterize the genetic material of mammalian, plant, and microbial species. Research efforts include studies of genome organization (examination of the interposition of genes with structural and regulatory elements in DNA), identification of genes, and prediction of the proteins that genes produce. Comparative genomics (cross-species analysis) is an important method to study evolution, gene function, and human disease.

The enabling technologies for genomics research include physical mapping, DNA sequencing, gene discovery, computations and informatics, and automation and robotics. The development of DNA sequence identification as a unique identifier of species or individuality is relevant to this effort. In particular, Livermore's Human Genome Center has been at the forefront of DOE's efforts to advance the needed technologies and perform accurate, high-throughput DNA mapping and sequencing of the human genome. The efforts of the center have recently merged with the two other DOE genome centers at Berkeley and Los Alamos national laboratories to create the DOE Joint Genome Institute (JGI). The institute's primary task is to map and sequence by 2005 a substantial fraction of the 3 billion total bases of the human genome. In addition to our work with the JGI, we are working with universities and other research institutions to provide a comprehensive public collection of complementary DNA (cDNA) clones. The DOE-sponsored I.M.A.G.E. Consortium, based at Livermore, includes over 1.5 million arrayed clones, 1.5 million sequences, and over 15,000 mapped cDNAs.

***Program Thrusts***

We are committed to providing the technical and managerial support required for the JGI to succeed in its ambitious goals. In partnership with Lawrence Berkeley and Los Alamos national laboratories, we have developed and are currently implementing a strategy for "production mode" DNA sequencing. Central to this production mode is the operation of a new DNA sequencing facility in Walnut Creek, California. Success in production sequencing also depends on an effective program of new technology development, which will make efficient use of the laboratories' capabilities as well as external sources. In particular, Livermore's expertise in engineering and the physical sciences will be applied to develop new instrumentation, automation, and integrated robotics systems to minimize human intervention, reduce error, and reduce costs. Production sequencing and characterization efforts will be targeted on biologically selected genomic domains of roughly megabase sizes that promise to deliver the greatest return on investment.

The JGI will provide immediate and full public data release and will rely on Livermore's unique computing and bioinformatics expertise to provide for analysis, storage, and networking of data.

For our microbial studies, we couple our technologies and competencies in the national security area (e.g., biological nonproliferation and counterterrorism) with those in the biological sciences (e.g., microbial genetics, enzymology, genomics) and in engineering (e.g., microfabricated bioinstruments). Applications relevant to national security include the detection and biological signature analysis of samples collected from air, soil, or water. Specific applications of genomic technologies support our national security, energy, and environmental programs. Of interest are methods and resources to identify species within the animal, plant, and microbial communities for use in forensic, bioremediation, or biodiversity applications. Such methods might be DNA- or antibody-based, but new technologies are also sought. Important to these methods are automated approaches for scale-up, miniaturization, and multiplex analysis.

### Laboratory Initiatives

- Joint Genome Institute (KP), p. 61.
- Microbial Genomics (KP), p. 62.

## 3.2.2 Disease Susceptibility Identification and Prevention

### Situation and Issues

The focus of research in disease susceptibility and prevention is the relation between an individual's genes and disease. Cancer and other human diseases are often caused by defective proteins or damage produced by radiation or by molecules that bind to and alter DNA. To understand the structure of proteins and defects in the structure, we must rely on high-resolution experimental methods and computational modeling of the molecules.

Research at Livermore already has led to identifying the genetic causes of a number of diseases, such as two forms of dwarfism. Other efforts have led to a clearer understanding of the role of cooked food (food mutagens) in genetic changes and cancer. In these activities, we have been able to draw on existing capabilities at the Laboratory, including cloning, gene expression, biophysics and structural biology (crystallography, x-ray diffraction, and nuclear magnetic resonance), analytical chemistry (biological accelerator mass spectroscopy), computational biology, and bioengineering.

### Program Thrusts

Our goals are to identify genes that control individual susceptibility (with emphasis on DNA repair genes), understand how the associated proteins might be involved in the disease process, assess human variability for these genes, and estimate risk for disease based upon an individual's genetic constitution. We will couple this research to genomic approaches, which should expedite rapid discovery. A special focus area will continue to be risk assessment of ill health from adverse exposure to radiation and chemicals, either directly through human studies or based on cellular and animal data.

Livermore maintains state-of-the-art x-ray crystallography and nuclear magnetic resonance facilities, for both our own research and external collaborations, as well as a protein structure prediction center for the scientific community. We will develop new molecular, instrumentation, and computations methods that will allow the genome of any organism to be scanned and analyzed quickly for gene content and function. By coupling biophysical measurements of protein structure with computational approaches for protein folding and function prediction, we may be able to link gene and protein information to measure genetic variation and biochemical function in humans. These efforts will take advantage of the unique high-speed computing capabilities at Livermore.

### Laboratory Initiatives

- Disease Susceptibility: Genetic and Structural Basis (KP), p. 62.
- Computational Biochemistry (KP), p. 62.

## 3.2.3 Healthcare and Medical Biotechnology

### Situation and Issues

Affordable, accessible healthcare has become an issue of national importance. Each year in the U.S., about 14% of the gross domestic product is spent on health care—about $3,000 for every American. Livermore researchers are working to develop more cost-effective healthcare technologies. Projects exploring improved or new healthcare technologies evolve at Livermore from diverse research efforts, in many cases applying or adapting technologies, devices, and processes that were developed for our national security mission. Livermore efforts are already having an impact on the frontiers of research and in the treatment of such maladies as cancer, heart disease, stroke, diabetes, osteoporosis, and repetitive strain injury as well as such specialty fields as ophthalmology and prosthesis design and manufacture. The ultimate goal of such work is to transfer new, cost-effective devices to industry for manufacture.

Our efforts are usually multidisciplinary and often involve external collaborators. We work closely with healthcare deliverers and industry to develop and demonstrate novel healthcare technologies, such as high-tech tools to aid stroke treatment. Increasingly, industry is expressing interest in partnering in and funding development activities. We benefit from our proximity to the San Francisco Bay Area's biotechnology firms, many of which lead the country in research.

### Program Thrusts

Current major application areas include medical device development for diagnosis and treatment of stroke, radiation treatment planning, and patient monitoring. Projects combine the Laboratory's expertise in sensors, imaging, computational physics, informatics, microfabrication, and lasers with university and industry knowledge in biomedicine. For example, Livermore is developing novel methods and surgical tools for the treatment of stroke. We have adapted physics simulation capabilities into a unique planning tool (PEREGRINE) for radiation treatment of cancer, which could help the more than 350,000 Americans each year diagnosed with a curable form of cancer. We will also explore the establishment of a molecular medicine program to couple our strengths in molecular and cellular biology to the development of diagnostic instruments and, ultimately, to clinical treatment.

## 3.3 Fundamental Science and Applied Technology

One of the DOE's primary missions is to provide capabilities that enable the U.S. to maintain its world leadership in science and technology. It is widely recognized that the nation's advances of fundamental knowledge and innovation provide the U.S. an advantage in an increasingly competitive world.

The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-the-art applied technology is used to advance fundamental science in areas pertinent to the Laboratory's major missions, in some cases relying on Laboratory Directed Research and Development funding. For example, we have successfully demonstrated that adaptive optics using a laser guide star can correct for atmospheric turbulence. Livermore's development and installation of a laser guide star on the 10-meter-diameter Keck II Telescope on Mauna Kea, Hawaii, will significantly improve the quality of its images.

The Laboratory's scientific advances—and technologies developed in pursuit of fundamental science—have important spinoff and spinback applications. The laser guide star technology is also helping us in the design of the National Ignition Facility. The discovery of fluid metallic hydrogen—a new state of matter—contributes to planetary science and generates new knowledge about the properties of hydrogen needed for Laboratory programs. Livermore's petawatt laser enables physics experiments never before possible and also has precision cutting applications for advanced manufacturing in stockpile management and broader applications. Technologies developed to build the petawatt laser are enabling revolutionary advances in flat-panel displays for computers and televisions. In addition, materials synthesis and materials engineering at the atomic level have led to the development of an aerogel dielectric that will contribute to continued advances in integrated circuit performance. These developments have also led to multilayer optics (grown layer by layer) that have mapped the x-ray spectrum of the sun in incredible detail and provided extraordinary images of its surface.

The DOE Strategic Plan specifies the Department's strategic objectives in science and technology, which are:

- To develop the science that underlies DOE's long-term mission.
- To deliver leading-edge technologies that are critical to the DOE mission and the nation.
- To improve the management of DOE's research enterprise to enhance the delivery of leading-edge science and technology at reduced costs.
- To assist in the government-wide effort to advance the nation's science education and literacy.

Our fundamental science and applied technology efforts align with the DOE's objectives. To develop the science that underlies DOE's long-term mission, we sustain and strengthen the Laboratory's science and technology base through effectively managed internal investments in Laboratory Directed Research and Development, including:

- **Laboratory Directed Research and Development (LDRD).** LDRD supports research and development projects that enhance Livermore's core strengths, expand DOE's and the Laboratory's scientific and technical horizons, and create new capabilities in support of the Laboratory's missions. These investments help Livermore to meet challenging, long-term mission needs effectively and to respond promptly to national priorities as they change.

We further develop the science that DOE requires and deliver leading-edge technologies to the nation by applying the special expertise and capabilities of the Laboratory, which are needed for our national security mission:

- **Application of Mission-Directed Science and Technology.** Excellence in science and technology is required for the Laboratory to achieve mission goals. Livermore has developed a strong science and technology infostructure that is focusing on problem solving to meet the demands of our missions. As an institution with stable mission responsibilities and program continuity, Livermore has acquired considerable knowledge and expertise and has unique research facilities and capabilities. It also enables us to meet other important national needs and to respond to new challenges.

We deliver leading-edge technologies and contribute to DOE's management of its laboratories as an integrated system through partnerships with industry and other laboratories:

- **Partnerships That Create New Capabilities.** Partnering has been important at the Laboratory ever since our establishment as part of the University of California and the early days of supercomputer development to meet the needs of the weapons program. It will play an even more significant role in the future. Partnering activities will span a wide range—from very-large-scale strategic alliances and "virtual laboratories" to licensing of individual technologies, academic research, and support for the small business community. Partnerships and collaborations help us accomplish our programmatic goals more efficiently and cost effectively. We also work with others to share expertise and make available research capabilities.

The Laboratory also partners with universities and advances the nation's scientific and technical literacy through academic collaborations and science education programs:

• **Effective Academic Collaborations and Science Education Programs.** As a part of the University of California and a DOE national laboratory, Livermore shoulders significant science education responsibilities. By making the Laboratory's research facilities and staff accessible to the academic and industrial communities, we provide valuable opportunities to visiting researchers while we strengthen our science and technology base. We are home to several University of California scientific research institutes and other centers that support hundreds of ongoing projects with faculty, post-doctoral fellows, and graduate students. We also help train the nation's next generation of scientists and engineers through our science and technology outreach programs that span every educational level.

## 3.3.1 Laboratory Directed Research and Development

Since its inception, Livermore's Laboratory Directed Research and Development (LDRD) Program has provided support for many important and innovative scientific and technological advances. The LDRD Program has played and continues to play a vital role in developing new science and technology capabilities that respond to the DOE and Laboratory missions and in attracting the most qualified scientists and engineers to the Laboratory. LDRD is one of the Laboratory Director's most important tools for developing and extending the Laboratory's intellectual foundations, for enhancing its core strengths, and for driving its future scientific and technological vitality. Research and development that expands the horizons of science and technology is essential to the continued vitality of the Laboratory and its ability to meet future mission needs.

LDRD was established by Congress as a means for DOE laboratories to directly fund creative, innovative basic and applied research activities in areas aligned with their principal missions but not immediately supported by sponsors. In FY 1998, LDRD at Livermore was funded the allowed annual level of 6%, with a budget of $56.8 million. LDRD funds are reinvested in the mission areas of sponsoring programs and in R&D projects that align with the strategic vision of the Laboratory. Accordingly, Livermore's LDRD portfolio has a strong emphasis on national security. Each year Livermore's proposed plan and requested program funding is evaluated against Congressional requirements regarding support of national security programs. Based on our assessments for the past four years and an estimate of the FY 1999 portfolio, national security sponsors of work at Livermore receive an LDRD return than far exceeds the 6% investment—over 90% of the Laboratory's LDRD projects contribute to our national security missions.

In fact, all sponsors of research and development at the Laboratory draw a return greater than their LDRD investment. Livermore's LDRD portfolio reflects the Laboratory's focus on its special capabilities, which are applied to multiple mission areas, and on advancing those areas of science and technology to simultaneously address a number of enduring national needs. Many LDRD projects advance capabilities that are important to more than one mission area—for example, ASCI-scale computing, fundamental materials science, advanced sensors and instrumentation, diode lasers, and geoscience.

### *Program Structure*

Livermore's LDRD Program has three major components: Strategic Initiatives, Exploratory Research, and the Laboratory-Wide Competition. In FY 1998, about 25% of the funding was invested in Strategic Initiatives, about 70% in Exploratory Research, and about 5% in the Laboratory-Wide Competition.

Strategic Initiatives are selected on the basis of their alignment with the Laboratory's strategic directions and long-term vision. Proposals for these projects are responsive to the R&D needs of at least one of the Laboratory's five strategic councils: the Council on National Security, the Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, the Council on Strategic Science and Technology, and the Council on Strategic Operations. Strategic Initiatives are usually more challenging than projects in the other categories and typically entail the efforts of 5- to 10-person multidisciplinary research teams.

Exploratory Research proposals are submitted by the directorates, who first review the proposals to ensure their alignment with the directorate's strategic R&D requirements. The selection process for Exploratory Research projects weighs each proposal's ability to attract and develop young scientists, maintain the scientific and technological competence of the Laboratory, further the organization's strategic vision, and reach academic and industrial communities.

The Laboratory-Wide Competition provides all members of the Laboratory staff the opportunity to pursue their own creative ideas for one to three years. In this competition, the winning innovative projects further the missions of the Laboratory but are not required to pass a line-management filter.

#### *Recent Accomplishments*

Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. Program accomplishments are described in detail in *Laboratory Directed Research and Development FY 1997* (UCRL-LR-113717-97). In FY 1997, for example, 29 of Livermore's 64 patents were LDRD-funded, as were the seven R&D 100 Awards:

- Absolute Interferometer.
- Ultra-Clean Ion-Beam Sputter Deposition System.
- Femtosecond Laser Materials Processing.
- Multiscale Electrodynamics.
- Oil Field Tiltmeter.
- Ultra-High-Gradient Insulator.
- High-Performance Storage System.

In FY 1998, of the seven R&D 100 awards garnered by Livermore, four were based on ongoing or prior LDRD work. They are:

- High-performance Electromagnetic Roadway Mapping and Evaluation System (HERMES).
- Optical Dental Imaging System.
- Two-Color Fiber-Optic Infrared Sensor.
- INDUCT95 Software Simulation Code.

In addition, LDRD projects provide valuable support for student and postdoctoral research—130 students and 114 postdoctoral fellows in FY 1997. The participation of these scholars-in-training adds vitality to the Laboratory's R&D efforts and provides a pool of talented prospects for future career scientists and engineers.

The Laboratory's national security mission—for example, stockpile stewardship of U.S. nuclear weapons and nonproliferation and counter-proliferation of weapons of mass destruction—provides a focus for Livermore's LDRD portfolio. An overview of LDRD support to national security programs at all three DOE Defense Program laboratories (Livermore, Los Alamos, and Sandia) is presented in *Laboratory Research and Development: Innovation and Creativity Supporting National Security* (Los Alamos publication LALP-96-147, April 1997). Two recent Livermore LDRD strategic investments in the national security area, discussed in more detail in Section 2, exemplify how LDRD provides a scientific and technological foundation for subsequent program accomplishments:

- A femtosecond laser machine tool for precision processing of materials. Following a breakthrough demonstration of a Petawatt (100-trillion-watt) laser developed under LDRD, the R&D100 Award-winning laser machine tool has been delivered to the Oak Ridge Y-12 Plant for use in supporting stockpile stewardship programs (Section 2.1.4).
- Field-portable instruments for biological agent detection. Livermore researchers have developed unique instruments for detecting and identifying biological weapons agents. In DoD-sponsored field trials, the instruments performed exceedingly well. Progress is being made to improve both the speed and sensitivity of the instruments (Section 2.2.3).

Highlights of other LDRD research include the development of the PEREGRINE radiation dose calculation system and the groundwater cleanup technologies that have been subsequently used in major technical demonstrations (Section 3.1.5). See the LDRD Annual Reports for other major accomplishments. The FY 1998 LDRD report is in preparation.

### 3.3.2 Application of Mission-Directed Science and Technology

With many specialized centers of excellence—needed to achieve mission goals—Livermore has special capabilities to meet some of the nation's broader challenges in fundamental science and applied technology. Centers of excellence are a consequence of Livermore's overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified. Much of the expertise necessary to support national security programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have expertise to support innovative efforts in advanced materials, precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

Many specialized centers of excellence exist at Livermore. Some applications of our special capabilities to meet the nation's challenges in fundamental science and applied technology include:

- **Astrophysics and Space Science.** In partnership with many other scientific institutions, we make important advancements in astrophysics and space science through application of the Laboratory's special expertise in high-energy-density physics, nuclear fusion, and scientific computing. Livermore also makes important advances in instrumentation, as demonstrated by the development of sensors for the Clementine satellite, which mapped the entire surface of the Moon. This sensor technology is leading to other advances, such as development of a revolutionary camera system and its use to discover massively compact halo objects (MACHOs).

• **Accelerator Technology.** We make strong contributions to national accelerator development programs, capitalizing on the way our physicists and engineers work together to solve problems in accelerator design, technology, and manufacturing. Livermore is part of the three-laboratory effort building the B-Factory at Stanford University, and we are collaborating on the development of the Next Linear Collider. Important national security applications of our accelerator expertise include the development of Accelerator Production of Tritium and the Advanced Hydrotest Facility.

• **Microelectronics and Optoelectronics.** The Laboratory's strengths in microelectronics and optoelectronics help us meet the demands for enhanced surveillance of aging nuclear weapons as well as for advanced diagnostics and precision target fabrication in the inertial confinement fusion program. Expertise in thin-film processing and microfabrication technology has many applications in lithography, semiconductor processing and process modeling, electronics packaging, communication and computing systems, and biotechnology.

• **Advanced Materials.** Our work in materials science ranges from fundamental research on the properties of materials to the engineering of novel materials at the atomic or near-atomic levels, which are often pursued to the stage where they can be readily manufactured. Aerogels and nano-engineered multilayer materials developed at Livermore have tremendous implications for new products and future Laboratory programs. Other advances include highly efficient energy-storage components; ultralight structural materials; tailored coatings; and novel electronic, magnetic, and optical materials. The Laboratory's fundamental research, for example, includes work for the Office of Basic Energy in areas such as interfaces and grain boundaries and their role in the behavior of metals and the superplastic deformation of metals and intermetallics. Through efforts in fundamental science, we have also developed an improved understanding of material deformations and radiation effects on materials.

• **Laser Science and Technology.** The Laboratory has unmatched capabilities in high-energy and high-power solid-state lasers. We will apply this expertise to meet critical needs in national security, energy security, and environmental applications. In addition, we will expand collaborations with industry and other partners to identify laser and electro-optics technologies that can be developed and transferred to the private sector.

#### *Major Initiatives*

• Accelerator Technology Development (Multiple Offices), p. 67.
• Materials Studies and Surface Characterization (ER), p. 63.
• Computational Materials Science and Chemistry (Multiple Offices), p. 68.

### 3.3.3 Partnerships That Create New Capabilities

Livermore is committed to promoting partnerships with U.S. industries, other laboratories, and universities. Often partnerships are the most cost-effective way to fulfill the Laboratory's mission and goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive impact on the U.S. economy or other important national priorities.

**3.3.3.1 Partnerships with Industry.** We anticipate that the Laboratory's partnerships and alliances with industry will continue to grow. Livermore has always pursued industrial partnering through its procurement strategy. To cost effectively acquire the state-of-the-art technologies needed for our major research and development programs, we continually interact with private industries to understand their capabilities and products so that we can make informed decisions. (See the Small Business and Disadvantaged Procurement Table, Table 3-1.)

For example, over 75% of the total funding for construction of the National Ignition Facility will go to U.S. companies, including high-technology firms producing optical components. In some cases, Livermore's programmatic needs actually spur the development of new businesses or new product lines in existing companies. Advances in state of the art may be developed at the Laboratory and transferred to a commercializing partner or developed by the company to meet Laboratory requirements in order to generate a production-scale source of equipment, instrumentation, or components for some of our larger experimental facilities. In the Accelerated Strategic Computing Initiative (ASCI), the three DOE national security laboratories, industry, and academia will drive computer advancements and refinements of prototype machines to meet DOE Stockpile Stewardship computational requirements. These increasingly capable supercomputers, initially purchased by the laboratories from U.S. industry will, in turn, help ready the companies for the wider marketplace. Table 3-2 shows Livermore's interactions with industry for years 1993 through 1997.

We also work with U.S. industry through a variety of cooperative research and development agreements (CRADAs) in which intellectual property rights are negotiated. Many CRADAs were initiated in the mid-1990s with funding from what is now the DOE's Technology Transfer Program (TTP). As the program winds down, Livermore's CRADAs are increasingly funded either as Laboratory-funded (cooperative efforts on technologies we vitally need) or as funds-in projects (industry backing for cooperative efforts). One major funds-in CRADA is the collaborative project involving Livermore, Lawrence Berkeley, and Sandia national laboratories and an Intel-led consortium of microelectronics companies that will develop technology for fabricating advanced integrated circuits perhaps two generations beyond current techniques.

Other means by which the Laboratory works with industry include:

- **Licensing agreements.** Through licenses, Livermore grants permission for commercial and noncommercial access to reproduction, manufacture, sale, or other exploitation and use of Laboratory-developed intellectual property. As an example, Southern California Edison and the Laboratory jointly issued a press release announcing exceptionally effective environmental cleanup results. The project used the Laboratory's dynamic underground stripping technology to clean up groundwater contamination at a site previously used to treat power poles with preservatives such as creosote at Visalia, California. Dynamic underground stripping and important auxiliary technologies were licensed to SteamTech Environmental Services to perform the clean-up operations. In the first nine months of use, the process removed or destroyed in place an amount of contaminants that would have required more than 1,000 years with traditional pump-and-treat.
- **Industrial work-for-others (WFO).** WFO agreements provide non-DOE organizations with access to highly specialized or unique DOE facilities, services, or technical expertise. In our AVLIS program, for example, technology developed under DOE funding to provide a lower-cost, environmentally safer method for producing fuel for commercial nuclear power plants is being commercialized. When completed, this multibillion dollar effort will represent our largest transfer of technology to the private sector. Most WFO agreements are of much smaller scale.
- **Small business programs.** Our small business activities include Small Business CRADAs, Small Business Technical Assistance, and participation in the Small

**Table 3-1. Small and Disadvantaged Procurement. Program activities in FY 1997 (BA in millions of dollars).**

| | FY 1997 | FY 1998 |
|---|---|---|
| Procurement from small and disadvantaged businesses | $42.9 | $43.9 |
| Percent of annual procurement | 16.0% | 12.1% |
| Socioeconomic baseline on which the achievements were based | $267.9 | $362.0 |

**Table 3-2. Laboratory interaction with industry, FY 1993–1998.**

| Type of interaction | FY 1993 | FY 1994 | FY 1995 | FY 1996 | FY 1997 | FY 1998 | Total |
|---|---|---|---|---|---|---|---|
| Licenses of Laboratory Patents (number issued) | 16 | 36 | 59 | 60 | 65 | 36 | 272 |
| Royalties (in $M) | 0.4 | 0.6 | 1.1 | 1.1 | 2.4 | 2.3 | 7.9 |
| DOE (TTI) CRADAs (number active) | 55 | 84 | 114 | 85 | 55 | 15 | 408 |
| DOE funding (in $M) | 33.4 | 51.1 | 55.5 | 52.3 | 19.5 | 5.0 | 216.8 |
| Lab-funded CRADAs (number active) | 8 | 10 | 20 | 26 | 24 | 19 | 107 |
| Lab/DOE funding (in $M) | 0.6 | 3.2 | 2.9 | 3.4 | 4.4 | 3.4 | 17.9 |
| Industry-funded CRADAs (number active) | 2 | 10 | 12 | 22 | 34 | 28 | 108 |
| Industry Funds-In* (in $M) | 0.2 | 4.3 | 6.8 | 4.9 | 17.8 | 29.2 | 63.2 |
| Work-for-Others Projects with Industry (number active) | – | – | 41 | 56 | 85 | 90 | 272 |
| Industry Funds-In (in $M) | – | – | 2.7 | 3.6 | 3.4 | 9.1 | 18.8 |
| Other Partnerships (AVLIS) (number active) | – | 1 | 1 | 1 | 1 | 1 | 5 |
| Industry Funds-In (in $M) | – | 38 | 48 | 83 | 76 | 90 | 335 |
| Lab SBIR Projects (awards made) | – | – | 16 | 5 | 3 | 5 | 29 |
| Industry Funds-In (in $M) | – | – | 0.3 | 0.1 | 0.2 | 0.2 | 0.8 |
| Spin-Off Companies (number) | – | 2 | 3 | 2 | 4 | 3 | 14 |

*Industry Funds-In is the funding provided to support Laboratory activities by industry sources.

Business Innovative Research Program (SBIR) and the Small Business Technology Transfer Program (STTP).

• **User Facilities.** The Laboratory has three designated User Facilities that industrial partners may use for research, testing, and development of prototypes. They are the Livermore Center for Advanced Manufacturing and Productivity (LCAMP), the Livermore User Facility for Inspection and Characterization (LUFIC), and the Virtual Laboratory Testbed (VLT).

• **Livermore's Industrial Partnering and Commercialization (IPAC).** This office facilitates many of our interactions with industry. IPAC provides information on licensing, cooperative research, and other opportunities for businesses to benefit from technology transfer and negotiates the contracts that govern these relationships.

**3.3.3.2 Teamwork with Other Laboratories.** We are working with other national laboratories to coordinate and integrate programmatic efforts to provide the best scientific and technical capabilities for the dollars invested. Livermore's collaborative activities are increasing through participation in integrated national programs, such as the Stockpile Stewardship Program and the Joint Genome Institute. Collaborations include the design, construction, and shared use of major research facilities such as the National Ignition Facility at Livermore and the B-Factory at the Stanford Linear Accelerator Center.

Factors critical to the success of these team efforts include effective high-level DOE leadership, well-defined program goals and deliverables, complementary capabilities among the national laboratories, confidence in each other's commitment and performance, and a healthy competition of ideas within a collaborative framework.

### 3.3.4 University Collaborative Research and Education Programs

The Laboratory's University Relations Program encourages and expands research collaborations between LLNL and universities, other research organizations, and industries. The program contributes to the intellectual vitality of all the partners through basic and applied research collaborations. By facilitating the flow of ideas and people between institutions and by making our unique facilities and expertise available to students and faculty, we address problems that are of interest to the broad U.S. research community and help solve complex problems of importance to the nation. The University Relations Program also oversees the Laboratory's science and technology education efforts. We help train the nation's next generation of scientists and engineers through our outreach programs that span every educational level. The Laboratory also benefits by enlarging the pool of talent and raising awareness about Livermore and its national security mission—our continuing success depends on recruiting and retaining quality staff.

**3.3.4.1 University Collaborative Research.** Individual collaborations between Livermore scientists and university faculty and students have taken place since the Laboratory was founded. Our research collaborations with university faculty and students are designed to blend basic research with applied researchers. The collaborations provide effective ways for unique Laboratory facilities and expertise to be made available to the broad U.S. research community. Table 3-3 shows Livermore's collaborations with universities from FY 1995 through mid-FY 1998.

Several Livermore–university institutes have been established in specific subject areas, setting a focus for collaborations with the nine University of California campuses as well as with many other universities. They provide a hospitable environment for visiting students and faculty. These institutes advance the strategic goals of the Laboratory by aligning subject matter with expertise needed to execute Laboratory programs. The institutes include:

• **Institute of Geophysics and Planetary Physics (IGPP).** The Livermore branch of IGPP (a Multi-Campus Research Unit) runs the Astrophysics Research Center, which carries out a significant research program and manages the astrophysics part of the University Collaborative Research Program (UCRP). The Center for Geosciences in IGPP promotes UC collaborative research in the earth sciences. The center's research emphasis is on the physics and chemistry of Earth, including seismology, geochemistry, experimental petrology, mineral physics, and hydrology.

• **Center for Accelerator Mass Spectrometry (CAMS).** Processing about 20,000 samples per year with its extremely sensitive measurement capability, CAMS supports research programs that range from archaeological dating to biomedical research, and from global climate change to geology. The capabilities of CAMS are available to all qualified users under standard DOE procedures. Some 75 service contracts are currently in place with nonprofit foundations, non-DOE agencies, and private corporations.

• **Institute for Scientific Computing Research (ISCR).** A major objective of the ISCR is to encourage original work that has the potential for significant impact in computing research and reinforces the scientific and technological strengths of the Laboratory. ISCR's educational outreach is accomplished in part through proposals where the funds support graduate students and postdoctoral researchers.

• **Institute for Laser Science and Applications (ILSA).** ILSA is a center of excellence at Livermore in the area of laser plasma physics. We focus on high-peak-power lasers and advanced ultrahigh-speed diagnostics. The University of California, principally the Davis and Berkeley campuses, is a strong collaborator in ILSA. Collaborations with other universities across the country are already extensive and will continue to expand.
• **Materials Research Institute (MRI).** MRI promotes the highest-quality materials research and innovation through collaboration between universities and the Laboratory. We are concentrating on projects that highlight and use the Laboratory's unique capabilities, such as the Nova laser, the Electron Beam Ion Trap (EBIT), the Positron Microprobe, and Livermore's high-pressure shockwave and diamond-anvil-cell facilities.

In addition, the Department of Applied Science, a part of the College of Engineering at the University of California, Davis, with facilities at both Davis and Livermore, offers a limited number of temporary positions to selected UC Davis graduate students who are pursuing their degrees in applied science or computer science. These students have the opportunity to work in one of the Laboratory's major research facilities while conducting thesis research related to the programmatic research work at the Laboratory.

Other collaborative activities among the three UC-managed DOE national laboratories are supported by two funds established by the UC/DOE management contract. The University of California Directed Research and Development (UCDRD) Fund, with up to $11 million allocated each year to the laboratories, is available to support research activities at the discretion of each laboratory director. Livermore uses UCDRD funds for strategic investments at the Laboratory and for integrating support with other UC collaborative efforts. The other fund, a $3-million Complementary and Beneficial Activities (CBA) Fund, was established specifically to support collaborative research efforts through the Campus–Laboratory Collaborations (CLC) Program.

Among the research opportunities offered by the Laboratory is a newly established Lawrence Livermore Fellowship, a distinguished postdoctoral program. The Fellows will have world-class resources to support their research. Fellowships are awarded only to candidates with exceptional talent, credentials, scientific track records, and potential for significant achievements. The Fellows are expected do original, independent research in one or more aspects of science relevant to the competencies at the Laboratory.

Finally, the Partnership for Environmental Technology Education (PETE), established at Livermore in 1991 and now a national nonprofit organization, fosters training in environmental technologies at the community college level. PETE links the 600 participating colleges with the technical resources of DOE, DoD, EPA, and NASA laboratories, which assist in curriculum development for training technicians in environmental and hazardous materials.

**3.3.4.2 Science and Technology Education Programs.** Livermore's Science and Technology Education Program (STEP) applies the unique resources of Lawrence Livermore to facilitate partnerships and collaborations between the Laboratory and the education community. Through STEP, Livermore helps to contribute to the nation's development of a highly skilled, diverse workforce and enhances scientific and technical literacy. Table 3-4 shows Livermore participation in university and science education programs in FY 1997.

A principal sponsor for STEP activities is DOE Defense Programs.

**Table 3-3. Laboratory–university collaborations FY 1995 to mid-FY 1998. [a]**

| Type of collaboration | FY 1995 | FY 1996 | FY 1997 | FY 1998 [b] |
|---|---|---|---|---|
| **Collaborations with University of California (total number)** | 499 | 408 | 176 | 260 |
| UC faculty | 183 | 174 | 38 | 58 |
| UC research staff | 79 | 61 | 92 | 142 |
| UC students | 237 | 173 | 46 | 60 |
| **Collaborations with other California universities (total number)** | – | – | 185 | 190 |
| Faculty | – | – | 22 | 22 |
| Research staff | – | – | 23 | 27 |
| Students | – | – | 140 | 141 |
| **Collaborations with non-California universities (total number)** | 726 | 1029 | 1214 | 1206 |
| Faculty | 90 | 54 | 117 | 116 |
| Research staff | 369 | 85 | 115 | 156 |
| Students | 267 | 890 | 982 | 934 |

[a] University and college faculty, research staff, and students involved in collaborations with the Laboratory at Livermore, at their home institutions, or both.
[b] Estimated.

Through a variety of research participation programs and collaborative projects, we help ensure a diverse future workforce for the science and technology challenges within DOE's Defense Programs mission needs. Example efforts include:

- **Actinide Sciences Summer School Program.** The Actinide Sciences Summer School Program is an educational opportunity for undergraduate and graduate students arranged through the Glenn T. Seaborg Institute for Transactinium Science (GTS-ITS) at the Laboratory. The program provides an opportunity for students to interact with practicing scientists in the laboratory and gain a broader sense of how radiological science is done. Activities encourage students to pursue scientific careers and give them exposure to the actinide sciences so that they may consider careers in these fields, which are the heart of the DOE mission.
- **Historically Black Colleges and Universities (HBCUs) Research Projects.** Initiated in 1994, our Research Collaborations Program (RCP) establishes scientific collaborations between accomplished research faculty at HBCUs and principal investigators at the Laboratory in areas of core competency. The program provides unique research opportunities for participants and provides Livermore additional expertise and staffing for basic research efforts through the involvement of professors, postdoctoral researchers, graduate students, and undergraduate students.
- **Laser Science and Optics for the Classroom (LSOC).** The LSOC program integrates laser and optics technology into high school science and math curricula. LSOC lessons are activity-based, giving students hands-on experience using laser and optics equipment.
- **Military Academic Research Associates (MARA).** The MARA program provides opportunities for students at the U.S. military academies to spend their summers participating in national security research activities at the Laboratory.
- **Research Internships for Education (RIE).** The RIE program assists undergraduate and graduate students in science, mathematics, engineering, technology, and science teaching to complete their degree requirements and prepare for transition into scientific careers.
- **The Undergraduate Research Semester (URS).** URS is an opportunity for undergraduate and pre-grad-school students to conduct research at one of the DOE Defense Programs laboratories. The program offers students 16 weeks of "hands-on" research under the guidance of Laboratory scientists and engineers.

Through other internally funded Livermore education and training programs, we reach out to the community and provide educational resources for teachers and students at all levels of education. Efforts include:

- **Internet Resources.** We are advancing use of the Internet to introduce students and teachers to DOE's work, with a special emphasis on national security. Efforts include: National Education Supercomputer Program, California Super Computer Challenge, Virtual Visitors Center, Technology Workshops on the Internet, and Atmospheric Interactive Research Program.
- **Science Outreach.** Our science education community outreach activities enhance scientific and technical literacy. These activities include many regional partners and activities: the Tri-Valley Science and Engineering Fair, Fun with Science Program, Expanding Your Horizons Program, Education Speakers Bureau, and Science on Saturday Program.

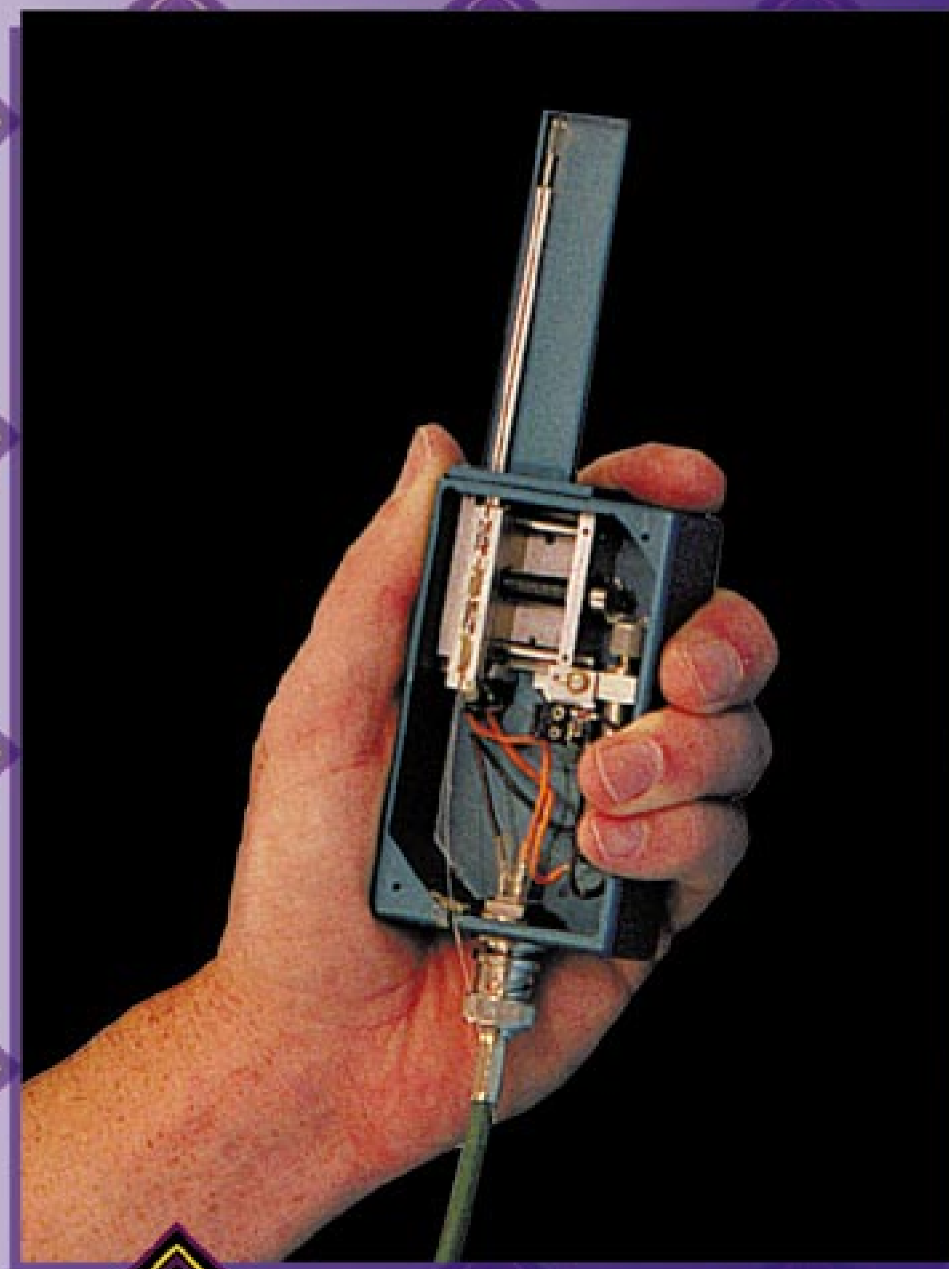
**Table 3-4. Livermore participation in Science Technology Education Program (STEP) activities in FY 1997.**

| Type of program | Participants* |
|---|---|
| **Pre-college programs** | |
| Student programs | 1077 |
| Teacher programs | 1378 |
| Special programs | 140 |
| **Undergraduate programs** | 468 |
| **Graduate and postgraduate programs** | 112 |
| **Faculty programs** | 13 |

*Does not include Internet use of STEP education software, which has over 10,000 participants.

# SECTION 4





# Laboratory Initiatives

# R&D 100 AWARD

## Optical Dental Imaging System

**Optical Dental Imaging System, a noninvasive imaging technology to view internal tooth and soft tissue microstructure for dental applications.**

*Livermore's Medical Technology Program and the University of Connecticut Health Center.*

The following initiatives are proposed as major additions to existing programs or as new directions within our missions. We have included information about major, ongoing Stockpile Stewardship initiatives—the National Ignition Facility, the Accelerated Strategic Computing Initiative, Enhanced Surveillance, and the Advanced Design and Production Technology Program.

For new initiatives, the programs and budget figures are provided for consideration by the Department of Energy. The detailed Program Resource Requirements tables do not reflect the growth in resource requirements needed to pursue the initiatives. Their inclusion in this Plan does not imply DOE approval of or intent to implement the proposal. Listed after each initiative title is its Budget and Reporting Code designation.

## 4.1 Assistant Secretary for Defense Programs

### 4.1.1 National Ignition Facility (DP)

The National Ignition Facility (NIF) is a vital element of DOE's Stockpile Stewardship Program. The NIF will provide the capability to conduct laboratory experiments that address the high-energy-density physics and thermonuclear fusion issues important to the safety, reliability, and performance of the stockpile.

The NIF provides unique capabilities in the laboratory. The ignition of an inertial fusion capsule in the laboratory will produce extremely high temperatures and densities that only occur in the sun and nuclear weapons. Other specially designed targets will be used to test important issues of weapon physics. These experiments will provide critical data for understanding weapons physics and testing advanced codes being developed for modeling nuclear weapons. In addition, NIF will be important for training new stewards of the stockpile. NIF also can be used to perform studies on the effects of nuclear weapons output. In addition, the NIF will become a unique and valuable laboratory itself for experiments relevant to many areas of basic science and technology.

A complementary long-range DOE program goal is to generate electric power using inertial confinement fusion (ICF). The NIF will be used to establish the requirements for driver energy and target illumination for high-gain fusion targets and to develop materials and technologies needed for civilian fusion power reactors.

The NIF is the most recent in a series of high-powered lasers built at LLNL. The NIF will have 192 beams, each consisting of 40-centimeter-aperture neodymium-doped glass laser and optics system. These beams will focus on a 10-meter-diameter target chamber with associated controls and diagnostics. The project includes constructing a new Laser and Target Area Building to house the laser and target chamber. In addition, an Optics Assembly Building is being constructed for processing and refurbishment of optics.

The NIF is presently being built at the Laboratory by a multilaboratory team led by LLNL. Planning for NIF began in January 1993 after DOE approved a Key Decision Zero, which established mission need. The Conceptual Design Report (CDR) for the NIF was completed in May 1994. On October 21, 1994, the Secretary of Energy issued a Key Decision One for the NIF, which initiated the line-item funding cycle for the project and the advanced conceptual design. Title I design of the conventional facilities and special equipment began in December 1995 following the Secretary's determination that the NIF construction supports the U.S. nonproliferation objectives (Key Decision One Prime). The Title I design was completed and comprehensively evaluated by a team of independent reviewers to determine NIF's technical readiness to proceed with the Title II detailed engineering phase of the project. This review, completed November 22, 1996, identified no issues that precluded proceeding; the project requested and DOE granted approval to initiate final Title II design and long-lead-time procurements. The NIF project received approval to begin construction (Critical Decision Three) on March 7, 1997, and is proceeding on schedule. The NIF project is scheduled to be completed at the end of FY 2003.

Although the NIF project is not scheduled to be completed until the end of FY 2003, experiments are scheduled to begin at the beginning of FY 2002. The modular design of the laser allows for sets of beams to be used for experiments as they are completed. This is consistent with DOE orders to transition facilities from construction to operation as soon as possible. This early transition to operation allows NIF to perform experiments in support of stockpile issues before the end of the project.

The estimated cost of the NIF project is $1.2 billion. Table 4-1 shows the total project cost, which includes the cost of preparing the CDR, developing vendor facilities, preparing documents and permits, and construction. Through 1999, the project will have received approximately 65% of the total funding.

*To Stockpile Assessment: Section 2.1.3, p. 22.*

### 4.1.2 Contained Firing Facility (DP)

Funding began in FY 1996 for the $49.7-million Contained Firing Facility, a 2,700-square-meter indoor explosives testing facility at Site 300. The facility, which also houses the newly upgraded Flash X-Ray (FXR) machine, is the most versatile and complete explosives testing facility in the world. The containment addition will include a reinforced firing chamber, a support staging area, and additional diagnostic space for testing up to 60 kilograms of explosives materials. Emissions to the environment will be drastically reduced; and hazardous waste, noise, and blast pressures will be minimized. Site preparation began in FY 1998. The engineering design has been revised to reduce costs, and a contract for facility construction is now up for bid. The facility will be shut down for use in April 1999 and reactivated in FY 2000 when construction is completed. Table 4-2 presents the construction costs for this facility.

**Table 4-1. Resources required for construction of the National Ignition Facility.**

| Fiscal year | BA in $M* |
|---|---|
| 1993 | 6.0 |
| 1994 | 6.2 |
| 1995 | 6.0 |
| 1996 | 61.0 |
| 1997 | 191.1 |
| 1998 | 229.1 |
| 1999 | 291.0 |
| 2000 | 254.0 |
| 2001 | 80.0 |
| 2002 | 66.4 |
| 2003 | 8.1 |
| Total | 1198.9 |

*Includes Operating Costs, Capital Equipment, and Construction.

**Table 4-2. Resources required for construction of the Contained Firing Facility (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | BA in $M |
|---|---|
| 1996 | 6.6 |
| 1997 | 17.1 |
| 1998 | 19.3 |
| 1999 | 6.7 |
| 2000 | 0.0 |
| 2001 | 0.0 |
| 2002 | 0.0 |
| Total | 49.7 |

*To Stockpile Stewardship, Section 2.1, p. 19.*

### 4.1.3 Accelerated Strategic Computing Initiative (DP)

The Accelerated Strategic Computing Initiative (ASCI) is a program that will extend the computational capability of DOE Defense Programs (DP). The initiative's goal is to shift from nuclear-test-based methods to computer-based methods for assuring the safety, reliability, and performance of the U.S. nuclear stockpile. ASCI simulation capabilities will link experimental data from above-ground test facilities, archival nuclear test data, and improved scientific understanding to provide predictive simulation capabilities needed to support decisions about the enduring stockpile. The objective is to provide the ability to analyze, evaluate, maintain, and prototype nuclear weapons and weapons components in the absence of nuclear testing and with a reduced nuclear weapons infrastructure.

To succeed, the ASCI program must create leading-edge computational modeling and simulation capabilities based on advanced simulation codes and high-performance computing technologies. A new generation of weapons simulation codes will combine advanced fundamental physics models, much greater spatial resolution, and the ability to model weapons behavior in three dimensions. Using these codes will require computers hundreds to thousands of times more powerful than the best available today. The three DP laboratories are working with industrial partners to accelerate the development of new High Performance Computing Platforms with the needed levels of capability.

In response to DOE priorities, Livermore is:

- Developing three-dimensional simulation codes with high resolution and high-fidelity physics simulation codes.
- Applying the expertise of experienced nuclear weapon scientists and engineers to validate these models for behavior, performance, safety, reliability, and manufacturing scenarios.
- Establishing and following a collaborative acquisition path to computer systems with 100 trillion floating-point operations per second (100 TeraOPS) and the necessary infrastructure of utilities, storage, networks, and visualization.
- Developing a distributed-at-a-distance computing numerical test and assessment site to allow access to 100-TeraOPS computers by designers at all three laboratories.

In addition to simulation code development and verification and validation efforts, Livermore, in collaboration with Sandia and Los Alamos, is developing Problem-Solving Environments (PSEs) to accelerate the development and application of the new ASCI simulation codes to the problems of stockpile stewardship by our weapon scientists. Key elements of this environment are advanced code-development tools, very large and fast data storage facilities, and high-speed communication links for both classified and unclassified data. The scientific applications will be generating huge output files (by 2000 it is possible that an overnight run could generate many trillions of bytes) and the scientists must be able to assimilate the information. A major element of the coming simulation environment is the development of very-high-performance visualization capabilities. These can be located either in the designer's office or in a separate assessment theater, depending on the scale of the problem. Of course, behind this theater will be a powerful hardware and software infrastructure. Much of the research to develop and refine the visualization resources is being done today, in collaboration with partners in the National Science Foundation and University Alliances. Another long-term goal of the ASCI researchers is to permit pervasive collaboration and sharing computer resources among the laboratories to support both ASCI and the larger Stockpile Stewardship Program.

A central component of ASCI is the accelerated development of highly parallel, terascale computers in partnership with the U.S. computer industry. The Laboratory retired the first of a sequence of ASCI systems delivered by IBM (the 512-node IBM SP) earlier this year and accepted a far more powerful 320-node Symmetric Multiprocessor-based system called the Technology Refresh System in March 1998. The peak capability of this computer is just over 0.9 TeraOPS. Additional deliveries, the 3-TeraOPS Sustained Stewardship TeraOPS (SST) system and a 10-TeraOPS successor, are planned for 1999 and 2000, respectively. Further increases in capability will require a new computer facility at Livermore, the Terascale Simulation Facility (TSF), described below.

The high-performance computing technologies that are developed as part of the ASCI program will directly support the nation's technology base. Academic partnerships are also important to ASCI. Livermore will be working with five major American universities that are participating in Academic Strategic Alliances Program (ASAP), which is a $250-million initiative to assist the three DOE national security laboratories in meeting ASCI computational science and simulation goals. The participating universities have each proposed very-large-scale applications that collectively drive the development of modeling and computing capabilities. Table 4-3 shows the resource requirements for the ASCI initiative. This table includes operating dollars that are spent at Livermore (Advanced Applications and Problem Solving Environments) and dollars that flow through Livermore to others (PathForward and Alliances).

*To Stockpile Assessment, Section 2.1.3, p. 22.*

### 4.1.4 Terascale Simulation Facility (DP)

The Terascale Simulation Facility (TSF) is about creating a simulation environment rather than just a very large, but traditional, computer center. The change in concept from "computing" to "simulation" is fundamental. The latter entails the development of a seamless partnership between the ability to generate terascale quantities of data and the ability to assimilate the information and make it accessible to the human eye and mind. The scientific applications being developed today promise an unprecedented level of physical and numerical accuracy. This level of accuracy and a sophisticated supporting environment to visualize simulation experiments are required by ASCI for stockpile stewardship to succeed. Simulation, in this sense, which includes detailed visualization, represents a fundamental conceptual shift that dictates the scope and timeline for the proposed TSF.

Expansion of Livermore's computing power beyond the 10-TeraOPS platform will require such a new facility. The technical objective is to construct a complex to house and coordinate two complementary elements: (1) the most advanced computers

**Table 4-3. Resources required for the Accelerated Strategic Computing Initiative (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating and maintenance cost |
|---|---|
| 1997 | 46.7 |
| 1998 | 70.7 |
| 1999 | 110.3 |
| 2000 | 128.0 |
| 2001 | 128.0 |
| 2002 | 128.0 |

**Table 4-4. Resources required for the Terascale Simulation Facility at Livermore (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | BA in $M |
|---|---|
| 1997 | 0.0 |
| 1998 | 0.0 |
| 1999 | 0.0 |
| 2000 | 8.0 |
| 2001 | 22.0 |
| 2002 | 22.0 |
| 2003 | 22.0 |
| 2004 | 9.5 |
| Total | 83.5 |

available, aggregated in configurations such that their capability, physical size, and power requirements will be unequaled outside the Stockpile Stewardship Program; and (2) tools for the management, transmission, and comprehension of the vast data sets generated, referred to as Data and Visualization Corridors. Plans for the TSF have been developed and a Conceptual Design Report has been approved. Construction requires a FY 2000 line-item authorization of $8.0 million. The estimated total cost of the facility is $83.5 million and, with timely funding, TSF will be completed late in 2004 (see Table 4-4 for resource requirements). About 24,000 square feet of the machine room (of the 48,000 square feet planned) will be available and fully equipped to accept an ASCI-scale system as early as August 2002.

Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers. Between 6 and 8 megawatts are required to run the computer, and cooling needs an additional 4 to 5.5 megawatts. For smooth integration of old system to new system, two floors will be built. Because the computer is expected to be composed of multiple frames with many nodes in each frame and because each node must communicate with a central switch, the underfloor will have to accommodate hundreds of copper and fiber cables yet have enough room for free air flow. The chilled air will be pushed up from the first floor directly into the frames. The air will then be captured in the ceiling of the second-floor computer room and returned through the walls to the basement for cooling and recirculation. The air in the machine room is be exchanged several times per minute. The center is designed for accommodating any computer architecture.

The building will also house the growing staff of computer and physical scientists who support the computers or work on research and development projects such as the Data and Visualization Corridors (DVCs) necessary for assimilating terascale data sets. ASCI applications use extremely high-resolution (and growing) models—as large as tens of billions of cells—and generate vast amounts of raw data that can overwhelm scientists. DVCs combine high-performance storage and networking with a visualization architecture in a way that allows interactive exploration of large quantities of data. These tools provide opportunities for weapon scientists to visualize the results of ASCI calculations and for visualization researchers to experiment with capabilities that are among the best in the world.

*To Stockpile Assessment, Section 3.1.2, p. 22.*

### 4.1.5 Advanced Design and Production Technology Program (ADaPT) (DP)

The ADaPT Program is a DOE-complex-wide effort to develop innovative technologies for new processes and practices to enable cost-effective production of stockpile weapon components. The enduring weapons stockpile, as well as workforce skills, will be maintained by a combination of repairs, refurbishments, and as-needed replacements. ADaPT integrates the skills and facilities of the three weapons labs—Livermore, Los Alamos, and Sandia—with the four production plants—Savannah River, Pantex, Y-12, and Kansas City. The ADaPT Program has defined four areas of strategic investment:

- Enterprise integration, through a secure, complex-wide, high-speed digital network.
- Integration of product and process design (concurrent engineering).
- Development and qualification of new, advanced processes for efficient, environmentally benign production.
- Contingency planning, for various scenarios such as major rebuilds.

Livermore is actively involved in each of these endeavors. For example, Livermore developed a femtosecond laser-cutting technology that reduces costs and wasted materials in weapon refurbishment activities. A demonstration of the laser-cutting technology was conducted in an environmentally controlled workstation, designed and built at Livermore in cooperation with Y-12 personnel. The Laser Cutting Workstation (LCWS) at Y-12 is to be used for recovery of high-value components for the W87 Life Extension Program. Laser cutting of high explosives continues to attract significant interest—from DOE and DoD. In particular, the demilitarization of high explosives in various legacy systems is a significant application for the femtosecond laser technology.

Livermore is involved in the cross-complex effort to develop secure internet technologies. Recent demonstrations at Livermore have led to several unique approaches to defining the “need-to-know” access criteria for classified information access via secure internet Web browsers. Most recently, Livermore instituted classified e-mail systems between the Livermore site, Y12, and Los Alamos. Systems for Web-browser-based interrogation of classified surveillance databases are under development.

Livermore is also engaged in developing advanced processes for manufacturing plutonium and uranium parts that minimize wasted materials and significantly reduce the waste stream. We are working with Y-12 to develop environmentally benign lithium recovery technologies. We are also working with Pantex to develop an advanced process for future production of TATB that may result in a great cost savings. We are in the process of completing milestones for the development of spin-forming technology for case production. This near-net shape technology promises to reduce footprint and costs at the Y-12 plant for routine production of weapons components.

The resource planning for ADaPT at Livermore, based on current planning within DP-20, is shown in Table 4-5.

*To Stockpile Refurbishment, Section 2.1.4, p. 23.*

### 4.1.6 Enhanced Surveillance (DP)

The Enhanced Surveillance Program (ESP) is a five-year program aimed at providing the Core Surveillance Program with improved diagnostic tools and predictive capability to determine when refurbishing or remanufacturing weapons materials and components will be necessary. The objectives of ESP are to develop tools, techniques, and models that enable us to provide advanced capability to measure, analyze, calculate, and predict the effects of aging on weapons materials and components and to understand these effects as they impact reliability, safety, and performance of weapons that are aged beyond their originally designed lifetimes. The lifetime predictions are intended to allow accurate planning for production or refurbishments. Development of ESP techniques are conducted on selected enduring and retired stockpile weapon systems. ESP projects are reviewed on an annual basis, resulting in termination of unsuccessful projects and addition of new advanced R&D concepts.

Activities under this program are carried out at the DOE weapon production plants and design laboratories—the Kansas City Plant, Y-12 Plant, Savannah River Site, Pantex Plant, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. There is a strong partnership among the labs and production sites to coordinate planning and project selection and to foster teamwork in the conduct of research projects for the ESP. Because an enormous base of data already exists from the many years of core surveillance program studies, it is highly desirable to store and manage this information so that trends in behavior can be readily identified. Accordingly, ESP is also tasked with supporting leading-edge projects for this data-driven activity.

At Livermore, the program is organized into six teams: pits, high explosives, secondaries, systems, transfer of new primary diagnostics into the Stockpile Evaluation Program, and transfer of new secondary diagnostics into the program. Most of a requested $4.6-million budget increase between FY 1998 and FY 1999 is for important new work aimed at assessing the lifetime of pits and high explosives. This includes an accelerated aging study for pits and work to deliver diagnostics for early detection of potential flaws on schedule to the Stockpile Evaluation Program. The requested additional $3.2-million budget increase between FY 1999 and FY 2000 is to execute the tasks associated for determining pit, high-explosive, and CSA lifetimes. The initiative includes accelerated pit aging studies, accelerated aging studies for main-charge high explosives, and significant funding for the early flaw-detection diagnostics.

LLNL proposes a $15.8-million budget for FY 1999 and $19.0 million for FY 2000. See Table 4-6 for resource requirements.

*To Stockpile Surveillance, Section 2.1.2, p. 21.*

### 4.1.7 NTS Two-Stage Light Gas Gun—JASPER Facility (DP)

An important experimental technique for determining the properties of materials at high pressures, temperatures, and strain rates is to shock the material by impacting a small sample with a projectile traveling at high velocity and diagnosing the material response. These tests are conducted using gas guns. Currently, the only facility available for performing these tests on special nuclear materials (SNM)

**Table 4-5. Resources required for the ADaPT Initiative at Livermore (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating and maintenance cost |
|---|---|
| 1997 | 5.0 |
| 1998 | 9.9 |
| 1999 | 9.9 |
| 2000 | 14.0 |
| 2001 | 14.0 |
| 2002 | 14.0 |

**Table 4-6. Resources required for Enhanced Surveillance ($M).**

| Fiscal year | Operating and maintenance cost |
|---|---|
| 1997 | 10.3 |
| 1998 | 9.9 |
| 1999 | 15.8 |
| 2000 | 19.0 |
| 2001 | 19.0 |
| 2002 | 19.0 |

is the 40-millimeter, single-stage gas gun located in TA-55 at Los Alamos. This gun can achieve a maximum projectile velocity of about 2 kilometers per second. Much higher projectile velocities are required to fully achieve the desired shocked material conditions. These higher velocities can be achieved by using a two-stage gas gun.

The technology, target design, and diagnostic needs of such a gun are well known; similar guns have been in operation at Livermore, Los Alamos, and Sandia national laboratories for many years. However, SNM can not be tested in these guns. Members of the shock compression physics groups at these three laboratories have developed the scientific requirements for a shock compression facility using a two-stage gas gun for the study of plutonium and toxic materials at extreme conditions. The initial design will enable projectile velocities of up to 8 kilometers per second, with velocities up to 15 kilometers per second possible with future design modifications. A siting study resulted in a decision to base this technology at the Nuclear Explosives Assembly Facility at the Nevada Test Site (NTS), no longer needed for assembly since the new Device Assembly Facility has become operational. The project has been authorized for construction.

The Joint Actinide Shock Physics Experimental Research (JASPER) Facility Project was kicked off in January of this year. A multi-organizational project team consisting of Livermore, Los Alamos, Sandia, Brookhaven, and DOE/NV has been formed. Livermore has responsibility for overall project management, physics definition, engineering, health and safety, and authorization-basis documents. JASPER will be the first nuclear facility at the NTS (Hazard Category 3 nonreactor) and will be operated by Livermore.

JASPER experiments will support the Stockpile Stewardship Program in several ways and are complementary to subcritical experiments also being conducted at the Nevada Test Site. Because of the well controlled environment of the gas gun, JASPER will provide scientists with more precise equation-of-state data than can be obtained from any other type of experiment.

The project is scheduled for completion in the year 2000, and it is estimated that the laboratories will perform about 25 experiments annually.

*To Stockpile Assessments, Section 2.1.3, p. 22.*

### 4.1.8 Advanced Hydrotest Facility (DP)

The Advanced Hydrotest Facility (AHF) is proposed to incorporate advanced technology that is needed to infer the nuclear performance (criticality, cavity shape, and mix) of primaries from nonnuclear tests. The facility would include a broad array of diagnostics for dynamic testing with special nuclear materials and would broadly support national security concerns, including the disablement of potential proliferant or terrorist weapons.

The proposed AHF will provide information that is needed to assess primary performance and safety. The preliminary specifications were established through an interlaboratory collaboration referred to as the Physics Requirements Committee, which will continue to refine requirements during a period of technology development. This effort has already established the need for high-resolution multiframe imaging along several axes, which is driving the development of advanced accelerator and detector technologies. Research is being conducted on three different radiographic technologies: linear induction accelerators, inductive voltage-adder accelerators, and proton radiography.

The weapons directors of the laboratories functioning as the Tri-Laboratory Executive Committee have appointed an external advisory committee to review and evaluate the technology research and advise on the technology or technology mix to be implemented in an AHF. Preliminary estimates for the construction of this facility range from $500 million to $900 million based on today’s dollars. These estimates will be further refined during preconceptual and conceptual design phases.

*To Stockpile Assessments, Section 2.1.3, p. 22.*

## 4.2 Office of Nonproliferation and National Security

### 4.2.1 Activities with Russia and the NIS (NN)

The U.S. is engaged in numerous activities to assist Russia and the other newly independent states (NIS) in protecting their nuclear materials, engaging their nuclear weapons institutes on arms control and nonproliferation issues, and developing areas of productive and challenging nonweapons research for their weapons scientists. The largest initiative in this area is in nuclear material protection and control. Through the DOE’s Material Protection, Control, and Accounting (MPC&A) Program, we are working with more than 50 sites in Russia and have the lead at 13 sites to assist in upgrading their physical protection and material accountancy systems and in motivating a cultural change that will sustain and further improve their MPC&A systems. Our participation in the MPC&A Program is expected to grow in the coming years, as the number of facilities participating in the program increases. Of special significance is work with the Russian navy and the Murmansk Shipping Company to protect the fuel for their nuclear-powered vessels and proposed work at the Serial Production Enterprises (the Russian weapon assembly and disassembly plants).

A new thrust in our NIS activities involves work with the 10 Russian closed nuclear cities. We will be working with these cities to assist them in finding ways to exploit their technical and scientific strengths to become economically self-sufficient. The specific goal is to create 50,000 new (Russian) jobs to correspond to the 50,000-job downsizing planned by Russia for its nuclear weapons complex. This Nuclear Cities Initiative will start with projects at Chelyabinsk-70 (fiber optics), Arzamas-16 (project not yet selected), and Krasnoyarsk-26 (poly-silicon for the computer industry).

We are also collaborating in international efforts to counter nuclear smuggling. Our expertise in nuclear detection, nuclear forensics, and MPC&A; operation of the Communicated Threat Credibility Assessment for the DOE; and participation in the Nuclear Emergency Search Team contribute to these activities.

*To Proliferation Prevention and Arms Control, Section 2.2.1, p. 25.*

### 4.2.2 Support of Arms Reduction Treaties (NN)

With continued support, often in a leadership role, Livermore supports U.S. arms reduction treaties and various dismantlement transparency and material disposition agreements. We are developing methods for monitoring warhead dismantlement and for verifying the weapons-related origin of the nuclear materials. Livermore chairs the working group that is evaluating warhead radiation signatures for tracking warheads through the dismantlement process. We also have the technical leadership role in negotiations for the mutual reciprocal inspections of fissile material removed from dismantled weapons. We are working with our Russian counterparts to develop instrumentation for measuring radiation signatures to confirm or deny the weapons origin of inspected nuclear materials without revealing sensitive information. We contribute to discussions related to the U.S. position for START III, with its provisions for verifiable dismantlement of nuclear warheads. We also have a principal role in the Fissile Materials Disposition Program, a DOE-led interagency task force that is studying, in partnership with Russian counterparts, various options for disposing of excess weapons-grade fissile materials, specifically plutonium. Two plutonium disposition options are being considered: burning in nuclear reactors (the Russian preferred option) and immobilization in glass or ceramic (the U.S. preferred option). We are the leaders for developing the technology and plant processes for immobilizing plutonium in a ceramic waste form for permanent disposition in a geologic repository.

*To Proliferation Prevention and Arms Control, Section 2.2.1, p. 25.*

### 4.2.3 Counterterrorism (NN)

We are building on Livermore's historic role in supporting and responding to nuclear accidents and acts of nuclear terrorism to define our role for countering terrorism using nuclear, biological, or chemical weapons. Our scientific and technical programs provide basic science and new technical concepts to support national weapons of mass destruction (WMD) response capability. We are addressing major national initiatives to counter WMD terrorism—specifically, Presidential Decision Directives 39 (1995) and 62 (1998) and the Nunn–Lugar–Domenici legislation (H.R. 3730, 1996). This focus on counterterrorism is also reflected in the recent studies conducted by the Livermore Study Group and the Defense Science Board.

We are a key player in DOE's Chemical and Biological Weapons Nonproliferation Program. Expertise in analytical methods and instrumentation resident in the Forensic Science Center serves as a base for our work to counter chemical weapons. Livermore has become a central player in the federal biowarfare response community through new programs in biodetectors, genetic information, transport and fate, and decontamination. We are pursuing two approaches to biodetection—immunofluorescence-based methods using flow cytometry and nuclear acid identification using the polymerase chain reaction (PCR). We have tested these instruments with notable success against standardized performance criteria at the 1996 and 1997 Joint Field Trials, held at the Dugway Proving Grounds in Utah, clearly demonstrating the feasibility of both techniques for field detection of biological agents.

We have launched an important new initiative directed at civilian, urban counterterrorism needs. Urban first responders and local emergency managers play a critical role in countering and mitigating acts of WMD terrorism in the U.S. After contacting the emergency planning organizations in Los Angeles and New York, we participated in a major exercise in each city and are now a regular member of the Los Angeles emergency planning group. We are working with Los Alamos to understand the gaps in urban first-responder WMD capabilities and to identify capabilities within the national laboratories that could help in urban WMD emergency response. Even in the early stages of this initiative, it is apparent that technologies resident at the national laboratories can be quickly applied to counterterrorism problems in an urban environment.

*To Counterterrorism and Incident Response, Section 2.2.3, p. 27.*

### 4.2.4 Critical Infrastructure Protection (NN)

Presidential Decision Directive 63 was issued in response to the report by the recently concluded President's Commission on Critical Infrastructure Protection. PDD 63 recognizes the vulnerability and interconnectedness of the nation's critical infrastructures (energy, water, transportation, finance, etc.) and the need for critical functions to continue in the event of a physical or cyber attack by terrorists. The DOE's obligations under PDD 63 include protection of its own infrastructure and complex, protection of the U.S. energy infrastructure (particularly the electric power grid), and research and development to provide cost-effective protection and rapid reconstitution of critical infrastructures in the event of an attack.

We are marshaling Livermore strengths to assist the DOE in meeting its responsibilities in this vital area. Within the past 18 months, we sponsored three workshops on critical infrastructure protection, which assisted the Presidential Commission in understanding the problem, identifying vulnerabilities, and formulating recommendations. Applicable Laboratory capabilities include the ARGUS system for enhanced physical security, the Computer Incident Advisory Center (CIAC) for cyber protection and emergency response, and a fundamental core competency in complex systems analysis. In addition, our IOWA (information operations, warfare, and assurance) project will provide a valuable tool for identifying vulnerabilities in and protections for Livermore and DOE information networks. We have formed a multidisciplinary, multidirectorate effort—comprising Energy, Computations, Engineering, and Nonproliferation, Arms Control, and International Security Directorates—to focus Laboratory efforts that address this threat. Independent of the formation of or funding for new programs, the Laboratory must protect its site and the DOE its complex from attacks on critical infrastructures and functions in order to carry out national security missions.

*To Critical Infrastructure Protection and Law Enforcement, Section 2.3.2, p. 27.*

### 4.2.5 Sensitive Compartmented Information Facility (NN)

A new Sensitive Compartmented Information Facility (SCIF) building will reduce maintenance and special security costs and consolidate Livermore's national security programs in one area of the Laboratory site, enhancing our ability to execute those projects. The Building 261 SCIF, constructed 37 years ago, cannot accommodate all of the people or communications and computer hardware that now are required to be in a secure facility (information management, networking, data storage and retrieval, and real-time secure communications with DOE and the U.S. intelligence community). In addition, the current SCIF needs major repairs, is outside the core security area, and thus is no longer cost- or mission-effective to maintain.

The new SCIF building will be located just north of B132 North and west of parking lot A-4. It will use the B170 building plans with slight modifications necessary to accommodate a SCIF and the required contiguous Q space. The new SCIF will house approximately 125 people in some 115 offices, a graphic illustrators' room, photo lab, print shop, document work areas, and computer rooms. The SCIF will also contain four conference rooms, a library area, a work room for team projects, classified disposal rooms, and six special access program (SAP) rooms with additional security. The Q space will house about 50 people and consist of about 45 offices, secretarial areas, conference room, and work room.

Estimated cost for the new SCIF building is $19 million. This estimate was confirmed upon completion of a Conceptual Design Report and project validation in March 1998.

*To International Assessments, Section 2.2.4, p. 28.*

### 4.2.6 Environmental Security Initiative (NN)

Water resources and pollution that threatens water resources have emerged as critical regional environmental issues that are amenable to technical mitigation and thereby can serve as a vehicle for regional cooperation. The DOE and DOE laboratories have formulated a regional Environmental Security Initiative that is designed to address these issues in four regions of national security interest to the U.S.—the Middle East, China, Former Soviet Union and Eastern Europe, and Latin America. As this initiative is implemented and gains momentum, it can clearly be extended to other regions and other environmental threats (e.g., earthquakes). Livermore has assisted the DOE in inventorying the capabilities of the Department and its laboratories for these applications.

Livermore has also led the formation of a collaboration between Jordan, Israel, and the Palestinian Authority under the aegis of the DOE, Environmental Protection Agency (EPA), and USAID, with active participation from Sandia, Los Alamos, and the National Renewable Energy Laboratory, to develop water-management strategies for the aquifers and surface water resources shared by Jordan, Israel, and the Palestinian Authority. Several visits have already taken place at selected sites, and a workshop was held in Ammon, Jordan, in July 1998 to plan this effort. Laboratory capabilities of particular relevance to this effort include modeling and monitoring of precipitation, surface and subsurface flow, aquifer withdrawals and recharge, and the hydrology of aquifer environments. The capacity to purify sewage for reuse as drinking water or for aquifer recharge and the possibility of reusing gray water directly for irrigation purposes are also important considerations. Other capabilities that could be important for environmental security in the region include renewable and fossil energy technology, contamination prevention, and environmental remediation.

A similar conference in China is scheduled for early 1999 to initiate plans to protect China's water resources from pollution from its burgeoning industrial, urban, and agricultural activities. This work will be led by the U.S. Office of Science and Technology Policy; The national laboratory effort, led by Los Alamos, will involve Livermore and Sandia.

Talks are under way among the U.S., Russia, and the Scandinavian countries to identify ways of disposing of spent fuel and nuclear waste from decommissioned submarines to avoid further contamination of the Arctic north of Russia. These plans are needed to enable further submarine decommissions and are of interest to the U.S. Department of Defense. Past Russian disposal practices have caused radioactive contamination of Arctic waters, which in turn threatens fish and other ocean resources in that region. Impact studies and mitigation responses are needed to solve this problem.

In May 1998, a conference involving many of the Arab states of the Middle East, North Africa, and Eastern Europe was held in Amman, Jordan, to discuss seismic monitoring and earthquake simulation technology to plan monitoring, mitigation, preparation, and emergency response to earthquakes in those regions.

The resources required to move this initiative from planning to implementation are listed in Table 4-7. Projects involving other federal agencies are expected to receive additional direct support from those agencies.

*To Proliferation Prevention and Arms Control, Section 2.2.1, p. 25.*

## 4.3 Assistant Secretary for Energy Research

### 4.3.1 Accelerated Climate Prediction Initiative (KP)

Climate, weather, and atmospheric dispersion predictions have long been constrained by computing capabilities in both hardware and software. Under the DOE's Accelerated Strategic Computing Initiative (ASCI), computing capabilities are improving at an unprecedented rate. DOE's Strategic Simulation Initiative, including the Accelerated Climate Prediction Initiative (ACPI), intends to use this emerging capability for critical national needs beyond defense, thereby broadly improving the national scientific computing capability. The goals of the Accelerated Climate Prediction Initiative (ACPI) are to accelerate and extend the state of the art in climate modeling, to decrease the uncertainties in multi-decadal climate change predictions on global and regional scales, and to make these assessments and predictions accessible to a much broader research community.

A key participant in ASCI, Livermore has extensive experience in atmospheric modeling on global scales with its Program for Climate Model Diagnosis and Intercomparison (PCMDI) and on local scales with the National Atmospheric Release Advisory Center (NARAC). Through a recent collaboration with the Naval Research Laboratory at Monterey, California, we have jointly developed a multiprocessor version of their regional weather prediction model, thus providing us significant modeling capability at all levels: global, regional, and local or urban.

Because of our modeling capabilities, Livermore has provided quantitative support for national assessments of potential climate change and estimates of the impacts of international environmental agreements. As a consequence, a Livermore scientist was recently recognized nationally for his key contributions to the Intergovernmental Panel on Climate Change. More generally, we have worked to enhance the scientific basis for effective, economically viable, environmental national policy. These analytic efforts call for much more sophisticated and accurate modeling tools, as well as greater standardization of coding methods and data structures to facilitate access and comparison. What is ultimately required is a process-comprehensive, scale-coupled, data-corroborated atmosphere–ocean modeling capability.

We are planning and initiating (as resources allow) significant improvements in the resolution, physics, and chemistry of our and our collaborators' current models and in coupling calculations of nested scales to improve prediction resolution and regional specificity. Needed physics improvements include improved modeling of the hydrological cycle and cloud–radiation interactions (including cloud formation) and better treatment of aerosols and reactive (non-$CO_2$) greenhouse gases. In coupling the oceans and atmosphere, improvement is needed particularly in subgrid-scale (unresolved) processes, such as local air–sea material and energy exchange and mixing and sea-ice thermodynamics. Through ocean biochemical and terrestrial ecosystem processes, changes in the global and regional environments are most readily manifested. These changes are both the best diagnostics and the most important effects of global climate changes. Eventually our models must couple all of these processes at all of the relevant scales—a daunting challenge.

These modeling efforts will necessarily be cooperative ones among a wide number of government, laboratory, university, and private modeling efforts. We have established working arrangements with the PCMDI community of laboratories and universities, and we have initiated modeling collaborations with the National Center for Atmospheric Research, the National Oceanographic and Atmospheric Agency, the National Aeronautics and Space Administration, and the Naval Research Laboratory.

We propose to increase our involvement in enhancing and expanding the science base for atmosphere and ocean model assessment and prediction and to assist in developing the infrastructure for modeling standards, databases, archives, and networks. The resources needed for this are given in Table 4-8.

*To Atmospheric Prediction of Climate and Weather Processes, Section 3.1.4, p. 37.*

**Table 4-7. Resources required at Livermore to support the Environmental Security Initiative ($M).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 0.05 | 0.0 | 0.05 | 0.5 |
| 1999 | 0.25 | 0.0 | 0.25 | 1 |
| 2000 | 1.0 | 0.1 | 1.1 | 4 |
| 2001 | 2.0 | 0.2 | 2.2 | 7 |
| 2002 | 2.5 | 0.2 | 2.7 | 8 |
| 2003 | 3.0 | 0.2 | 3.2 | 10 |

### 4.3.2 Spheromak Fusion Reactor (AT)

Energy production from fusion is the long-standing goal of worldwide fusion research. Although much of this research has focused on the tokamak, the U.S. is now restructuring its national program toward concept improvement, including both improvements to the tokamak and to alternatives to the tokamak concept.

At Livermore, we are undertaking a detailed examination of one of those concepts, the spheromak, which offers the promise of confinement in a simple and compact magnetic field system. In the spheromak, the primary magnetic fields used for energy confinement are generated by a magnetic dynamo, whereas the primary field in the tokamak is generated by external coils. Consequently, relative to the tokamak, the spheromak offers the opportunity for considerable engineering simplicity and lower cost.

In FY 1997, we began work on the Sustained Spheromak Physics Experiment (SSPX). The physics and experimental efforts are funded by the Laboratory's LDRD Program; construction and operation are funded by the DOE Office of Fusion Energy Sciences. The overall goal is to understand and optimize energy confinement in the spheromak.

SSPX will demonstrate progress toward an advanced experiment with three major milestones:

- Establishing a sustained plasma, with good control of the magnetic geometry and impurities.
- Evaluating the relationship between energy confinement and the magnetic fluctuations associated with the dynamo and achieving temperatures of a few hundred electronvolts during sustainment.
- Learning how to transfer the equilibrium to external fields (poloidal

field coils) and exploring feedback or other control of the tilt and shift modes.

If the results from SSPX are sufficiently promising, our goal is to develop a larger, follow-up experiment, which would include achieving plasma temperatures in the range of multiple kiloelectronvolts, controlling low mode-number instabilities (perhaps with a feedback system), and developing the technology of long-pulse current drives. See Table 4-9 for resource requirements to continue spheromak research.

*To Advanced Utilities (Fixed Energy) Systems, Section 3.1.2, p. 35.*

### 4.3.3 Joint Genome Institute (KP)

In the past three years, the goals of the LLNL Human Genome Center have undergone a dramatic evolution. This change is the result of several factors both intrinsic and extrinsic to the Human Genome Initiative. They include: (1) the successful completion of the first phase of the project, namely a high-resolution, sequence-ready map of human chromosome 19; (2) advances in DNA sequencing that allowed us to accelerate scaling this operation; and most significantly (3) the formation of a Joint Genome Institute (JGI) for the Department of Energy during 1997. The JGI includes the three genome centers at the Livermore, Berkeley, and Los Alamos national laboratories.

In the last year, the primary emphasis of our Livermore Center activities has been on establishing the scientific goals, organizational responsibilities, and management structures for the JGI and particularly for the planned high-throughput sequencing facility being constructed in Walnut Creek. The Livermore team has taken the lead in developing shotgun sequencing methodology, sequence quality standards, and informatics infrastructure. Our primary focus will be meeting the ambitious sequencing goals established for the JGI by the Department of Energy and preparing to transfer much of our production sequencing operation to the JGI production sequencing facility in Walnut Creek.

Looking further ahead, we plan to move our focus back to the functional aspects of genomic research. This work has been temporarily scaled back to allow us to concentrate on establishing the high-throughput sequencing capability for the JGI. For the long term, we believe that extracting biologically relevant information from sequence data should be a focus of work at LLNL, including comparative sequencing, particularly of regions of the mouse genome, cDNA characterization, protein characterization, computational data mining, and understanding the relevance of human polymorphisms. Continuing resources needed to carry forward this initiative are shown in Table 4-10.

*To Genomics, Section 3.2.1, p. 39.*

### 4.3.4 Disease Susceptibility: Functional and Structural Genomics (KP)

With funding from several sources, we have initiated a program in disease susceptibility that combines our genomics capabilities with new capabilities in functional and structural biology to bring a scientific basis to

**Table 4-8. Resources required at Livermore to support the Accelerated Climate Prediction Initiative ($M); the first column represents ongoing programs in global change research, such as PCMDI and others, while other columns include the implementation of ACPI.**

| Fiscal year | Operating costs | ACPI operating | ACPI capital | Total costs | Direct FTEs |
|---|---|---|---|---|---|
| 1998 | 6.0 | 0.0 | 0.0 | 6.0 | 24 |
| 1999 | 7.5 | 0.0 | 0.0 | 7.5 | 30 |
| 2000 | 6.0 | 8.0 | 4.0 | 18.0 | 47 |
| 2001 | 6.5 | 14.0 | 4.5 | 25.0 | 63 |
| 2002 | 7.0 | 18.0 | 5.0 | 30.0 | 70 |
| 2003 | 7.0 | 21.0 | 5.0 | 33.0 | 75 |

**Table 4-9. Resources required for Spheromak Fusion Reactor ($M).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 2.8 | 0.0 | 2.8 | 8 |
| 1999 | 2.8 | 0.0 | 2.8 | 8 |
| 2000 | 2.8 | 0.0 | 2.8 | 8 |
| 2001 | 5.0 | 0.0 | 5.0 | 15 |
| 2002 | 20.0 | 0.0 | 20.0 | 60 |
| 2003 | 20.0 | 0.0 | 20.0 | 60 |

disease risk assessment. This program is relevant to DOE's growing interest in linking products of the Human Genome Project and its biosciences capabilities to disease susceptibility and to increasing national interest in identifying how genetic defects alter molecular structure and cause cancer and genetic disease. We have established and will make use of a state-of-the-art cryocrystallography and x-ray diffraction facility, a 600-megahertz nuclear-magnetic-resonance facility, computational biochemistry, mouse genomics, microbial genomics, and a protein-structure prediction center.

In FY 1997, DOE provided funding to initiate study of the sequence variation in human DNA repair genes and to support the protein structure prediction center, in which we have been advancing methods of identifying protein structure from its DNA sequence. Additional funds are needed to support DNA sequencing of susceptibility genes during the period when the Joint Genome Institute is generating human DNA sequence in a production mode and to extend the genetic variation studies beyond the current pilot phase. Funds are also needed to maintain the core Livermore capabilities in x-ray diffraction and for three-dimensional structure analysis of DNA repair proteins, nucleic acids, and the complexes they form with one another and with other molecules. GPP funding is needed to renovate our existing animal facility for mouse genomics. This program will produce insights and tools to predict the structure (and possibly the function) of proteins from DNA sequences, a critical capability when DNA sequences are becoming available from the Human Genome Project at a rapidly accelerating rate. Table 4-11 shows resource requirements for this initiative.

*To Disease Susceptibility Identification and Prevention, Section 3.2.2, p. 40.*

### 4.3.5 Computational Biochemistry (KP)

The Biology and Biotechnology Research Program (BBRP), in collaboration with the Computation and Physics Directorates, has initiated development of an integrated computational chemistry capability. Our goal is to increase the impact of computational chemical modeling in ongoing programs and seed new programs. The Laboratory's new teraOPS computing capacity will allow highly realistic simulations, including multihundred-atom quantum-chemistry and microsecond molecular-dynamics calculations. These powerful new modeling capabilities will have applications in numerous Livermore programs, including the study of normal and chemically modified DNA to support the BBRP's DNA repair and disease susceptibility research and the Laboratory-wide applications in studies of corrosion and aging and in designing new materials.

Accomplishing these goals requires a multidisciplinary approach. Chemical modeling algorithms and software must be developed and validated, an effort primarily of computational chemists. Networks and transparent interfaces between desktop computing resources and supercomputers must be developed, primarily by computer scientists with expertise in networking and software development. Education and guidance in using these new resources must be ongoing to ensure the maximum synergy between end users with varying research needs and the team responsible for continuing development.

This effort, started in FY 1997 with support of the Laboratory Directed Research and Development Program, requires additional and sustained funding to maximize its impact on biotechnology. Table 4-12 shows resources required for the initiative.

*To Disease Susceptibility Identification and Prevention, Section 3.2.2, p. 40.*

### 4.3.6 Microbial Genomics (KP)

To study organisms of interest to those working in health effects, environmental remediation, and biological nonproliferation, we would like to continue to broaden our genomics program, using the technologies developed for the human genome project. An expanded program in microbial genomics would lead to a variety of potential health benefits. We recently began a program in the genomics of microbial pathogens, focusing on virulence factors with both

**Table 4-10. Resources required for LLNL Joint Genome Institute effort (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 14.9 | 1.5 | 16.4 | 60 |
| 1999 | 15.6 | 1.6 | 17.2 | 63 |
| 2000 | 16.4 | 1.7 | 18.1 | 66 |
| 2001 | 17.2 | 1.8 | 19.0 | 69 |
| 2002 | 18.1 | 1.9 | 20.0 | 72 |
| 2003 | 19.0 | 2.0 | 21.0 | 76 |

sequencing and hybridization-based methods. Similar technologies could be applied to organisms of interest for environmental studies and bioremediation. Table 4-13 gives the resource requirements for this effort.

*To Genomics, Section 3.2.1, p. 39.*

### 4.3.7 Office Space for Biology and Biotechnology Research Program Staff (GPP)

T-3675 is a 1,100-square-meter modular office structure that was built around 1980 with a service life of 15 years. It now has begun to deteriorate. In addition, over three years ago, some 25% of the building's residents began to exhibit respiratory problems similar to allergies. After a building survey failed to identify significant agents, modifications were made to the HVAC system. Complaints continued to increase and roughly 25% of the affected residents were relocated, with an immediate, positive effect. Given that the structure is past its intended service life, replacement is more appropriate than refurbishment. A 1,700-square-meter, two-story replacement could be built for about $2.5 million, providing sufficient office space to accommodate the residents of T-3675 and T-3629 (another aging facility) and the projected near-future expansion of BBRP. With recent changes in DOE guidelines, this would be a GPP-funded activity. The facility could be available for occupancy in as little as seven months after receipt of funding.

### 4.3.8 Materials Studies and Surface Characterization (KC)

Livermore is developing a suite of experimental capabilities to improve the ability to characterize and study materials and surfaces. These new capabilities will permit unparalleled experimental accuracy in investigations of defects, voids, surface contaminants, and the impact of aging, stress, and impurities on the microscopic behavior of materials. These capabilities offer opportunities for breakthroughs in materials research—of interest to the Office of Basic Energy Sciences in DOE Energy Research—and for detailed examination and characterization of materials in aging nuclear weapons—of interest to DOE Defense Programs. The new and developing initiatives include:

- **The LLNL Positron Facility.** Livermore is developing a unique and powerful set of technologies using positrons to study defects and voids in materials. The presence of such defects—even at the atomic level—represents the dominant factor controlling changes of the mechanical and electrical properties of technological materials such as metals, semiconductors, and insulators. The unique capabilities of the Positron Facility, which enable advances in our understanding of material defects and the phenomena that produce them, have attracted the interest of the entire materials community, including scientists at Los Alamos and other national laboratories, researchers from a broad academic community, and various industrial concerns. Scientists have

**Table 4-11. Resources required for Individual Susceptibility: Genetic and Structural Basis (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 3.2 | 0.5 | 3.7 | 8 |
| 1999 | 4.0 | 0.4 | 4.4 | 10 |
| 2000 | 4.8 | 0.4 | 5.2 | 11 |
| 2001 | 6.0 | 0.5 | 6.5 | 15 |
| 2002 | 7.0 | 0.5 | 7.5 | 18 |
| 2003 | 8.0 | 0.5 | 8.5 | 20 |

In addition to the KP dollars above, GPP funds for FY 1999 are being dedicated to upgrading facilities for this project.

| Fiscal year | GPP funds | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1999 | 0.6 | 0.0 | 0.6 | 0 |

**Table 4-12. Resources required for Computational Biochemistry (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 0.8 | 0.1 | 0.9 | 2 |
| 1999 | 1.5 | 0.1 | 1.6 | 3 |
| 2000 | 2.5 | 0.1 | 2.6 | 6 |
| 2001 | 3.5 | 0.1 | 3.6 | 8 |
| 2002 | 4.5 | 0.1 | 4.6 | 10 |
| 2003 | 5.0 | 0.1 | 5.1 | 11 |

begun moving unique instrumentation to Livermore to conduct materials research with positron beams. Probing vacancy-type defects at the atomic scale to determine their size and concentration requires an innovative approach—positron spectroscopy. The sensitivity of this technique extends to smaller defect sizes and lower concentrations than reachable by any other method. Leveraging the capabilities at Livermore's 100-MeV LINAC, we are developing a truly unique instrument—the positron microprobe—which will provide an unrivaled defect analysis capability to model three-dimensional maps of buried defects with submicron spatial resolution.

• **Surface Characterization with Highly Charged Ions.** Using the Electron Beam Ion Trap (EBIT) facility at Livermore, we are developing a technique to obtain extremely detailed information about a surface and its contaminants. When a highly charged ion produced in the EBIT approaches a surface, the enormous potential energy causes the surface to emit hundreds of electrons. For many materials, this loss of electrons from a nanometer-scale area of the surface results in a large local excess of positive charge, which, in turn, leads to a highly localized breakup or sputtering of the surface that can be studied in great detail. The use of EBIT for surface characterization is of interest to both DOE Defense Programs and Energy Research, and the approach presents innovative research opportunities for many university-based research programs. In addition to materials research, the potential of the technique to modify surfaces at the nanometer scale is being examined by scientists for a variety of industrial and national-security applications.

*To Application of Mission-Directed Science and Technology, Section 3.3.2, p. 43.*

## 4.4 Assistant Secretary for Energy Efficiency

### 4.4.1 Center for Fuels Assessment (EE)

Transportation fuels are a crucial component of the economic infrastructure of the U.S. However, they pose a variety of health and environmental risks. Historically, regulatory agencies, as well as the auto and oil industries, have had difficulties in predicting and managing those risks. For example, the health and environmental impacts associated with the use of tetra ethyl lead and, recently, methyl tertiary butyl ether, were never properly assessed before their introduction to the market. Part of the problem is that such assessments are inherently complex and multidisciplinary and cannot be completed in any coherent fashion by multiple organizations with different missions.

A collaborative effort between Lawrence Livermore and Sandia national laboratories and the University of California can provide the needed expertise to create and implement methodologies for science-based analyses of fuels and fuel additives. To formalize this collaboration, we are establishing a Center for Fuels Assessment, whose charter will be to conduct strategic health and environmental evaluations of the nation's fuels for the 21st century. Although the scientific and policy expertise found at the Laboratory and collaborating institutions constitute the foundation of the center, the collaboration's success will depend on strong links to the oil and automotive industries.

Livermore is uniquely qualified to lead this effort because we have the technical capabilities to assess the health and environmental consequences of the entire lifecycle of a given fuel or additive—its production, distribution, storage, and use. The center's research of each lifecycle element will address three fundamental topics:

• Quantification of contaminant releases to air, surface water, groundwater, and soil.
• Characterization of the transport and transformation of fuel-related substances in environmental media.
• Assessment of the potential health and ecological risks of those substances.

Our expertise in these assessment topics includes both state-of-the-art computer models and experimental methods. For example, Livermore has

**Table 4-13. Resources required for Microbial Genomics (BA in millions of FY 1999 dollars after FY 1998).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 2.4 | 0.1 | 2.5 | 6 |
| 1999 | 3.6 | 0.2 | 3.8 | 8 |
| 2000 | 4.8 | 0.3 | 5.1 | 11 |
| 2001 | 5.9 | 0.3 | 6.2 | 15 |
| 2002 | 7.0 | 0.3 | 7.3 | 18 |
| 2003 | 8.0 | 0.3 | 8.3 | 20 |

developed sophisticated chemical kinetic models for simulating combustion products from an engine, while Sandia has a laboratory devoted to measuring emissions produced by combustion of different fuels. An important resource is our extensive suite of models for simulating the transport of fuel-related contaminants in air, soil, surface water, and groundwater. Our analytical capabilities for measuring contaminants in various sample matrices range from standard chromatographic techniques to the world-class Center for Accelerator Mass Spectrometry. Risk-assessment capabilities include models and experimental techniques for quantifying inhalation, ingestion, and dermal exposures to contaminants, as well as the internal doses and associated risks.

The key to establishing a successful center will be to implement assessment methodologies that take full advantage of our capabilities and result in scientifically sound assessments of the risks posed by fuel compounds. We are directing our current efforts toward defining integrated assessment methodologies and establishing collaborations with industry, government agencies and laboratories, and the University of California campuses to set the stage for interactions with potential sponsors. Our goal is to secure the funding for the center within the next year and begin studies that will help the nation determine the best fuels for the next century.

The primary funding source for the center will be the Assistant Secretary for Energy Efficiency supplemented by funds from the Office of Fossil Energy and the U.S. Environmental Protection Agency. Table 4-14 shows the resources required for this effort.

*To Environmental Risk Reduction, Section 3.1.5, p. 37.*

**Table 4-14. Resources required for the Center for Fuels Assessment ($M).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 0.1 | 0.0 | 0.1 | 0.5 |
| 1999 | 0.5 | 0.0 | 0.5 | 2.5 |
| 2000 | 2.0 | 0.0 | 2.0 | 10 |
| 2001 | 3.0 | 0.0 | 3.0 | 15 |
| 2002 | 3.0 | 0.0 | 3.0 | 14 |
| 2003 | 3.0 | 0.0 | 3.0 | 14 |

### 4.4.2 Hydrogen as an Alternative Fuel (AR)

Alternative fuels that are clean, efficient, and potentially carbonless and that lessen U.S. dependence on foreign energy supplies are critical to ensuring U.S energy security and sustainability. Hydrogen is a strong near-term contender as an alternative fuel because it satisfies these strategic criteria and can be made from a variety of domestic sources using existing infrastructures.

In the longer term, when renewable electric power sources, such as wind and solar thermal and photovoltaic power, become major suppliers to the national energy grid, hydrogen will provide both transportation fuel and the “energy intermediation” needed when demand peaks exceed primary grid supplies. Hydrogen will then be produced by utilities for centralized fuel distributions and some recycling to electricity and by local electrolysis at service stations and homes for distributed transportation needs. We propose several initiatives that can positively impact the feasibility of hydrogen fuel.

We have developed and tested an economic equilibrium model that can optimize the cost structure for future electric utility and transportation sector configurations. For the long-term, we propose to identify the most cost-effective integration of carbonless electric and transportation sectors. We propose to use this model to determine the critical technology performance criteria, compare technology options, and plan transition strategies.

Two technologies—critical for transitions now and in scenarios of the future—are light, compact onboard fuel storage for cars and trucks and efficient, scalable steam electrolysis. We have proposed and begun development of a cryogenic-capable pressure tank that can efficiently store pressurized hydrogen gas for short range and at-home refueling and liquid hydrogen for long-range and station refueling. We estimate a vehicle range as great as 800 miles for the Partnership for the Next Generation of Vehicles’ performance vehicles. We propose to engineer, performance test, and safety test this storage mode for inclusion in a vehicle demonstration.

Steam electrolysis with a solid-oxide electrolyte can achieve hydrogen production efficiency greater than 100% if auxiliary heat is available from other process sources. The hydrogen can be produced either from a pure water (steam) feed stock or from steam and methane, which might require carbon sequestration, but which has strong electrochemical efficiency advantages that might compensate for the additional processing. We propose a three-year program to develop and demonstrate a 10-kW solid-oxide electrolyzer, which would be adequate to provide fuel for a single vehicle. This same technology is applicable to the development of efficient, solid-oxide fuel cells.

Remote power applications offer immediate opportunities to demonstrate the technical feasibility of hydrogen technology systems because of the high cost of off-grid power. We are studying use of hydrogen for remote power applications in Nevada, Alaska, Pike's Peak National Monument in Colorado, the Philippines, and southern Italy.

We would like to provide energy system options that can influence national transportation and utility decisions within the next decade and be economically significant within two decades. See Table 4-16 for resource requirements for this effort. In addition to DOE support (Table 4-15), we will continue to develop industrial partnerships.

*To Advanced Transportation (Mobile Energy) Systems, Section 3.1.3, p. 36.*

**Table 4-15. Resources required for Hydrogen as an Alternative Fuel ($M).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 0.8 | 0.0 | 0.8 | 3 |
| 1999 | 2.0 | 0.3 | 2.2 | 7 |
| 2000 | 5.0 | 0.4 | 5.4 | 15 |
| 2001 | 4.5 | 0.4 | 4.9 | 16 |
| 2002 | 4.0 | 0.3 | 4.3 | 13 |
| 2003 | 4.0 | 0.2 | 4.2 | 12 |

## 4.5 Multiple Program Offices

### 4.5.1 Nuclear Materials Initiative (Multiple Program Offices)

We will work with other laboratories and multiple DOE Program Offices as well as other interlaboratory teams put together to respond to initiatives being developed by the Secretary's Office and by the Albuquerque Operations Office.

DOE and its predecessors have been responsible for a wide variety of nuclear materials and operations that are used to fuel civilian power reactors and research reactors (domestically and in other countries), to produce defense-related materials, and to power naval vessels. DOE controls an extremely complex and dynamic inventory of resources, facilities, and operations with which nuclear materials are created, processed, used, stored, and prepared for disposal. These activities are governed by numerous laws and regulations, by DOE responsibilities to state and other federal agencies, by U.S. cooperation with international organizations, and by U.S. treaty obligations.

In this context, Livermore serves as a national technical resource in enhancing safe, secure, economic, and environmentally sound conduct of nuclear operations. Although other DOE laboratories have large research efforts under way in either nuclear energy or nuclear weapons, Livermore is unique in the breadth and scale of aggregate nuclear activities, which span from nuclear weapon materials to the nuclear fuel cycle, nuclear systems safety, and public health. We now perform more than $300 million of nonweapon, nuclear-materials-related research per year as outgrowths of our science and technology base and of our experience with nuclear systems in support of national security missions.

Our intention is to coordinate these activities and use our aggregate capabilities to create a broadly applicable national resource for the management of nuclear materials. Emerging strategic issues that are likely to help shape DOE missions and U.S. nuclear materials agendas over the next 5 to 10 years include:

- Excess special nuclear material from weapons, generated by the build-down of nuclear arsenals in the U.S. and the Former Soviet Union. These materials require a disposition path that is politically acceptable and technically feasible.
- The post–Cold War environmental legacy, with environmental cleanup and waste management needs of the defense complex continuing to have a major impact on DOE budgets, credibility, operations, and missions.
- Management and disposal of civilian spent nuclear fuel, with DOE facing significant deadlines in 1998 regarding spent fuel acceptance and the Yucca Mountain repository site viability. Because Yucca Mountain is currently the expected disposition endpoint for many defense-related, high-level nuclear waste materials, the impact of Yucca Mountain decisions and activities will eventually be felt in other parts of the defense complex.

• Uranium enrichment costs. Laser-based enrichment technologies (atomic vapor laser isotope separation, or AVLIS) are driving down costs, which should reduce uranium fuel prices and enhance the U.S. position in the global marketplace. However, the availability of fuels blended from excess highly enriched uranium (HEU) may complicate market behavior, even though such redirection of HEU helps meet nonproliferation objectives.
• Growing demands for nuclear power (particularly in Asia), with the U.S. facing significant competition in the nuclear technology marketplace. Nuclear fuel reprocessing is continuing globally despite U.S. efforts to discourage this.

Drawing upon our resources that are spread across several directorates and disciplines, we will continue supporting DOE in resolving these strategic issues and will focus on new mission-oriented work, especially in support of high-level waste, plutonium stabilization and disposition, mixed oxides (MOX), and greater-than-Class-C (GTCC) wastes. See Table 4-16 for resource requirements to continue this effort.

*To Advanced Utility (Fixed Energy) Systems, Section 3.1.2, p. 35.*

### 4.5.2 Accelerator Technologies (Multiple Program Offices)

Livermore contributes to national accelerator R&D programs with its innovative approaches to accelerator design and detector systems and its broadly based capabilities engineering, precision manufacturing, and multidisciplinary project management. We are part of the three-laboratory effort building the B-Factory at Stanford, and our accelerator expertise is being applied to important national security applications, including the development of Accelerator Production of Tritium and the Advanced Hydrotest Facility (AHF). One of the major candidates for AHF is the use of high- energy protons as the radiographic probe. We have been working on the design of a machine and detectors for proton radiography. This design effort has been carried out in collaboration with the DOE's High Energy Physics Program at several DOE national laboratories (BNL, FNAL, and SLAC). It is anticipated that a decision on the technology for an AHF will be made soon and that important technology demonstration experiments will be conducted.

In addition, Livermore is partnering with Los Alamos, several other national laboratories, and industry to investigate the use of high-power proton accelerators to transmute radioactive waste into more manageable forms. Transmutation of waste is being studied as a technology that can contribute to the disposition some 70,000 tons of radioactive wastes from the nuclear power industry. A five-year R&D program is envisaged to optimize the techniques, investigate options within the program, conduct the appropriate system studies, and understand the impact on the overall problem facing the nation.

We can also make important contributions to major user facilities being planned by the DOE Office of Energy Research:
• **The Next Generation Light Source.** Advances in low-emittance electron linacs over the past several years have opened up the possibility of a fundamentally new kind of synchrotron light source of unprecedented brightness. A free-electron laser (FEL) consisting of such a linac driving a long precision-fabricated undulator can produce monochromatic 1-angstrom radiation 10 billion times brighter than existing "third-generation" facilities such as the Argonne Advanced Photon Source. The recent review of the national synchrotron facilities by a Basic Energy Sciences Advisory Committee (BESAC) subpanel gave its highest recommendation to a vigorous R&D program on "fourth-generation" light sources. Livermore is a charter member of a consortium including SLAC, LANL, and UCLA that is carrying out R&D toward a demonstration facility, called the Linac Coherent Light Source (LCLS). LCLS is a $100-million project that would begin construction in FY 2001. Livermore is involved in several key aspects of the project, including undulator design, low-emittance electron sources, and novel x-ray optics. A milestone experiment validating the physics of this new FEL regime will take place at Brookhaven National Laboratory in FY 1999.
• **The Next Linear Collider.** The next major high-energy physics machine in the world after the CERN Large Hadron Collider will likely be a teraelectronvolt electron–positron linear collider. This Next Linear Collider (NLC) would be a 30-km-long facility, costing several billion dollars, with the U.S. and Japan as the major players. The scientific thrust of the NLC is a full exploration of physics beyond the

**Table 4-16. Resources required for Nuclear Materials Initiative ($M).**

| Fiscal year | Operating costs | Capital equipment | Total costs | Direct FTEs |
|---|---|---|---|---|
| 1998 | 1.0 | 0.0 | 1.0 | 4 |
| 1999 | 5.0 | 0.0 | 5.0 | 7 |
| 2000 | 5.0 | 0.0 | 5.0 | 10 |
| 2001 | 10.0 | 0.0 | 10.0 | 20 |
| 2002 | 10.0 | 0.0 | 10.0 | 20 |
| 2003 | 10.0 | 0.0 | 10.0 | 20 |
| 2004 | 10.0 | 0.0 | 10.0 | 20 |

Standard Model, including the study of the spectra of Higgs particles and determining whether Supersymmetry is a valid description of nature. The U.S. and Japan have recently entered into an agreement to work on one technical baseline design for the machine. The recently-issued High Energy Physics Advisory Panel (HEPAP) subcommittee report strongly recommended DOE to proceed with a Conceptual Design Report (FY 1999 to 2001). The collider is patterned after the very successful B Factory collaboration. Construction would begin in FY 2002 if approved, with commissioning around FY 2008. SLAC, LLNL, and LBNL are the U.S. leaders for this project. The Laboratory has undertaken advanced manufacturing, one of the most challenging roles in the R&D program, namely advanced manufacturing on the 20-km precision accelerator structures, to make large cost reductions in the project. The Laboratory is also applying its unique expertise in high-average-power, short-pulsed lasers toward the design of a second interaction region: a high-luminosity gamma–gamma collider that would open up entirely new physics complementary to the electron–positron collisions.

*To Application of Mission-Directed Science and Technology, Section 3.3.2, p. 43.*

### 4.5.3 Computational Materials Science and Chemistry (Multiple Program Offices)

The Laboratory is committed to continuing the expansion and enhancement of our ability to accurately model and predict the behavior of emerging and aging materials. Materials often must perform in adverse and stressing environments (corrosion, radiation, high temperature, etc.), and we are actively engaged in understanding the impact of such environments. Livermore's research efforts cover a broad spectrum of activities, from molecular design and metal physics to predicting the macroscopic behavior of materials. Much of our effort is focused on the atomistic and molecular regime where *ab initio* calculations of interatomic potentials lead to predictions of atomic structure and molecular stability. We are also developing an understanding of mechanical properties by examining the relationship between defect structures described atomistically and the deformation behavior of individual grains of a metal. Our goal is to develop, in a predictive manner, the macroscopic materials parameters that are essential input to macro-scale simulation codes that are used to characterize the mechanical response of complex materials assemblies to loads. We are also developing models of radiation-induced changes in solids based on an atomistic understanding of the defect structure and its influence on microstructure evolution, as well as methods to model and predict stress-corrosion cracking.

*To Application of Mission-Directed Science and Technology, Section 3.3.2, p. 43.*

# SECTION 5



## Laboratory Operations

# HERMES Bridge Inspection System



**High-Performance Electromagnetic Roadway Mapping and Evaluation System (HERMES), a high-resolution, radar-based mobile inspection system for detecting and mapping defects in bridge decks.**

*Laser Programs and Engineering at Livermore and the Federal Highway Administration.*

Safe and efficient operations, sound business practices, and attention to the Laboratory's valuable resources make possible Livermore's technical achievements. High-quality, cost-effective operations provide essential support to the Laboratory's mission. They facilitate a high level of technical accomplishment while assuring sponsors of sound business practices and compliance with applicable regulations.

In all Laboratory operations, we strive to set a standard of excellence in performance and safety among high-technology applied research and development institutions. A key to our success is teamwork, a broadly applied principle at the Laboratory that uses a matrix management system to focus scientific and engineering talent where needed and integrates operational support with programs. For seamless integration of Laboratory operational support with programs, staff and systems must be agile and cost-effective, adding value to Livermore's technical work.

The Laboratory's operational services must consider a diverse set of customers—the technical programs, sponsors, Congress, Laboratory employees, and the local community—to name just a few. To best meet the different, sometimes conflicting needs of these customers, the Laboratory operates as an integrated system. Our goal is to have an overall balance of capability and infrastructure that successfully support the Laboratory's objectives.

In 1992, the University of California (UC) and the Department of Energy pioneered a contracting approach that integrated performance-based requirements into the contract for operating the three UC laboratories. Performance-based management of the Laboratory is at the forefront of a national trend that is evident in federal initiatives such as the National Performance Review (NPR) and the Government Performance and Results Act (GPRA). Both initiatives attempt to reconstitute systems, formerly governed by federal norms, that are more competitive and cost-effective. The objectives and performance measures in the UC/DOE contract flow from the corporate management and science and technology objectives in the DOE Strategic Plan. Through an annual contract performance evaluation process, Laboratory self-assessments are reviewed and graded by DOE. This process provides the Laboratory an opportunity to update and align specific performance measures in the contract with DOE requirements and criteria.

Within the framework of the Laboratory's performance-based management system, we are taking steps, as U.S. industry is doing, to streamline business practices, improve information management, and outsource services when practical and cost-effective. The Laboratory has reduced general and administrative (G&A) costs by about 30% (inflation adjusted) between FY 1993 and FY 1998. These reductions have returned about $50 million to the Laboratory for programs and for meeting strategic institutional reinvestment needs. The following three steps reflect Laboratory priorities:

### *Reshape and Shrink the Operational Support Base*

This step includes: establishing a Cost Cutting Initiative Task Force and implementing recommendations, restructuring operations management in the Laboratory, designating a Chief Information Officer to drive improvements in the computer-based information infrastructure, designating an Institutional Facilities Manager, and implementing a Workforce Restructuring Program consisting of a voluntary separation program and a restricted hiring policy.

### *Make Operational Support More Agile and Responsive*

Livermore is accelerating and expanding its use of best business practices, which include an emphasis on learning from the experiences of organizations outside the Laboratory. Operations organizations within the Laboratory are conducting a systematic review of externally available systems, products, technologies, and services to assure that the Laboratory takes advantage of appropriate opportunities to achieve cost savings and operational efficiencies. Benchmarking and roadmapping business processes are key, as are adopting commercial solutions for operations problems and using teams to focus on high-payoff solutions.

### *Ensure appropriate stewardship of resources as we reduce operational support costs*

The Laboratory is committed to ensuring the health and safety of employees and the public, preserving the environment and capital investments at the Laboratory, and protecting Special Nuclear Materials and classified information. Financial and business practices must be of high integrity. And we must reinforce a Laboratory-wide operations culture to align with our operations vision and goals.

## 5.1 Environment, Health, and Safety (ES&H)

Livermore's goals are for Laboratory operations to be conducted in an environmentally responsible manner, for safety to be integrated into programmatic and support activities as a top priority and executed in a cost-effective manner, and for ES&H performance to be comparable to the best of our peers.

We aim to be recognized as an institution capable of carrying out challenging projects and state-of-the-art research and development in a safe manner. Accidents are preventable through close attention to potential hazards and diligence by each individual and responsible organization. It is of paramount importance that employees take responsibility for making the Laboratory a safe place to work and that the community sees us as a good neighbor, concerned about safety as well as health and the environment. To achieve our ES&H goals:

- Our Laboratory culture must place high priority on ES&H as both a line management responsibility and an individual responsibility.
- ES&H must be fully integrated into all Laboratory activities, with appropriate balance between risk acceptance and costs.

### *Situation and Issues*

The Laboratory is known as a safe place to work. Our policy is that safety of both workers and the public has the highest priority. Although we work with hazardous materials and execute complex operations, our activities must be conducted safely, and the public and the environment must be protected. Employees are well trained and empowered to stop work when they are uncertain of the safety of an operation.

In December 1997, DOE completed a Safety Management Evaluation (SME) that reviewed the broad scope of the Livermore's ES&H program. The SME used the basic principles of DOE's Integrated Safety Management approach as a guide in evaluating the Laboratory. Overall, the Laboratory's program exhibited many strengths with strong performance in four of the seven ISM principles. These strengths include clearly defined management roles and responsibilities, mechanisms for contractual accountability, an appropriate balance between safety and mission-related priorities, and effective identification of requirements. No deficiencies in need of immediate remedial action were identified; however, the SME identified three areas for improvement:

- The translation of top-level policies into working-level process and guidance.
- Performance evaluation and feedback.
- Work planning and execution.

Special emphasis was placed on needed improvements in work planning, e.g., hazard identification and analysis and the planning, authorization, and control of work.

At Livermore, we have tended to focus our attention on special hazards associated with high-technology research projects. However, we can and must do better at preventing minor accidents connected with day-to-day activities. Most Laboratory accidents and injuries involve strains and sprains associated with routine work and could be reduced by better work planning, greater personal awareness of safety issues, and positive steps to fully integrate safety considerations in all operations. Top management involvement and leadership; clear roles, responsibilities, and performance expectations; and accountability are essential for improving safety performance.

Senior Laboratory management is involved in and committed to the success of DOE's Integrated Safety Management (ISM) System that is being implemented at the Laboratory. In pursuing ISM and improved ES&H performance, we will continue to communicate openly with the community on ES&H matters that has already brought strong support from the local community. For example, several years ago, the Laboratory successfully adopted a practice of providing timely news releases on significant ES&H events to build trust with the community. Community members participate on working groups related to Livermore's Superfund groundwater cleanup and construction of the National Ignition Facility. *Ad hoc* public hearings are also held, as appropriate, on ES&H issues.

Livermore's *Site Annual Environmental Report*, prepared each year by the Environmental Protection Department at the Laboratory, summarizes the results of environmental monitoring and provides an assessment of the impact of Laboratory operations on the environment and the public. In addition to our responsibilities to employees and neighboring communities, we must ensure compliance of Laboratory programs with the National Environmental Policy Act (NEPA), the California Environmental Quality Act, and related federal and state requirements. Environmental protection efforts include environmental monitoring, risk assessment, and analysis, as well as major endeavors in environmental restoration—principally groundwater cleanup—and hazardous waste reduction and disposition.

### *Strategy Thrusts*

We are proceeding with the implementation of Integrated Safety Management (ISM), including Work Smart Standards (WSS), at all levels of the Laboratory. ISM is now part of our performance-based management system. Through effective involvement of senior management together with line organizations and employees across the Laboratory, we will improve the safety management process, enhance the Laboratory's safety culture, and significantly improve safety performance. As part of this effort, Livermore is selecting a WSS set that will be implemented throughout the Laboratory for the full spectrum of our activities, from R&D to routine maintenance and operations. ISM-defined formality of work processes, which are well-defined procedures to follow depending on the task, will be tailored to match the level of complexity and the risks posed by associated hazards.

We are also establishing Laboratory policy guidelines specific to ES&H to enhance accountability. Practices followed at high-performance, private-sector R&D organizations are being studied as a guide. A major focus will be to better define and articulate the flow of responsibility in Livermore's matrix management system. We will also review our system of rewards and discipline for ES&H to assure consistency and to both promote safety and better deal with safety violations or poor safety performance.

Consistency across the Laboratory in ES&H practices is important for achieving cost efficiency while meeting safety goals. Full implementation of ISM will lead to the identification of practices to be uniformly implemented across the Laboratory and will provide guidance for local adjustments to meet special circumstances. These measures will ensure clear communication of expected safety practices, effective training, and interchangeability of skills. Clearly defined roles and responsibilities will be formalized through memoranda of agreement between all organizations and facilities. These agreements, which are particularly important issues for the Laboratory's nuclear and other hazard-ranked facilities, will delineate communication protocols, maintenance responsibilities, and reporting requirements.

Environmental protection efforts will continue to focus on the use and further development of cost-effective technologies and acceptable methods, regardless of origin, for pollution prevention and site cleanup as well as for waste reduction and management. Direct funding for environmental restoration and waste management at the Laboratory is shown in Table 5-1. Because environmental protection begins with pollution prevention and waste minimization, we are taking concerted steps to reduce both the hazardous and nonhazardous waste generated by Laboratory programs. As for waste management, the Laboratory's facilities and waste-handling operations are managed to minimize the impact on the environment and to maximize the efficient use of environmental management operating funds. We will strive to continually improve efficiency and reduce waste inventory as we operate Livermore's waste facilities.

We also will continue activities to better characterize and clean up hazardous materials and contaminated groundwater at the Livermore site and Site 300. In these environmental remediation and restoration efforts, we will develop and test innovative solutions that have broad application to environmental problems at other contaminated sites.

## 5.2 Facilities and Plant Infrastructure

Lawrence Livermore National Laboratory comprises two sites: the main Livermore site and Site 300, a 28-square-kilometer remote explosives test facility located about 25 kilometers southeast of Livermore. The Livermore site has 170 permanent buildings and 331 temporary structures and houses over 9,000 people. At Site 300, there are 66 permanent buildings and 10 temporary structures. The replacement plant value is estimated to be $3 billion, which does not include some $1.8 billion in personal property and land value (see Tables 5-1 through 5-3 and Figures 5-2 through 5-6).

Stewardship of DOE lands and facilities at Livermore is an important responsibility. The Laboratory has world-class scientific facilities that are essential for national security and provide unique capabilities to meet other enduring national research and development needs. Facilities and infrastructure at Livermore—and our

**Table 5-1. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives (in millions of dollars), including capital funding.**

| | FY 1997 | FY 1998 | FY 1999 | FY 2000 | FY 2001 | FY 2002 | FY 2003 and beyond |
|---|---|---|---|---|---|---|---|
| Waste Minimization and Pollution Prevention | 1.6 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Environmental Restoration | 23.1 | 21.5 | 22.3 | 22.3 | 24.1 | 28.1 | 30.0 |
| Waste Management | 32.1 | 30.9 | 28.8 | 31.1 | 28.8 | 24.5 | 23.0 |

investment strategy for maintenance, renovation, and new construction—must be aligned with the Laboratory's programmatic and operational requirements.

We want every employee to take pride in Livermore's campus setting—a physical plant that is attractive, accessible, and designed to be cost effective and inviting. This goal requires modern facilities at the Laboratory, designed and sized for current and future operations and well maintained at competitive costs. A quality campus environment attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success.

**Table 5-2. Laboratory space distribution (in thousands of square feet).**

| Type of Space | Area |
|---|---|
| Main site | 5,775 |
| Leased-university | 0 |
| Leased-off-site | 48 |
| Site 300 | 357 |
| Total | 6,180 |

**Table 5-3. Facilities replacement value (in millions of dollars).**

| Type of Asset | Value |
|---|---|
| Buildings | $1,936 |
| Utilities | $490 |
| All other | $565 |
| Total Value | $2,991 |

### *Situation and Issues*

At the core of the Laboratory's strength in facilities are unique, state-of-the-art, experimental research facilities. The major national security directorates all have some modern core facilities in use or under construction. Construction is in progress on the $1.2-billion National Ignition Facility, which will be a cornerstone of the nation's nuclear weapons stockpile stewardship program. In addition, planning is under way for the Terascale Simulation Facility to house the Laboratory's ASCI computers and needed office space for the program. The modern office space designed into these research facilities—and the space in other recently constructed facilities at the Laboratory—helps to improve the overall living conditions of the Laboratory population. Recent actions, such as line items for electrical and infrastructure modernization, have also helped upgrade the Livermore site. In addition, the communications and information systems infrastructure at the Laboratory has undergone continual upgrade, in part to keep pace with the unprecedented high-performance computing capability that Livermore is acquiring.

On the other hand, many structures are 30 to 50 years old and need rehabilitation or replacement (see Figure 5-1). These conditions place stress on strategic management of Laboratory facilities and site planning, which must balance the needs and resources for maintenance, facility rehabilitation, and new facilities development.

To keep our aging facilities operational, we continually update a prioritized list of institutional maintenance requirements. (See Figures 5-2 and 5-3.) Only half of our employees currently reside in permanent space and the majority of temporary office space is nearing or already beyond the end of service life. As more facilities age beyond their intended life, our needs for modern office space will continue to grow. In addition, we have outdated and unusable laboratory space from long discontinued programs which must be decommissioned, decontaminated (where necessary), and demolished. Livermore's legacy facilities and other excess marginal space require

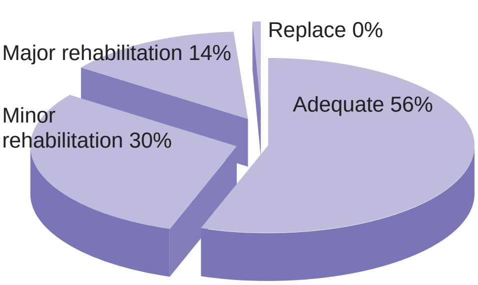



Figure 5-1. Condition of Laboratory space

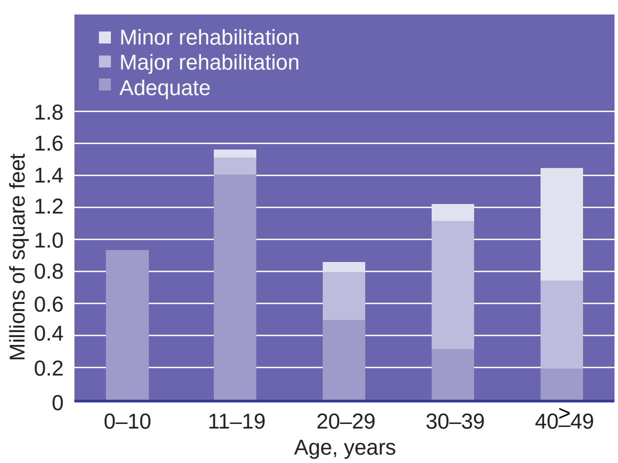



Figure 5-2. Age and condition of Laboratory buildings.

considerable up-front investment to rectify or demolish.

### *Strategy Thrusts*

Initially appointed in 1997, the Institutional Facility Manager serves as the focal point for developing and implementing a long-term strategy for managing facility investments at Livermore. This manager acts in partnership with senior managers from each Laboratory organization to establish priorities, develop policies, and effect changes. In particular, the Institutional Facilities Manager leads a council, comprised of senior managers from each major organization at the Laboratory, to provide a coherent strategic management perspective for developing new facilities that are required to meet the Laboratory's missions. In addition, the Institutional Facilities Manager chairs the Site Planning and Capital Asset Management working group that focuses primarily on the development and execution of tactical solutions to achieve improved operational efficiency throughout the Laboratory.

Several planning exercises are under way to directly address significant facility issues. The Laboratory is developing a multiyear maintenance plan and is taking immediate actions to meet the most critical institutional maintenance needs. In addition, we are taking steps to better identify and prioritize approaches to fund and reduce the deferred maintenance inventory or maintenance backlog, which has resulted from facility aging and a shortage of capital and operating funds in recent years. Furthermore, a coherent Laboratory-wide office requirements plan is being developed to address the needs of the nearly 3,000 employees who work in inadequate space—trailers, modular units, or World War II-era buildings. At a time when programmatic line items can be expected to draw considerable funding, solutions to office space issues must entail a combination of new, renovated, and revitalized facilities. In this connection, we are exploring workable options for innovative, cost-effective, facility revitalization and new construction/ renovation.

## 5.2.1 Facility Plans and Resource Requirements

Table 5-4 provides a summary of funded and proposed construction projects at the Laboratory with total estimated cost (TEC) in excess of $5 million. Construction projects that are funded or are proposed to begin in FY 1999 or FY 2000 include:

- **Sensitive Compartmented Information Facility (SCIF) (FY 2000 start, TEC: $19.7 M).** The planned Sensitive Compartmented Information Facility (SCIF) is proposed as a two-story 5,400-square-meter building to be sited on the west side of the Laboratory, adjacent and north of Building 132. The new SCIF is essential for NAI to continue to carry out its mission, to reduce maintenance and special security costs, and to consolidate Livermore's national security programs.
- **Protection of Real Property—Phase II (FY 1999 start, TEC: $19.9 M).** This project includes roof reconstruction of 11 major Laboratory buildings (Buildings 111, 113, 121, 141, 194, 231, 241, 251, 281, 321, and 332) with a combined area of approximately 52,000 square meters. These buildings perform functions vital to the Laboratory's capability to support the Stockpile Stewardship Program. Reconstruction of these roofs is an investment that will extend the useful life of these facilities for at least 20 years. This reconstruction project has been identified as the highest-priority work to upgrade facilities for the protection of critical weapons facilities at the Laboratory.
- **Isotope Sciences Facility (FY 1999 start, TEC: $17.4 M).** This project provides for a seismic retrofit to the Isotope Science Facility (Building 151) and construction of an office addition, retrofit of ventilation systems in Buildings 151 and 154, decontamination of the Refractory Materials Facility (Building 241), and disposal of existing trailers. Work conducted in the Isotope Sciences Facilities plays a key role in fulfilling the Stockpile Stewardship Program mission to annually certify nuclear weapons performance, provide important diagnostics to evaluate the

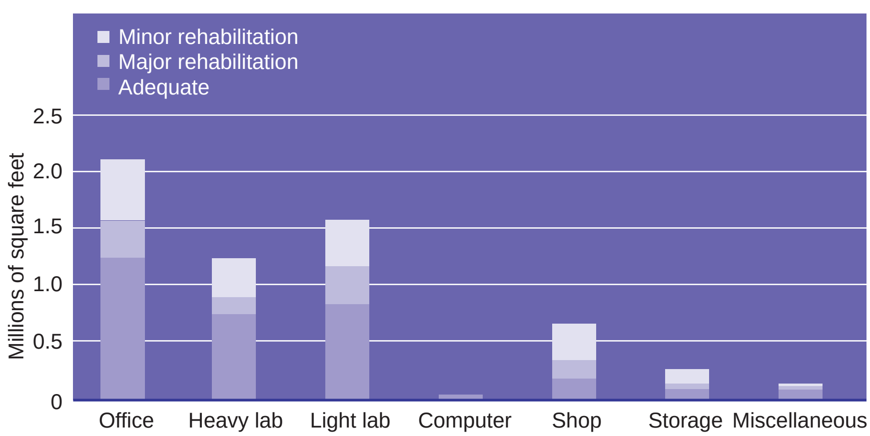



Figure 5-3. Use and condition of Laboratory space (in square feet).

performance of NIF/ICF capsules, and maintain the ability to resume nuclear testing

• **Rehabilitation of the Maintenance Facility (FY 1999 start, TEC: $7.9 M).** The purpose of this project is to renovate Livermore's principal maintenance and repair facility, Building 511. This 54-year-old facility is badly deteriorated and requires renovation to maintain a state of readiness for ensuring that critical maintenance and infrastructure support activities can be accomplished. Major features of the project include a new weathertight exterior shell including new windows and a main entry, elevator, restroom upgrades, ventilation for shop areas, and updates to the fire-protection and electrical systems.

• **Terascale Simulation Facility (TSF) (FY 2000 start, TEC: $83.5 M).** This project provides for the construction of a new 25,000-square-meter facility comprised of a four-story office tower flanked by two two-story computer structures. The computer structures will each house a computer machine room of approximately 2,200 square meters. The office tower will house staff, industrial partners, and Alliance and Tri-Lab collaborators. It will provide meeting rooms, offices, and a prototype advanced-concept Assessment Theater. TSF will provide a scalable facility for computers that will be rated at operational speeds of 100 teraOPS in 2004 and beyond.

• **Engineering Technology Complex Upgrade (FY 2000 start, TEC: $20.7 M).** The Building 321 Engineering Technology Complex will be upgraded and remodeled to make its four-decades-old shop facility capable of providing state-of-the-art service to

**Table 5-4. Funded and proposed construction (in millions of dollars).**

| Project Title | TEC $M | FY97 | FY98 | FY99 | FY00 | FY01 | FY02 | FY03 | FY04 & beyond |
|---|---|---|---|---|---|---|---|---|---|
| **Defense Program - Funded Projects:** | | | | | | | | | |
| National Ignition Facility | 1045.7 | 131.9 | 197.8 | 284.2 | 248.1 | 74.1 | 65.0 | 7.2 | |
| S-300 Contained Firing Facilities | 49.7 | 17.1 | 19.3 | 6.7 | | | | | |
| Protection of Real Prop (roofs) Phase I | 7.8 | 3.0 | 4.8 | | | | | | |
| S-300 Fire Station and Medical Facility | 5.4 | | 0.9 | 4.5 | | | | | |
| DP Total Funded Construction | | 152.0 | 222.8 | 295.4 | 248.1 | 74.1 | 65.0 | 7.2 | |
| **Defense Program - Proposed Projects:** | | | | | | | | | |
| Protection of Real Property - II | 9.9 | | | 7.3 | 6.4 | 6.2 | | | |
| Isotope Sciences Facility | 17.4 | | | 4.0 | 10.0 | 3.4 | | | |
| Rehabilitation of Maintenance Facility | 7.9 | | | 6.5 | 1.4 | | | | |
| Terascale Simulation Facility | 83.5 | | | | 8.0 | 22.0 | 22.0 | 22.0 | 9.5 |
| Engineering Technology Complex Upgrade | 20.7 | | | | | 2.0 | 8.5 | 7.0 | 3.2 |
| Adaptive Re-Use for Office Space | 24.0 | | | | | | 2.0 | 6.0 | 16.0 |
| DP New Funding Requirements | | | | 17.8 | 25.8 | 33.6 | 32.5 | 35.0 | |
| Total Defense Programs | | 152.0 | 222.8 | 313.2 | 273.9 | 107.7 | 97.5 | 42.2 | |
| **Nonproliferation and National Security - Proposed Projects:** | | | | | | | | | |
| SCIF Area for NAI | 19.7 | | | | 5.0 | 12.0 | 2.7 | | |
| **Energy Research - Proposed Projects:** | | | | | | | | | |
| B-543 Addition | 18.2 | | | | 3.5 | 10.7 | 4.0 | | |
| Genomics and Structural Biology | 40.5 | | 4.0 | 12.0 | 20.0 | 4.5 | | | |
| Total Energy Research | | | | 4.0 | 15.5 | 30.7 | | | |
| **EM Projects - Funded Projects:** | | | | | | | | | |
| Decontamination/Waste Treatment Facility | 62.4 | 9.5 | 10.0 | 5.0 | 2.5 | 2.0 | 0.2 | | |
| Total Laboratory | | 161.5 | 232.8 | 318.2 | 281.4 | 125.7 | 115.9 | 72.9 | |

the programs for at least the next 25 years. The complex will be upgraded to contain precisely controlled temperature, vibration, and cleanliness environments. Three wings of Building 321 will undergo structural retrofit to meet current seismic standards. Fabrication activities performed in the Building 321 Complex are critical to the success of the Stockpile Stewardship Program, the National Ignition Facility (NIF), and most other Laboratory programs.

• **Decontamination and Waste Treatment Facility (FY 1986 start—permits pending, TEC: $68 M).** The Decontamination and Waste Treatment Facility (DWTF) will enhance, improve, and expand hazardous waste and mixed waste management at the Laboratory through the construction of approximately 7,300 square meters of new state-of-the-art facilities for decontamination and waste treatment processes and 470 square meters of modifications to an existing building. DWTF will provide new, centralized, and integrated facilities for Hazardous Waste Management (HWM) operations that will meet the requirements for a Low Hazards Category 3 Facility. This project will continue to meet the goals of Livermore's waste management program while significantly enhancing the waste management capabilities.

## 5.3 Laboratory Personnel

Livermore's principal asset is its quality workforce. The Laboratory seeks a highly talented, productive, motivated, flexible staff that is committed to Livermore's goals and reflective of the diversity of California and the nation. We strive for a work environment in which all employees can contribute to their fullest and feel valued for their role. The size, job classification, and diversity of Livermore's career-employee workforce are characterized in the accompanying Tables 5-5 and 5-6.

Recruitment, reward, and advancement policy decisions are based on contribution to Livermore's success. The Laboratory greatly values outstanding scientific and technical achievements. Breakthrough accomplishments are critical to the success of Livermore's programs and provide the foundation for future programs to meet national needs. The Laboratory's programmatic achievements would not be possible without safe and efficient operations. All activities depend on the dedicated, high-quality efforts of Laboratory employees engaged in administrative and operational support. In both scientific work and operational support activities, we recognize and reward both individual and team excellence in performance. And we expect all employees to take pride in and responsibility for their work, improve their skills, and continue their professional growth.

### *Situation and Issues*

Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce. For the technical staff, the Laboratory provides creative research opportunities and an association with University of California that has led to an array of scientific and technical ties to academia that would not have been achievable otherwise. More generally, all employees have the opportunity to work with world-class peers and to make a difference by contributing to the solution of difficult real-world problems where the national interest is at stake. The strong bond between Livermore and the University nurtures an atmosphere at the Laboratory in which independent views and technical honesty are core values. University of California management of Livermore also provides employees an excellent benefits package and the underlying policy framework for the Laboratory's human resources program.

In spite of these competitive advantages, we must be more aggressive in policies and practices designed for recruitment and career development in

**Table 5-5. Laboratory staff composition as of March 31, 1998 (excludes summer hires and temporary program participants; may include indefinite employees).**

| | Ph.D. | M.S./M.A. | B.S./B.A. | Other | Total |
|---|---|---|---|---|---|
| Total scientists | 905 | 350 | 315 | 6 | 1,576 |
| Total engineers | 279 | 402 | 223 | 16 | 920 |
| Managers and administrators | 28 | 170 | 273 | 570 | 1,041 |
| Technicians | 1 | 23 | 279 | 1392 | 1,695 |
| All others | 0 | 5 | 33 | 1185 | 1,223 |
| Totals | 1213 | 950 | 1,123 | 3,169 | 6,455 |

selected disciplines where there is significantly increased competition for the best people and where demand far outpaces supply. The Laboratory's recruitment strength has been based on the work environment, the importance of the national security work, and the exciting technical challenges Livermore has been able to offer. However, compensation is also an issue. Although the Laboratory's compensation system is structured to recognize superior performance and is driven by the "market," it is not as flexible as some systems in private industry. In certain "hot" skills job classifications, such as computer scientists and optical engineers and technicians, the Laboratory cannot easily match the total compensation offered by others, particularly in the highly competitive San Francisco Bay Area. We are working with the DOE to ameliorate these difficulties and adjust the compensation system, where possible, to address the most critical problems. For example, as part of the merit increase package this year, we received approval from DOE to supplement by 10% the salaries for computer scientists, whose skills are in great demand in the Bay Area.

The Laboratory must retain a degree of flexibility in staffing. Program redirections will continue to occur as the nation continues to adjust to changing requirements for national security, energy security, and environmental quality. Workforce issues must be managed in a way that permits adaptable use of the workforce and encourages employee development while keeping employee dislocations to a minimum. The Laboratory therefore needs to continue its efforts to achieve a truly flexible workforce—a balance between the Laboratory being a storehouse of skills and a purchaser of skills as needed. Greater agility in managing shifting workforce demands greater attention to future workforce planning and improved employee development and placement programs. In addition, we must increase emphasis on leadership training because the Laboratory's future depends on the continual development of leaders who are visionary, skilled in managing and building programs, and sensitive to workforce needs.

### *Strategy Thrusts*

The Laboratory is reviewing its personnel practices (e.g., compensation, benefits, work environment, and services) and is implementing changes that enhance the Laboratory's ability to attract and retain employees as well as encourage their growth. A contemporary work environment requires both appropriate policies and attention to implementation, including equity in compensation and other personnel practices, effective and fair

**Table 5-6. Population of Laboratory career employees as of March 31, 1998 (by number and percentage).**

| | | Officials and managers | | Scientists & engineers | | Administrative | | Technicians | | All others | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | | (%) | | (%) | | (%) | | (%) | | (%) |
| White | M | 818 | (66.5) | 1360 | (72.1) | 152 | (24.9) | 1001 | (66.6) | 437 | (34.7) | 3768 | (58.1) |
| | F | 243 | (19.8) | 239 | (12.7) | 327 | (53.5) | 223 | (14.8) | 503 | (39.9) | 1535 | (23.7) |
| Black | M | 30 | (2.4) | 24 | (1.3) | 8 | (1.3) | 42 | (2.8) | 45 | (3.6) | 149 | (2.3) |
| | F | 8 | (0.7) | 12 | (0.6) | 27 | (4.4) | 15 | (1.0) | 32 | (2.5) | 94 | (1.4) |
| Hispanic | M | 40 | (3.2) | 41 | (2.2) | 10 | (1.6) | 89 | (5.9) | 74 | (5.9) | 254 | (3.9) |
| | F | 25 | (2.0) | 8 | (0.4) | 33 | (5.4) | 18 | (1.2) | 77 | (6.1) | 161 | (2.5) |
| Native American | M | 12 | (1.0) | 9 | (0.5) | 4 | (0.7) | 22 | (1.5) | 16 | (1.3) | 63 | (1.0) |
| | F | 5 | (0.4) | 0 | (0.0) | 10 | (1.6) | 10 | (0.7) | 14 | (1.1) | 39 | (0.6) |
| Asian | M | 28 | (2.3) | 141 | (7.5) | 14 | (2.3) | 62 | (4.1) | 30 | (2.4) | 275 | (4.2) |
| | F | 21 | (1.7) | 44 | (2.3) | 26 | (4.3) | 21 | (1.4) | 31 | (2.5) | 143 | (2.2) |
| Total minorities | M | 110 | (8.9) | 215 | (11.4) | 36 | (5.9) | 215 | (14.3) | 165 | (13.1) | 741 | (11.4) |
| | F | 59 | (4.8) | 64 | (3.4) | 96 | (15.7) | 64 | (4.3) | 154 | (12.2) | 437 | (6.7) |
| Unidentified | M | – | – | 7 | (0.4) | – | – | – | – | 1 | (0.1) | 8 | (0.1) |
| | F | – | – | 1 | (0.1) | – | – | – | – | – | – | 1 | (0.0) |
| Totals | M | 928 | (75.4) | 1582 | (83.9) | 188 | (30.8) | 1216 | (80.9) | 603 | (47.9) | 4517 | (69.6) |
| | F | 302 | (24.6) | 304 | (16.1) | 423 | (69.2) | 287 | (19.1) | 657 | (52.1) | 1973 | (30.4) |
| Lab totals | | 1230 | | 1886 | | 611 | | 1503 | | 1260 | | 6490 | |

complaint resolution processes, and means for assuring that employees feel well informed and have a shared sense of excitement about the success of the Laboratory.

Projections for long-term workforce needs are now being guided by a more formal workforce planning process. This process, which entails a periodic update to the Laboratory's workforce plan, is being used to shape staffing and sizing decisions. Workforce plans consider both programmatic needs and institutional goals, such as achieving a workforce that is reflective of the rich diversity of California and the nation. The plans set recruiting requirements for various skill areas and provide areas of emphasis for employee development. The Laboratory supports training, education, and career development programs for individuals that meet their needs for growth and are consistent with short- and long-term Laboratory goals. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for future assignments.

We have instituted two levels of supervisory training, one for new supervisors and one for all first-level supervisors across the Laboratory. These programs are designed to assure that all supervisors understand their full responsibilities, as well as Laboratory policies and procedures, and to develop solid leadership and people skills. We will be expanding the programs to include all levels of management.

## 5.4 Safeguards and Security

Safeguards and security are integral to effective and responsible Laboratory operations. Protection of critical information and assets depends not only on the efforts of the Laboratory's safeguards and security professionals, but also on the proper training and vigilance of all employees. Livermore's Safeguards and Security Program provides guidance and expertise in support of the Laboratory's mission and creates and maintains a secure environment that appropriately protects personnel, information, property, and nuclear material and complies with laws, policies, and procedures in a cost-effective manner.

### Situation and Issues

As a national security laboratory with important responsibilities for maintaining the safety and reliability of the nation's nuclear weapons stockpile and for preventing proliferation, we must provide a secure environment for sensitive information and special nuclear materials as well as protect valuable government property. At the same time, access by non-Laboratory employees to many of Livermore's facilities is necessary. We work in partnership with universities, industry, and other laboratories on many unclassified projects. More generally, we are part of the international science and technology community and depend on interactions with others to be cognizant of major advances and to acquire special expertise needed to accomplish mission goals.

### Strategic Thrusts

We take the issue of protecting sensitive information extremely seriously and are employing increasingly sophisticated measures to do so in a cost-efficient manner. The Laboratory prepares on an annual basis a comprehensive Site Safeguards and Security Plan for DOE concurrence that details the physical and procedural measures we are taking. The physical security of the Livermore site is maintained through a multilevel, graded approach to limit access and protect information. In response to evolving security requirements, the Laboratory is adding a Special Response Team to provide even greater protection of critical assets in the Superblock. We also continue to pursue technological innovations, such as sophisticated detection systems and the automated portals developed at Livermore to minimize costs. Our automated portal system (Argus) has been adopted as a DOE standard and is being installed at other facilities.

Physical security measures are augmented by a system of security controls that include a standard security plan for visitors, the development of detailed visit-specific plans when warranted, and periodic operations security assessments. In addition, Livermore's Computer Incident Advisory Capability helps to maintain the integrity of computer systems at the Laboratory and other DOE facilities. We also are expanding a counterintelligence program that works closely with the FBI and is helping to point the way for DOE-wide efforts in this area. Livermore's counterintelligence program, established in 1986, develops threat assessments for the Laboratory, reviews visits and assignments by foreign nationals, and runs a vigorous Laboratory-wide counter-espionage awareness program.

## 5.5 Indirect Services

Services that support programmatic work include—but are not limited to—business, procurement, financial, and security systems and services. Livermore is making considerable improvements in its operational support for programs, striving to size and manage indirect activities to optimize the overall cost effectiveness and performance. As gauged by performance measures in the UC/DOE contract, Laboratory support functions are of increasing quality, delivered in a timely manner, and priced competitively.

We strive for operational support to be provided in a professional manner and for procedures and systems that are deemed equitable, self-consistent, and supportive of Laboratory values. Good business practices are not the only consideration. As a public-sector organization engaged primarily in contract work for DOE and other Federal agencies, the Laboratory conforms to regulatory requirements—an important factor affecting the operations environment. Indirect organizations provide assurance that compliance is managed responsibly and efficiently and in a way that is clearly defensible to the public, to regulators, and to Laboratory programs.

### Situation and Issues

Many improvements have been made to reduce support and overhead costs to make more resources available for direct program work. System and procedure improvements have identified more closely the real cost of activities, thus enabling the Laboratory to explicitly address hidden subsidies. These actions have been taken with a view toward maintaining and improving institutional health and protecting the Laboratory's capability to conduct essential operations, such as in ES&H. Thus far, the Laboratory has increased the spending power of Laboratory programs through a reduction in institutional overhead costs of about $50 million from FY93 to FY98.

Functional elements that are responsible for providing many indirect services Laboratory-wide have undergone significant reengineering to improve efficiency, reduce costs, and better understand customer needs and expectations. We have adopted best commercial practices whenever possible and optimized business information systems to improve communications at all levels. This reengineering has benefited from a major change by the Department of Energy to an "outcome" based oversight model for some aspects of operations, a shift to an aggressive self-assessment process, and implementation of meaningful metrics to assess performance. Next steps in the reengineering of Laboratory indirect activities include taking advantage of the opportunities offered by rapid technology change and the major information systems improvements that are now widely available.

These dramatic improvements in performance have been made possible by the commitment, capability, and productivity of an excellent Laboratory workforce. Through the continuing efforts of Laboratory employees, we will continue to improve the indirect services provided to programs, even in functional areas that have already undergone cost cutting and reengineering. Employees who staff the indirect functions and the customers who use their services must work together to achieve site-wide implementation standards, avoid redundancy in support functions, avoid over-specialization in personnel skills that limit staffing flexibility, and balance short-term gains and long-term benefits when making decisions about overhead and support functions.

### Strategy Thrusts

The Laboratory will continuously improve systems and processes for providing indirect services and effectively communicate with and involve both employees and customers in the changed process. Successful reengineering includes anticipating customer expectations; soliciting continuous customer feedback to assess satisfaction, needs, and understanding of strategies; and continuing aggressive use of industry and government benchmarking to enable effective comparisons and adopt best practices. Reengineering approaches will take advantage of modern information technology, adopting off-the-shelf approaches whenever possible. In some cases, we will rely on institutional reinvestment to absorb short-term expenses that will lead to long-term cost savings. Moreover, our Laboratory indirect organizations will continue to find ways to better meet customer needs through the most appropriate combination of internal and external sources. Where outsourcing is a viable option, organizations should be staffed to take advantage of it.

In planning for and delivering operational support, the Laboratory will strive to balance resource allocations so that programmatic work is performed responsibly, cost effectively, and in compliance with regulatory and other requirements. Implementation of this strategy will also ensure that Laboratory policies permit local flexibility but not to the point where local optimization undercuts compliance or other institutional objectives. For these efforts to be successful, operational support organizations must communicate their vision, goals, and actions in a way that engenders Laboratory-wide support and buy-in. Support by all levels in the organization—senior management through individual contributors—is required to achieve the goals and high standards that we set for operations. Success also requires strengthened partnerships with relevant components of UC, DOE, other laboratories, and externally sponsored organizations.

## 5.6 Information Management

Livermore's principal product is scientific and technical information, which we share internally and disseminate widely to sponsors, other researchers, and the general public. We also generate a significant amount of administrative information in conducting Laboratory programs. Improved management of information internal to the Laboratory can enhance internal communications, improve program effectiveness, and help reduce costs. We are working to design and implement a Laboratory computer-based information system that will provide users with improved connectivity, universal compatibility, and intralaboratory interoperability. To be most effective, the Laboratory workforce needs accurate, reliable information in a usable format; secure computer systems; and high-capacity computer networks.

While scientific computing is a leading consideration, business planning, lab-wide communications, and operational processes are partners in the development of an integrated information management plan. These efforts are led by the Laboratory's Chief Information Officer (CIO), appointed in October 1996. The CIO's responsibility is to provide the vision and leadership for the development of an information system architecture for the future, to propose and implement standards for hardware and software, and to develop information system strategies that balance cost, technology, and service.

### Situation and Issues

Livermore is currently well positioned in most aspects of its information systems infrastructure. We are a major player in defining the applications and performance requirements of the high-end platforms used in scientific computing. The prime driver for these efforts is DOE's Accelerated Strategic Computing Initiative (ASCI), which directly supports the Stockpile Stewardship Program. A major long-term issue for distributed scientific computing may be the limitations of the computer networks that link the high-end platforms with the customers throughout the Laboratory. While the Laboratory-wide backbone network is in excellent shape, the wiring and routing equipment within many buildings needs upgrades to support very-high-speed access to the Laboratory's computer systems.

In addition, the Laboratory is accumulating a growing base of experience developing information management systems that point the way to the future. The Nuclear Weapons Information Project is archiving nuclear weapons information (digital information from photos, videos, and documents) to provide users throughout the weapons complex a searchable means to access the data on a need-to-know basis. Also within Laboratory programs, powerful data-management systems are being developed for human genome research, weapons life-cycle design, and eventual operation of the National Ignition Facility. Furthermore, we have made great strides in modernizing and reengineering the Business Information Systems structure at the Laboratory, and we have been moving to an electronic Library of the Future.

In the Library of the Future, end users can readily obtain the information they seek—rapidly, seamlessly, layer by layer, from computers inside and outside the Laboratory. Currently, over 14,000 Laboratory publications are available online. New Laboratory-authored, unclassified, unlimited-distribution technical reports are becoming available from "Documents On-Line" as are retrospective documents from our report collection. In addition to making documents available to Internet users, we work with DOE's Office of Scientific and Technical Information to ensure that Livermore's publications are accessible throughout the Department, to other Federal agencies, and to the public.

### Strategy Thrusts

A committee chartered by the CIO completed in 1998 the development of an Information Architecture (IA) plan for the Laboratory. The architecture is the framework for implementing a digital information infrastructure with well-integrated services and activities—a utility that is Laboratory-wide, secure, reliable, standards-based, and intuitive for users. The IA's interrelated elements support all information processes, including various applications provided through layered hardware and message protocols, system management, and system security. These elements and their interactions are discussed in the plan, as are the current situation, the desired future state, and the steps to get there. As we implement the IA plan, we will be moving from the *ad-hoc* system to a Laboratory-wide information architecture with information systems that operate flawlessly and transparently, providing Laboratory employees in all organizations ready access to the capabilities they need.

We are also taking steps to consolidate support activities for desktop computer systems and computer networks. This action will help to reduce costs and increase our overall efficiency through more effective management of Livermore's heterogeneous and distributed desktop computing and network environments. We need standard services and practices in place that are accepted and followed by all elements of the Laboratory. Following processes and direction established in the IA plan, we will be responsible for defining, documenting, and implementing Laboratory wide a consistent and effective set of distributed desktop computing and network support services and processes.

## 5.7 Internal and External Communications

The Laboratory is a national resource center of applied science and technology. In this role, we serve diverse customers and strive to meet the needs of many stakeholders. These interactions range from the broad scientific community and the leaders of the federal government to our own local community and Livermore employees.

Through efforts of senior management and the Public Affairs Office (PAO), Livermore has improved internal and external communications by bringing the Laboratory's messages to important audiences and seeking the concerns and comments of those audiences. Internally, the Laboratory needs effective communications to support dialogue on key issues, senior management decision making, and dissemination of institutional information. Externally, the Laboratory is striving to be seen locally, nationally, and internationally as a credible and authoritative source on issues relevant to our mission. We want to be perceived as an intellectual asset and a helpful neighbor in the Bay Area and California, and we want the communities around us to be proud we are here.

### Situation and Issues

The Laboratory's communications systems ensure that customers and stakeholders are identified and their concerns are considered in the Laboratory's leadership, decision-making, and planning processes as well as in the formulation of operational policies. For example, input was broadly sought in preparing *Creating the Laboratory's Future*. The document, which put forth Livermore's vision, goals, priorities, values, and strategy, was widely distributed to both external and internal audiences.

The Laboratory engages in considerable outreach with stakeholders and customers and makes extensive use of participatory forums. Enhanced outreach efforts by both the Director's Office and PAO this past year have resulted in improvements in Laboratory public affairs and community relations. The Director for Communications instituted several changes within PAO in response to the results of surveys conducted with employees, the local community, media, and others. PAO is now taking a more integrated and strategic approach to communications, with a focus on senior management needs and enhanced senior management attention to and involvement in communications planning and implementation.

### Strategic Thrusts

The Laboratory is making use of rapid advances in technology to improve internal communications and external communication with the general public, local and regional audiences, and leaders in the federal government. We are using the Internet for rapid internal communication and for institutional publications. For example, the Laboratory newspaper *Newsline* now has an online version (*NewsOnLine*) that is issued twice weekly. *Newsline* and *Grapevine* (the Laboratory's internal Internet home page) carry a "From the Director" column, which provides employees with information about key institutional efforts and Laboratory issues.

Institutional publications, such as *Creating the Laboratory's Future*, *Science & Technology Review*, the *Laboratory Annual Report*, and the *Institutional Plan*, are available on the Laboratory's external home page. These publications have been redesigned to make the information more accessible to general audiences. More generally, Livermore's external home page is a national resource of science and technology information. Many of the Laboratory's publications are available online, and information is provided about Livermore's operations and programs, as well as opportunities for employment and research partnerships.

The Laboratory is taking other steps to improve external communications. For example, Livermore has established an office in Washington, DC, for use by Laboratory employees on official business travel to facilitate access to and communication with DOE Headquarters and other federal agencies and organizations in the greater Washington, DC, area. The office has been in operation since May 1997. In the local community, the Director and other senior managers have increased their visibility through more frequent meetings with local officials and civic groups. In addition, Laboratory representatives participate in many community meetings and regional economic development public forums. Furthermore, as a Superfund site, Livermore participates in a national program on health assessment conducted by the Agency for Toxic Substances and Disease Registry. We are involved in community meetings focused on public health issues about Laboratory environmental restoration activities and operations.

# Appendices

R&D 100 AWARD

# INDUCT95 Software Simulation Code

**Livermore physicist Peter Vitello demonstrates INDUCT95, a computer software simulation tool developed for optimizing plasma-assisted manufacturing for semiconductor production.**

*Physics and Space Technology and Defense and Nuclear Technologies at Livermore and technology that grew out of a cooperative pact between the Laboratory, IBM, and AT&T.*

## 6.1 Program Resource Requirement Projections

Data for FY 1997 is taken from the FY 1997 LLNL Budget Office Annual Report. Data for FY 1998 through FY 2000 represent a combination of the FY 2000 Field Budget Submission and the FY 2000–2001 Defense Programs Field Budget Estimates (April 1998). The guidance case is used for all programs. The resource data for FY 1997 through 2003 are based on the following:

- FY 1997 through 1998, actual budget obligations and authority.
- FY 1999 through 2003, Program Managers' estimates of resource requirements.
- Inflation factor: from FY 1998 through 2000, inflation is 2.0%; for years beyond FY 2000, resources requirements are expressed in constant FY 2000 dollars.
- Personnel figures do not always add correctly because the numbers have been rounded to whole numbers.

The program resource projections are shown as follows:

- Table 6.1-1. Laboratory funding summary.
- Table 6.1-2. Laboratory personnel summary.
- Table 6.1-3. Resources by major DOE program.
- Table 6.1-4. Resource projections by sponsor for non-DOE reimbursable programs.
- Tables 6.1-5 through 6.1-17. Detailed resource breakouts by DOE sponsors.

**Table 6.1-1. Laboratory funding summary (in millions of dollars).**

| | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Sponsor-funded Operating | | | | | | | |
| DOE Direct | 602.7 | 686.6 | 710.7 | 709.3 | 709.3 | 704.6 | 704.5 |
| DOE Other | 81.1 | 70.2 | 49.6 | 43.2 | 43.2 | 43.2 | 43.2 |
| Non-DOE | 189.6 | 182.8 | 212.5 | 176.2 | 161.2 | 161.2 | 161.2 |
| Total Operating | 873.4 | 939.6 | 972.8 | 928.7 | 913.7 | 909.0 | 908.9 |
| DOE Capital | | | | | | | |
| Capital Equipment | 29.4 | 19.3 | 11.8 | 16.5 | 16.5 | 16.5 | 16.5 |
| Facility Construction [c] | 110.1 | 235.3 | 322.2 | 295.0 | 127.9 | 96.7 | 33.0 |
| Total Capital | 139.5 | 254.6 | 334.0 | 311.5 | 144.4 | 113.2 | 49.5 |
| Total Laboratory | 1012.9 | 1194.2 | 1306.8 | 1240.2 | 1058.1 | 1022.2 | 958.4 |
| NIF-TEC [c] | 67.5 | 197.8 | 284.2 | 248.1 | 74.1 | 65.0 | 7.2 |
| NIF-OPC [c] | 29.6 | 31.3 | 6.8 | 5.9 | 5.9 | 1.2 | 1.1 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.
[c] National Ignition Facility funding reflects total appropriation distributed nationally.

**Table 6.1-2. Laboratory personnel summary (in full-time employee equivalent).**

| | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Sponsor-funded Operating | | | | | | | |
| DOE | 2233 | 2496 | 2478 | 2478 | 2478 | 2478 | 2478 |
| Non-DOE | 637 | 500 | 717 | 717 | 717 | 717 | 717 |
| Total Operating | 2870 | 2996 | 3195 | 3195 | 3195 | 3195 | 3195 |
| DOE Capital | 23 | 13 | 0 | 0 | 0 | 0 | 0 |
| Construction | 289 | 396 | 330 | 330 | 330 | 330 | 330 |
| Total Sponsor Funded | 3182 | 3405 | 3525 | 3525 | 3525 | 3525 | 3525 |
| Distributed | 3672 | 3595 | 3775 | 3775 | 3775 | 3775 | 3775 |
| Total Laboratory | 6854 | 7000 | 7300 | 7300 | 7300 | 7300 | 7300 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-3. Resources by major program (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Defense Programs** | | | | | | | |
| Operating Costs | 411.1 | 402.3 | 446.0 | 442.3 | 442.3 | 437.6 | 437.5 |
| Capital Equipment | 18.3 | 14.4 | 5.0 | 5.4 | 5.4 | 5.4 | 5.4 |
| Construction | 93.4 | 222.8 | 313.2 | 282.1 | 114.2 | 94.0 | 33.0 |
| Total Cost/Funding | 522.8 | 639.5 | 764.2 | 729.8 | 561.9 | 537.0 | 475.9 |
| Direct Personnel | 1546 | 1720 | 1721 | 1691 | 1691 | 1691 | 1691 |
| **Nonproliferation & National Security** | | | | | | | |
| Operating Costs | 68.5 | 85.9 | 103.3 | 104.1 | 104.1 | 104.1 | 104.1 |
| Capital Equipment | 2.0 | 0.3 | 0.6 | 0.3 | 0.3 | 0.3 | 0.3 |
| Construction | 0.0 | 0.0 | 0.0 | 5.0 | 12.0 | 2.7 | 0.0 |
| Total Cost/Funding | 70.5 | 86.2 | 103.9 | 109.4 | 116.4 | 107.1 | 104.4 |
| Direct Personnel | 217 | 253 | 270 | 272 | 272 | 272 | 272 |
| **Fissile Materials Disposition** | | | | | | | |
| Operating Costs | 15.2 | 25.0 | 35.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| Capital Equipment | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 15.4 | 25.0 | 35.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| Direct Personnel | 44 | 57 | 54 | 54 | 54 | 54 | 54 |
| **Energy Research** | | | | | | | |
| Operating Costs | 39.4 | 49.6 | 50.9 | 61.8 | 61.8 | 61.8 | 61.8 |
| Capital Equipment | 3.9 | 2.0 | 5.7 | 10.6 | 10.6 | 10.6 | 10.6 |
| Construction | 9.5 | 0.8 | 2.5 | 1.5 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 52.8 | 52.4 | 59.1 | 73.9 | 72.4 | 72.4 | 72.4 |
| Direct Personnel | 185.1 | 183 | 241 | 275 | 275 | 275 | 275 |
| **Environmental Restoration & Waste Management** | | | | | | | |
| Operating Costs | 51.3 | 48.0 | 52.3 | 52.8 | 52.8 | 52.8 | 52.8 |
| Capital Equipment | 4.8 | 2.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 6.0 | 11.7 | 6.5 | 6.4 | 1.7 | 0.0 | 0.0 |
| Total Cost/Funding | 62.1 | 62.2 | 58.9 | 59.2 | 54.5 | 52.8 | 52.8 |
| Direct Personnel | 214 | 207 | 228 | 228 | 228 | 228 | 228 |
| **Total Environmental Safety & Health** | | | | | | | |
| Operating Costs | 3.8 | 2.9 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 |
| Capital Equipment | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 |
| Direct Personnel | 12 | 12 | 11 | 11 | 11 | 11 | 11 |
| **Nuclear Energy** | | | | | | | |
| Operating Costs | 7.8 | 6.7 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 7.8 | 6.7 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 |
| Direct Personnel | 20 | 21 | 34 | 34 | 34 | 34 | 34 |

**Table 6.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Fossil Energy** | | | | | | | |
| Operating Costs | 1.5 | 2.1 | 4.6 | 5.4 | 5.4 | 5.4 | 5.4 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.5 | 2.1 | 4.6 | 5.4 | 5.4 | 5.4 | 5.4 |
| Direct Personnel | 3 | 8 | 19 | 22 | 22 | 22 | 22 |
| **Energy Efficiency & Renewable Energy** | | | | | | | |
| Operating Costs | 3.6 | 3.3 | 5.4 | 7.0 | 7.0 | 7.0 | 7.0 |
| Capital Equipment | 0.0 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.8 | 3.4 | 5.7 | 7.1 | 7.1 | 7.1 | 7.1 |
| Direct Personnel | 11 | 10 | 20 | 26 | 26 | 26 | 26 |
| **Human Resources & Administration** | | | | | | | |
| **WM General Administration-Contractual Services** | | | | | | | |
| Operating Costs | 0.5 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.5 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Direct Personnel | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Policy, Planning & Program Evaluation** | | | | | | | |
| Operating Costs | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Office of Chief Financial Officer** | | | | | | | |
| Operating Costs | 0.0 | 60.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 60.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 165 | 0 | 0 | 0 | 0 | 0 |
| **Total DOE Direct** | | | | | | | |
| Operating Costs | 602.7 | 686.6 | 710.7 | 709.3 | 709.3 | 704.6 | 704.5 |
| Capital Equipment | 29.4 | 19.3 | 11.8 | 16.5 | 16.5 | 16.5 | 16.5 |
| Construction | 110.1 | 235.3 | 322.2 | 295.0 | 127.9 | 96.7 | 33.0 |
| Total Cost/Funding | 742.2 | 941.2 | 1044.7 | 1020.8 | 853.7 | 817.8 | 754.0 |
| Direct Personnel | 2256 | 2638 | 2601 | 2615 | 2615 | 2615 | 2615 |
| **Total DOE Other** | | | | | | | |
| Operating Costs | 81.1 | 70.2 | 49.6 | 43.2 | 43.2 | 43.2 | 43.2 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 81.1 | 70.2 | 49.6 | 43.2 | 43.2 | 43.2 | 43.2 |
| Direct Personnel | 289 | 267 | 208 | 193 | 193 | 193 | 193 |

**Table 6.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Total All DOE | | | | | | | |
| Operating Costs | 683.8 | 756.8 | 760.3 | 752.5 | 752.5 | 747.8 | 747.7 |
| Capital Equipment | 29.4 | 19.3 | 11.8 | 16.5 | 16.5 | 16.5 | 16.5 |
| Construction c | 110.1 | 235.3 | 322.2 | 295 | 127.9 | 96.7 | 33 |
| Total Cost/Funding | 823.3 | 1011.4 | 1094.3 | 1064 | 896.9 | 861 | 797.2 |
| Direct Personnel | 2545 | 2905 | 2808 | 2808 | 2808 | 2808 | 2808 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.
[c] Includes General Plant Projects.

**Table 6.1-4. Resource projections by sponsor for non-DOE reimbursable programs (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Department of Defense** | | | | | | | |
| Operating Costs | 53.7 | 49.4 | 53.1 | 45.4 | 45.4 | 45.4 | 45.4 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 53.7 | 49.4 | 53.1 | 45.4 | 45.4 | 45.4 | 45.4 |
| Direct Personnel | 148 | 169 | 172 | 172 | 172 | 172 | 172 |
| **NASA** | | | | | | | |
| Operating Costs | 3.1 | 5.0 | 3.9 | 3.0 | 3.0 | 3.0 | 3.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 3.1 | 5.0 | 3.9 | 3.0 | 3.0 | 3.0 | 3.0 |
| Direct Personnel | 9 | 15 | 19 | 19 | 19 | 19 | 19 |
| **U.S. Enrichment Corporation [c]** | | | | | | | |
| Operating Costs | 71.2 | 44.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 71.2 | 44.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 310 | 123 | 0 | 0 | 0 | 0 | 0 |
| **Other Federal Agencies** | | | | | | | |
| Operating Costs | 23.8 | 38.4 | 39.0 | 37.1 | 37.1 | 37.1 | 37.1 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 23.8 | 38.4 | 39.0 | 37.1 | 37.1 | 37.1 | 37.1 |
| Direct Personnel | 66 | 115 | 146 | 146 | 146 | 146 | 146 |
| **Non-Federal Agencies** | | | | | | | |
| Operating Costs | 37.8 | 45.4 | 116.5 | 90.7 | 75.7 | 75.7 | 75.7 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 37.8 | 45.4 | 116.5 | 90.7 | 75.7 | 75.7 | 75.7 |
| Direct Personnel | 105 | 79 | 380 | 380 | 380 | 380 | 380 |
| **Total Non-DOE** | | | | | | | |
| Operating Costs | 189.6 | 182.8 | 212.5 | 176.2 | 161.2 | 161.2 | 161.2 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 189.6 | 182.8 | 212.5 | 176.2 | 161.2 | 161.2 | 161.2 |
| Direct Personnel | 637 | 500 | 717 | 717 | 717 | 717 | 717 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.
[c] Due to USEC privatization at the end of FY 1998, funding for USEC is included in Non-Federal Agencies for FY 1999–FY 2003.

**Table 6.1-5. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalents).**

| Major Program | FY 1997 BO | FY 1998 [a] BA | FY 1999 [a,b] BA | FY 2000 [a,b] BA | FY 2001 [c] BA | FY 2002 [c] BA | FY 2003 [c] BA |
|---|---|---|---|---|---|---|---|
| **Assistant Secretary** | | | | | | | |
| **Core Stockpile and Stewardship-DP0101** | | | | | | | |
| Operating Costs | 241.4 | 247.4 | 301.5 | 292.2 | 292.2 | 292.2 | 292.2 |
| Capital Equipment | 14.3 | 8.5 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Construction [d] | 25.8 | 25.0 | 29.0 | 34.0 | 40.1 | 29.0 | 25.8 |
| Total Cost/Funding | 281.5 | 280.9 | 333.5 | 329.2 | 335.3 | 324.2 | 321.0 |
| Direct Personnel | 851 | 913 | 976 | 976 | 976 | 976 | 976 |
| **Inertial Confinement Fusion-DP02** | | | | | | | |
| Operating Costs | 84.4 | 89.4 | 99.8 | 108.1 | 108.1 | 108.1 | 108.1 |
| Capital Equipment | 2.1 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Construction | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 86.6 | 90.4 | 101.8 | 110.1 | 110.1 | 110.1 | 110.1 |
| Direct Personnel | 256 | 260 | 295 | 295 | 295 | 295 | 295 |
| **National Ignition Facility-DP0213 [e]** | | | | | | | |
| Operating Costs | 29.3 | 26.9 | 6.8 | 5.9 | 5.9 | 1.2 | 1.1 |
| Capital Equipment | 0.3 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction [d] | 67.5 | 197.8 | 284.2 | 248.1 | 74.1 | 65.0 | 7.2 |
| Total Cost/Funding | 97.1 | 229.1 | 291.0 | 254.0 | 80.0 | 66.2 | 8.3 |
| Direct Personnel | 265 | 373 | 298 | 298 | 298 | 298 | 298 |
| **Technology Transfer and Education-DP03** | | | | | | | |
| Operating Costs [f] | 20.1 | 3.4 | 3.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 20.4 | 3.4 | 3.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 68 | 27 | 30 | 0 | 0 | 0 | 0 |
| **Weapons Stockpile Management-DP04** | | | | | | | |
| Operating Costs | 27.1 | 31.6 | 32.7 | 34.6 | 34.6 | 34.6 | 34.6 |
| Capital Equipment | 1.3 | 0.5 | 0.0 | 0.4 | 0.4 | 0.4 | 0.4 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 28.4 | 32.1 | 32.7 | 35.0 | 35.0 | 35.0 | 35.0 |
| Direct Personnel | 89 | 138 | 118 | 118 | 118 | 118 | 118 |
| **Program Direction-DP05** | | | | | | | |
| Operating Costs [g] | 4.9 | 3.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.9 | 3.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Direct Personnel | 16 | 9 | 5 | 5 | 5 | 5 | 5 |

**Table 6.1-5, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalents).**

| Major Program | FY 1997 BO | FY 1998 [a] BA | FY 1999 [a,b] BA | FY 2000 [a,b] BA | FY 2001 [c] BA | FY 2002 [c] BA | FY 2003 [c] BA |
|---|---|---|---|---|---|---|---|
| **Indust Partnering NIS, former Soviet Union-GB0107** | | | | | | | |
| Operating Costs | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other Weapons Activities** | | | | | | | |
| Cap Asset Mgmt Process & Cond. Asset Svy-GB0513 | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 |
| **Worker & Community Transition Program** | | | | | | | |
| Worker & Community Transition Prog Mgmt-GG00 | | | | | | | |
| Operating Costs | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Defense Programs** | | | | | | | |
| Operating Costs | 411.1 | 402.3 | 446.0 | 442.3 | 442.3 | 437.6 | 437.5 |
| Capital Equipment | 18.3 | 14.4 | 5.0 | 5.4 | 5.4 | 5.4 | 5.4 |
| Construction [h] | 93.4 | 222.8 | 313.2 | 282.1 | 114.2 | 94.0 | 33.0 |
| Total Cost/Funding | 522.8 | 639.5 | 764.2 | 729.8 | 561.9 | 537.0 | 475.9 |
| Direct Personnel | 1546 | 1720 | 1721 | 1691 | 1691 | 1691 | 1691 |

[a] FY 1998, 1999, and FY 2000 data is from the DP Budget Submission.
[b] 2.0% escalation FY 1999 and FY 2000.
[c] FY 2001–2003 in constant FY 2000 dollars.
[d] FY 2001 $ amount and FTE are straightline projections of FY2000 estimates, except for construction amounts, which follow funding schedules through to project completion.
[e] National Ignition Facility funding reflects total appropriation distributed nationally.
[f] FY99 amount includes $2.7 M for DP Education, which was excluded from DP Budget Submission.
[g] FY98 includes $3.6 M and FY99-FY01 includes $1.5 M, which were excluded from DP Budget Submission.
[h] Includes General Plant Projects.

**Table 6.1-6. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars); personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Nonprolif & Verif Res & Develop-GC00** | | | | | | | |
| Operating Costs | 33.5 | 35.3 | 38.0 | 38.8 | 38.8 | 38.8 | 38.8 |
| Capital Equipment | 2.0 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 35.5 | 35.6 | 38.3 | 39.1 | 39.1 | 39.1 | 39.1 |
| Direct Personnel | 111 | 135 | 134 | 134 | 134 | 134 | 134 |
| **Arms Export Control & Nonproliferation-GJ** | | | | | | | |
| Operating Costs | 21.0 | 37.8 | 42.2 | 43.6 | 43.6 | 43.6 | 43.6 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 21.0 | 37.8 | 42.2 | 43.6 | 43.6 | 43.6 | 43.6 |
| Direct Personnel | 55 | 60 | 77 | 77 | 77 | 77 | 77 |
| **Emergency Management Program-ND** | | | | | | | |
| Operating Costs | 0.7 | 0.8 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.7 | 0.8 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Direct Personnel | 1 | 1 | 5 | 5 | 5 | 5 | 5 |
| **Program Direction-NN01** | | | | | | | |
| Operating Costs | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 5.0 | 12.0 | 2.7 | 0.0 |
| Total Cost/Funding | 0.2 | 0.3 | 0.3 | 5.3 | 12.3 | 3.0 | 0.3 |
| Direct Personnel | 0 | 0 | 2 | 4 | 4 | 4 | 4 |
| **Analytical Support-NT01** | | | | | | | |
| Operating Costs | 4.5 | 4.5 | 4.0 | 4.2 | 4.2 | 4.2 | 4.2 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.5 | 4.5 | 4.0 | 4.2 | 4.2 | 4.2 | 4.2 |
| Direct Personnel | 21 | 24 | 24 | 24 | 24 | 24 | 24 |
| **Counterintelligence-NT03** | | | | | | | |
| Operating Costs | 1.1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Direct Personnel | 5 | 8 | 8 | 8 | 8 | 8 | 8 |
| **Classification Resources-GD03** | | | | | | | |
| Operating Costs | 0.6 | 0.2 | 1.7 | 1.5 | 1.5 | 1.5 | 1.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.6 | 0.2 | 1.7 | 1.5 | 1.5 | 1.5 | 1.5 |
| Direct Personnel | 2 | 1 | 2 | 2 | 2 | 2 | 2 |

**Table 6.1-6, continued. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars); personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Operations & Support-GD05** | | | | | | | |
| Operating Costs | 0.5 | 0.7 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.5 | 0.7 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 |
| Direct Personnel | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| **Technology & Systems Development-GD06** | | | | | | | |
| Operating Costs | 4.7 | 4.6 | 13.0 | 11.7 | 11.7 | 11.7 | 11.7 |
| Capital Equipment | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.7 | 4.6 | 13.3 | 11.7 | 11.7 | 11.7 | 11.7 |
| Direct Personnel | 15 | 20 | 16 | 16 | 16 | 16 | 16 |
| **Related Security Investigations Activity-GH03** | | | | | | | |
| Operating Costs | 1.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 5 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Total Nonproliferation & National Security** | | | | | | | |
| Operating Costs | 68.5 | 85.9 | 103.3 | 104.1 | 104.1 | 104.1 | 104.1 |
| Capital Equipment | 2.0 | 0.3 | 0.6 | 0.3 | 0.3 | 0.3 | 0.3 |
| Construction | 0.0 | 0.0 | 0.0 | 5.0 | 12.0 | 2.7 | 0.0 |
| Total Cost/Funding | 70.5 | 86.2 | 103.9 | 109.4 | 116.4 | 107.1 | 104.4 |
| Direct Personnel | 217 | 253 | 270 | 272 | 272 | 272 | 272 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-7. Fissile Materials Disposition detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Storage and Disposition Options-GA01** | | | | | | | |
| Operating Costs | 15.2 | 25.0 | 35.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| Capital Equipment | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 15.4 | 25.0 | 35.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| Direct Personnel | 44 | 57 | 54 | 54 | 54 | 54 | 54 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-8. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Life Sciences-KP11** | | | | | | | |
| Operating Costs | 14.9 | 21.7 | 12.0 | 10.6 | 10.6 | 10.6 | 10.6 |
| Capital Equipment | 2.1 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 17.0 | 22.4 | 12.0 | 10.6 | 10.6 | 10.6 | 10.6 |
| Direct Personnel | 55 | 80 | 53 | 43 | 43 | 43 | 43 |
| **Environmental Processes-KP12** | | | | | | | |
| Operating Costs | 5.9 | 6.0 | 16.3 | 26.9 | 26.9 | 26.9 | 26.9 |
| Capital Equipment | 0.0 | 0.0 | 5.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 5.9 | 6.0 | 21.3 | 36.9 | 36.9 | 36.9 | 36.9 |
| Direct Personnel | 22 | 22 | 77 | 115 | 115 | 115 | 115 |
| **Environmental Remediation-KP13** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 1.2 | 0.8 | 2.5 | 1.5 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.2 | 0.8 | 2.5 | 1.5 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Medical Applications & Measurement Sci-KP14** | | | | | | | |
| Operating Costs | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Capital Equipment | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Direct Personnel | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fusion Energy Sciences-AT00** | | | | | | | |
| Operating Costs | 9.8 | 10.6 | 10.4 | 10.4 | 10.4 | 10.4 | 10.4 |
| Capital Equipment | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 9.9 | 10.7 | 10.4 | 10.4 | 10.4 | 10.4 | 10.4 |
| Direct Personnel | 34 | 46 | 46 | 46 | 46 | 46 | 46 |
| **Basic Energy Sciences-KC02** | | | | | | | |
| Operating Costs | 3.2 | 3.6 | 3.7 | 4.3 | 4.3 | 4.3 | 4.3 |
| Capital Equipment | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 3.7 | 3.9 | 4.0 | 4.6 | 4.6 | 4.6 | 4.6 |
| Direct Personnel | 8 | 10 | 17 | 20 | 20 | 20 | 20 |
| **Chemical Sciences-KC03** | | | | | | | |
| Operating Costs | 0.6 | 0.5 | 1.9 | 2.1 | 2.1 | 2.1 | 2.1 |
| Capital Equipment | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.7 | 0.6 | 2.1 | 2.3 | 2.3 | 2.3 | 2.3 |
| Direct Personnel | 2 | 1 | 14 | 14 | 14 | 14 | 14 |

**Table 6.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Engineering & Geosciences-KC04** | | | | | | | |
| Operating Costs | 2.0 | 1.6 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Capital Equipment | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 2.1 | 1.7 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Direct Personnel | 5 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Math, Information & Computation Sci-KJ01** | | | | | | | |
| Operating Costs | 1.6 | 2.5 | 3.3 | 4.1 | 4.1 | 4.1 | 4.1 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.6 | 2.5 | 3.3 | 4.1 | 4.1 | 4.1 | 4.1 |
| Direct Personnel | 4 | 9 | 15 | 18 | 18 | 18 | 18 |
| **Laboratory Technology Research-KJ02** | | | | | | | |
| Operating Costs | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Advanced Energy Projects-KJ03** | | | | | | | |
| Operating Costs | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Laboratory Cooperative Sci Educ Centers-KT01** | | | | | | | |
| Operating Costs | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **High-Energy Technology-KA00** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 8.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 8.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 44 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Facility Operations-KA02** | | | | | | | |
| Operating Costs | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 1.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 6 | 8 | 0 | 0 | 0 | 0 | 0 |

**Table 6.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **High-Energy Technology-KA04** | | | | | | | |
| Operating Costs | 0.4 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.4 | 0.7 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 |
| Direct Personnel | 1 | 1 | 5 | 5 | 5 | 5 | 5 |
| **Medium-Energy Physics-KB01** | | | | | | | |
| Operating Costs | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Heavy Ion Physics-KB02** | | | | | | | |
| Operating Costs | 0.1 | 0.2 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.2 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Direct Personnel | 0 | 0 | 3 | 3 | 3 | 3 | 3 |
| **Low-Energy Physics-KB04** | | | | | | | |
| Operating Costs | 0.4 | 0.4 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.4 | 0.4 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 |
| Direct Personnel | 1 | 1 | 6 | 6 | 6 | 6 | 6 |
| **Total Energy Research** | | | | | | | |
| Operating Costs | 39.4 | 49.6 | 50.9 | 61.8 | 61.8 | 61.8 | 61.8 |
| Capital Equipment | 3.9 | 2.0 | 5.7 | 10.6 | 10.6 | 10.6 | 10.6 |
| Construction | 9.5 | 0.8 | 2.5 | 1.5 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 52.8 | 52.4 | 59.1 | 73.9 | 72.4 | 72.4 | 72.4 |
| Direct Personnel | 185 | 183 | 241 | 275 | 275 | 275 | 275 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-9. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Program Direction (Defense)-EW10** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Corrective Activities (Defense)-39EW11** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Environmental Restoration-EW20** | | | | | | | |
| Operating Costs | 23.1 | 21.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 23.1 | 21.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 |
| Direct Personnel | 90 | 88 | 92 | 92 | 92 | 92 | 92 |
| **Waste Management (Defense)-EW31** | | | | | | | |
| Operating Costs | 20.6 | 19.2 | 22.3 | 22.8 | 22.8 | 22.8 | 22.8 |
| Capital Equipment | 4.1 | 2.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 5.4 | 11.7 | 6.5 | 6.4 | 1.7 | 0.0 | 0.0 |
| Total Cost/Funding | 30.1 | 32.9 | 28.9 | 29.2 | 24.5 | 22.8 | 22.8 |
| Direct Personnel | 94 | 90 | 106 | 106 | 106 | 106 | 106 |
| **Technology Development-EW40** | | | | | | | |
| Operating Costs | 3.9 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 3.9 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| Direct Personnel | 15 | 6 | 6 | 6 | 6 | 6 | 6 |
| **Environmental Management & Waste Mgmt - Def Environmental Management Science Program-EW45** | | | | | | | |
| Operating Costs | 1.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2. |
| Direct Personnel | 7 | 11 | 11 | 11 | 11 | 11 | 11 |

**Table 6.1-9, continued. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Facility Transition & Management-EW7** | | | | | | | |
| Operating Costs | 1.9 | 1.2 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Capital Equipment | 0.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| total Cost/Funding | 2.6 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Direct Personnel | 8 | 5 | 6 | 6 | 6 | 6 | 6 |
| **Environmental Restoration & Waste Mgmt(Non-D)** | | | | | | | |
| **Waste Management(Non-D)-EX31** | | | | | | | |
| Operating Costs | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Nuclear Material & Facility Stabilization-EX70** | | | | | | | |
| Operating Costs | 0.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |
| Direct Personnel | 0 | 7 | 7 | 7 | 7 | 7 | 7 |
| **Total Environmental Restoration & Waste Management** | | | | | | | |
| Operating Costs | 51.3 | 48.0 | 52.3 | 52.8 | 52.8 | 52.8 | 52.8 |
| Capital Equipment | 4.8 | 2.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 6.0 | 11.7 | 6.5 | 6.4 | 1.7 | 0.0 | 0.0 |
| Total Cost/Funding | 62.1 | 62.2 | 58.9 | 59.2 | 54.5 | 52.8 | 52.8 |
| Direct Personnel | 214 | 207 | 228 | 228 | 228 | 228 | 228 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-10. Environmental Safety and Health detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Line Management Support-HC11** | | | | | | | |
| Operating Costs | 0.7 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.7 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Direct Personnel | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Policy-HC20** | | | | | | | |
| Operating Costs | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Management & Administration-HC50** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Health Studies-HD20** | | | | | | | |
| Operating Costs | 2.7 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 |
| Capital Equipment | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 2.8 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 |
| Direct Personnel | 8 | 9 | 9 | 9 | 9 | 9 | 9 |
| **Health Studies-HD40** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Environmental Safety & Health** | | | | | | | |
| Operating Costs | 3.8 | 2.9 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 |
| Capital Equipment | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 |
| Direct Personnel | 12 | 12 | 11 | 11 | 11 | 11 | 11 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-11. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Nuclear Energy R&D | | | | | | | |
| Light Water Reactors-AF11 | | | | | | | |
| Operating Costs | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear Security - AF17 | | | | | | | |
| Operating Costs | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Advanced Reactor R&D-AF20 | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Program Direction - Nuclear Energy | | | | | | | |
| Program Direction - Nuclear Energy-KK05 | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Naval Reactors Development-AJ05 | | | | | | | |
| Operating Costs | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Direct Personnel | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Atomic Vapor Laser Isotope Separation-CD1008 | | | | | | | |
| Operating Costs | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Technology Partnerships-CD1009 | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 6.1-11, continued. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Program Management Services-CD1012** | | | | | | | |
| Operating Costs | 0.8 | 0.4 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.8 | 0.4 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| Direct Personnel | 2 | 1 | 3 | 3 | 3 | 3 | 3 |
| **Transparency Measures-CD1013** | | | | | | | |
| Operating Costs | 4.6 | 5.7 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.6 | 5.7 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 |
| Direct Personnel | 13 | 18 | 27 | 27 | 27 | 27 | 27 |
| **Depleted Uran Hexaflour Cyl & Mntc-CD1015** | | | | | | | |
| Operating Costs | 1.6 | 0.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.6 | 0.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Direct Personnel | 4 | 1 | 3 | 3 | 3 | 3 | 3 |
| **Total Nuclear Energy** | | | | | | | |
| Operating Costs | 7.8 | 6.7 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 7.8 | 6.7 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 |
| Direct Personnel | 20 | 21 | 34 | 34 | 34 | 34 | 34 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-12. Fossil Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Advanced Research & Technology Develop-AA15** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Natural Gas Research-AB05** | | | | | | | |
| Operating Costs | 0.1 | 0.7 | 1.6 | 1.9 | 1.9 | 1.9 | 1.9 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.7 | 1.6 | 1.9 | 1.9 | 1.9 | 1.9 |
| Direct Personnel | 0 | 0 | 5 | 6 | 6 | 6 | 6 |
| **Petroleum Research-AC10** | | | | | | | |
| Operating Costs | 1.3 | 1.4 | 3.0 | 3.5 | 3.5 | 3.5 | 3.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.3 | 1.4 | 3.0 | 3.5 | 3.5 | 3.5 | 3.5 |
| Direct Personnel | 3 | 7 | 14 | 16 | 16 | 16 | 16 |
| **Clean Coal Program Direction-AZ02** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Naval Petroleum Reserves Nos 1 & 2-CB01** | | | | | | | |
| Operating Costs | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Fossil Energy** | | | | | | | |
| Operating Costs | 1.5 | 2.1 | 4.6 | 5.4 | 5.4 | 5.4 | 5.4 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.5 | 2.1 | 4.6 | 5.4 | 5.4 | 5.4 | 5.4 |
| Direct Personnel | 3 | 8 | 19 | 22 | 22 | 22 | 22 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-13. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Solar and Renewable Resource Technologies-EB40** | | | | | | | |
| Operating Costs | 0.4 | 0.1 | 0.4 | 0.7 | 0.7 | 0.7 | 0.7 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.4 | 0.1 | 0.4 | 0.7 | 0.7 | 0.7 | 0.7 |
| Direct Personnel | 1 | 0 | 1 | 2 | 2 | 2 | 2 |
| **Hydrogen Research R&D-EB42** | | | | | | | |
| Operating Costs | 1.1 | 0.8 | 1.9 | 3.6 | 3.6 | 3.6 | 3.6 |
| Capital Equipment | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.1 | 0.8 | 2.0 | 3.6 | 3.6 | 3.6 | 3.6 |
| Direct Personnel | 3 | 2 | 7 | 13 | 13 | 13 | 13 |
| **Industry Sector-Total-ED18** | | | | | | | |
| Operating Costs | 0.0 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 |
| Direct Personnel | 0 | 1 | 3 | 2 | 2 | 2 | 2 |
| **Transportation Sector-EE00** | | | | | | | |
| Operating Costs | 2.0 | 2.1 | 2.5 | 2.2 | 2.2 | 2.2 | 2.2 |
| Capital Equipment | 0.0 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 2.0 | 2.2 | 2.7 | 2.3 | 2.3 | 2.3 | 2.3 |
| Direct Personnel | 5 | 7 | 10 | 9 | 9 | 9 | 9 |
| **Federal Energy Management Program-EL17** | | | | | | | |
| Operating Costs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **In-House Energy Management-WB00** | | | | | | | |
| Operating Costs | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Energy Efficiency & Renewable Energy** | | | | | | | |
| Operating Costs | 3.6 | 3.3 | 5.4 | 7.0 | 7.0 | 7.0 | 7.0 |
| Capital Equipment | 0.0 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 4.8 | 3.4 | 5.7 | 7.1 | 7.1 | 7.1 | 7.1 |
| Direct Personnel | 11 | 10 | 20 | 26 | 26 | 26 | 26 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-14. Human Resources & Administration detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Human Resource & Admin-WM10 | | | | | | | |
| Operating Costs | 0.5 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.5 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Direct Personnel | 2 | 3 | 3 | 3 | 3 | 3 | 3 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-15. Policy, Planning, and Program detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Total Policy, Planning & Program Analysis-PE | | | | | | | |
| Operating Costs | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-16. Office of Chief Financial Officer detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| Total Office of Chief Financial Officer - HG00 (AVLIS) | | | | | | | |
| Operating Costs | 0.0 | 60.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 0.0 | 60.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Direct Personnel | 0 | 165 | 0 | 0 | 0 | 0 | 0 |

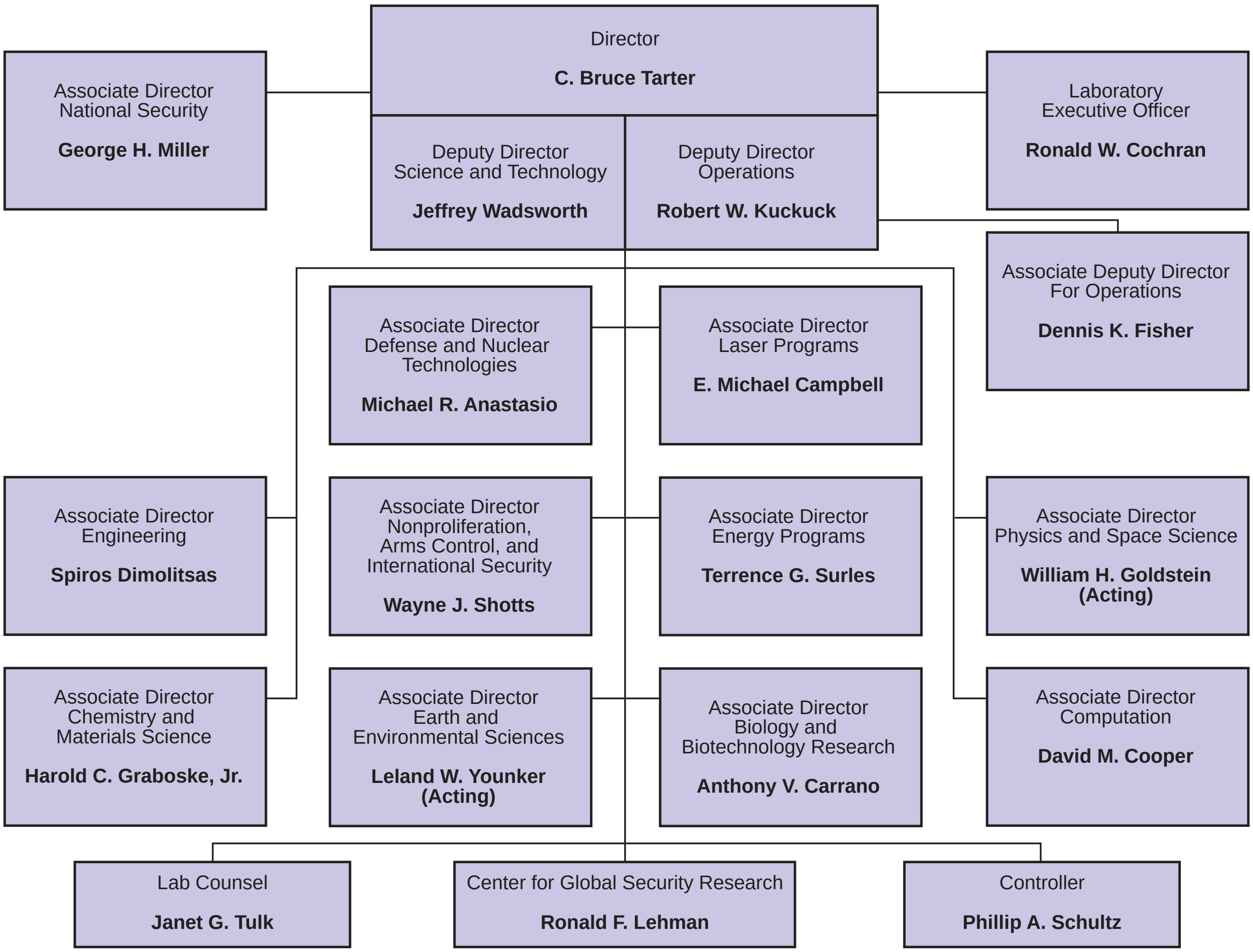
[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

**Table 6.1-17. Other DOE detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).**

| Major Program | FY 1997 BO | FY 1998 BA | FY 1999 [a] BA | FY 2000 [a] BA | FY 2001 [b] BA | FY 2002 [b] BA | FY 2003 [b] BA |
|---|---|---|---|---|---|---|---|
| **Work for DOE Integrated Contractors** | | | | | | | |
| Operating Costs | 37.2 | 25.6 | 26.5 | 24.5 | 24.5 | 24.5 | 24.5 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 37.2 | 25.6 | 26.5 | 24.5 | 24.5 | 24.5 | 24.5 |
| Direct Personnel | 118 | 97 | 101 | 94 | 94 | 94 | 94 |
| **Work for Other DOE Installations** | | | | | | | |
| Operating Costs | 43.9 | 44.6 | 23.1 | 18.7 | 18.7 | 18.7 | 18.7 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 43.9 | 44.6 | 23.1 | 18.7 | 18.7 | 18.7 | 18.7 |
| Direct Personnel | 171 | 170 | 107 | 99 | 99 | 99 | 99 |
| **Total Other DOE** | | | | | | | |
| Operating Costs | 81.1 | 70.2 | 49.6 | 43.2 | 43.2 | 43.2 | 43.2 |
| Capital Equipment | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Cost/Funding | 81.1 | 70.2 | 49.6 | 43.2 | 43.2 | 43.2 | 43.2 |
| Direct Personnel | 289 | 267 | 208 | 193 | 193 | 193 | 193 |

[a] 2.0% escalation FY 1999 and FY 2000.
[b] FY 2001–2003 in constant FY 2000 dollars.

## 6.2 Organization chart



## 6.3 Publications and Internet Addresses

General information about the Laboratory's work may be found electronically on the World Wide Web through the Laboratory's home page at http://www.llnl.gov. Other references called out in this Institutional Plan are shown below.

Please direct requests for hard copies of Livermore publications to:
Ellen Bradley
Off-Site Requests Coordinator
Lawrence Livermore National Laboratory
P.O. Box 808, L-658
Livermore, CA 94551
Phone 510-422-5820

### 6.3.1 Referenced Publications

*Science & Technology Review*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52000; published 10 times per year beginning July 1995.

*Creating the Laboratory's Future: A Strategy for Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-AR-12305, September 1997.

*Department of Energy Strategic Plan: Providing America with Energy Security, National Security, Environmental Quality, and Science Leadership*, Department of Energy, DOE/PO-00053, September 1997.

*Stockpile Stewardship Plan: Second Annual Update (FY 1999)*, Department of Energy Office of Defense Programs, April 1998.

*Laboratory Directed Research and Development FY 1997*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-LR-113717-97, 1997.

*Laboratory Research and Development: Innovation and Creativity Supporting National Security; Livermore, Los Alamos, and Sandia National Laboratories*; Los Alamos, NM, LALP-97, April 1997.

*1997 Site Annual Environmental Report*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-97, November 1997.

### 6.3.2 *S&TR* Articles

Many scientific and technical topics in Sections 2, 3, and 4 have been discussed in fuller detail in the Laboratory's *Science & Technology Review* over the last few years. Following are the topics and their Internet addresses. Hard copies are available through the Off-Site Requests Coordinator (address above).

**Section 2**
• Stockpile Stewardship:
http://www.llnl.gov/str/Alonso.html
• Nonproliferation Support:
http://www.llnl.gov/str/Dunlop.html
• Enhanced Surveillance of Weapons:
http://www.llnl.gov/str/Kolb.html
• Reducing Threat of Biological Weapons:
http://www.llnl.gov/str/Milan.html

**2.1.2**
• High Explosives for Surveillance:
http://www.llnl.gov/str/Lundberg. html
• Enhanced Surveillance of Weapons:
http://www.llnl.gov/str/Kolb.html

**2.1.3**
• Lasers for NIF:
http://www.llnl.gov/str/Payne.html
• Laser Targets:
http://www.llnl.gov/str/Lowns.html
• Computer Simulations for ASCI:
http://www.llnl.gov/str/Christensen.html
• NIF Laser Developments:
http://www.llnl.gov/str/Powell.html
• NIF Controls:
http://www.llnl.gov/str/Vanarsdall

**2.1.4**
• R&D 100 Awards:
http://www.llnl.gov/str/pdfs/10_97.pdf
• TATB:
http://www.llnl.gov/str/Pagoria.html

**2.2.1**
• Surplus Weapons from the Cold War:
http://www.llnl.gov/str/Gray.html

**2.2.2**
• Soil Gases Detect Nuclear Explosions:
http://www.llnl.gov/str/Carrigan.html

**2.2.5**
• Reducing the Threat of Biological Weapons:
http://www.llnl.gov/str/Milan.html
• Forensic Science Center:
http://www.llnl.gov/str/
• Technology and Policy:
http://www.llnl.gov/str/Lehman.html

**2.3.1**
• High Explosives in Stockpile Surveillance:
http://www.llnl.gov/str/Lundberg. html
• Explosives:
http://www.llnl.gov/str/Kury.html
• Detonation Modeling with CHEETAH:
http://www.llnl.gov/str/Fried.html

**2.3.2**
• Argus Protection System:
http://www.llnl.gov/str/Davis.html
• Forensic Science Center (December 1998): http://www.llnl.gov/str/

**Section 3**
**3.1.2**
• Corsica: Simulations for Magnetic Energy:

http://www.llnl.gov/str/Cohen.html
• Energy Overview at LLNL:
http://www.llnl.gov/str/

**3.1.3**
• Hydrogen Fuel:
http://www.llnl.gov/str/pdfs/03_96.3.pdf
• Electromechanical Battery:
http://www.llnl.gov/str/pdfs/04_96.2.pdf
• Unitized Regenerative Fuel Cell:
http://www.llnl.gov/str/Mitlit.html

**3.1.4**
• Carbon Dioxide in Global Warming:
http://www.llnl.gov/str/Duffy.html
• Energy Overview at LLNL:
http://www.llnl.gov/str/

**3.1.5**
• Groundwater Cleanup—Hydrous Pyrolysis Oxidation:
http://www.llnl.gov/str/Newmark.html

**3.2.1**
• DNA Sequencing:
http://www.llnl.gov/str/Ashworth.html
• High-Speed DNA Sequencing:
http://www.llnl.gov/str/Balch.html

**3.2.2**
• Kidney Gene with Human Genome Program:
http://www.llnl.gov/str/Hamza.html

**3.2.3**
Osteoporosis:
http://www.llnl.gov/str/pdfs/06_96.3.pdf
Ergonomics Research:
http://www.llnl.gov/str/Burastero.html
Peregrine:
http://www.llnl.gov/str/Moses.html
Technology for Stroke Attack:
http://www.llnl.gov/str/

**3.3**
• Metallic Hydrogen:
http://www.llnl.gov/str/pdfs/Nellis.html
• Petawatt Laser:
http://www.llnl.gov/str/Petawatt.html

**3.3.1**
• 1996 R&D 100 Awards:
http://www.llnl.gov/str/pdfs/10_96.2.pdf
• 1997 R&D 100 Awards:
http://www.llnl.gov/str/pdfs/10_97.pdf
• 1998 R&D 100 Awards:
http://www.llnl.gov/pdfs/10_98.pdf

**3.3.2**
• MACHO:
http://www.llnl.gov/str/pdfs/04_96.1.pdf
• B-Factory:
http://www.llnl.gov/str/VanBib.htm
• Microtechnology Center:
http://www.llnl.gov/str/Mariella.html
• Atomic Engineering:
http://www.llnl.gov/str/Barbee.html
• Petawatt Laser:
http://www.llnl.gov/str/Petawatt.html

**3.3.3**
• Micropower Impulse Radar:
http://www.llnl.gov/str/pdfs/01_96.2.pdf
• LANDMARC for Land Mines:
http://www.llnl.gov/str/Azevedo.html
• LLNL R&D 100 Awards:
http://www.llnl.gov/pdfs/10_98.pdf
• Stockpile Stewardship:
http://www.llnl.gov/str/Alonso.html
• B-Factory:
http://www.llnl.gov/str/VanBib.html

**3.3.4**
• Center for Accelerator Mass Spectrometry:
http://www.llnl.gov/str/Holloway.html
• Diamond Anvil Cell:
http://www.llnl.gov/str/pdfs/03_96.2.pdf
• Positron Technology (December 1998):
http://www.llnl.gov/str/
• Bridge Seismology and Modeling (December 1998): http://www.llnl.gov/str/

**Section 4**
**4.1.1**
• Lasers for NIF:
http://www.llnl.gov/str/Payne.html
• Laser Targets:
http://www.llnl.gov/str/Lowns.html
• Laser Developments for NIF:
http://www.llnl.gov/str/Powell.html
• National Ignition Facility Controls:
http://www.llnl.gov/str/Vanarsdall

**4.1.2**
• Contained Firing Facility:
http://www.llnl.gov/str/Baker.html

**4.1.3**
• Computer Simulations for ASCI:
http://www.llnl.gov/str/Christensen.html

**4.1.5**
• TATB:
http://www.llnl.gov/str/Pagoria.html

**4.1.6**
• High Explosives in Stockpile Surveillance:
http://www.llnl.gov/str/Lundberg.html

**4.2.1**
*Technology and Policy:*
*http://www.llnl.gov/str/Lehman.html*

**4.2.3**
• Reducing Biological Weapon Threat:
http://www.llnl.gov/str/Milan.html

**4.3.1**

- Carbon Dioxide in Global Warming: http://www.llnl.gov/str/Duffy.html
- Energy Overview at LLNL (December 1998): http://www.llnl.gov/str/

**4.3.3**

- DNA Sequencing: http://www.llnl.gov/str/Balch.html
- Kidney Gene with Human Genome Program: http://www.llnl.gov/str/Hamza.html

**4.3.8**

- Positron Technology (December 1998): http://www.llnl.gov/str/

**4.4.2**

- Hydrogen Fuel: http://www.llnl.gov/str/pdfs/03_96.3.pdf
- Unitized Regenerative Fuel Cell: http://www.llnl.gov/str/Mitlit.html

**4.5.1**

- Nuclear Waste: http://www.llnl.gov/str/pdfs/03_96.1.pdf
- Fusion Plan Cleanup: http://www.llnl.gov/str/pdfs/06_96.2.pdf
- Surplus Weapons from the Cold War: http://www.llnl.gov/str/Gray.html
- Energy Overview at LLNL (December 1998): http://www.llnl.gov/str/

**4.5.2**

- January 1997, B-Factory: http://www.llnl.gov/str/VanBib.html
- Positron Technology (December 1998): http://www.llnl.gov/str/

**4.5.3**

- Computational Mechanics: http://www.llnl.gov/str/Raboin.html

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