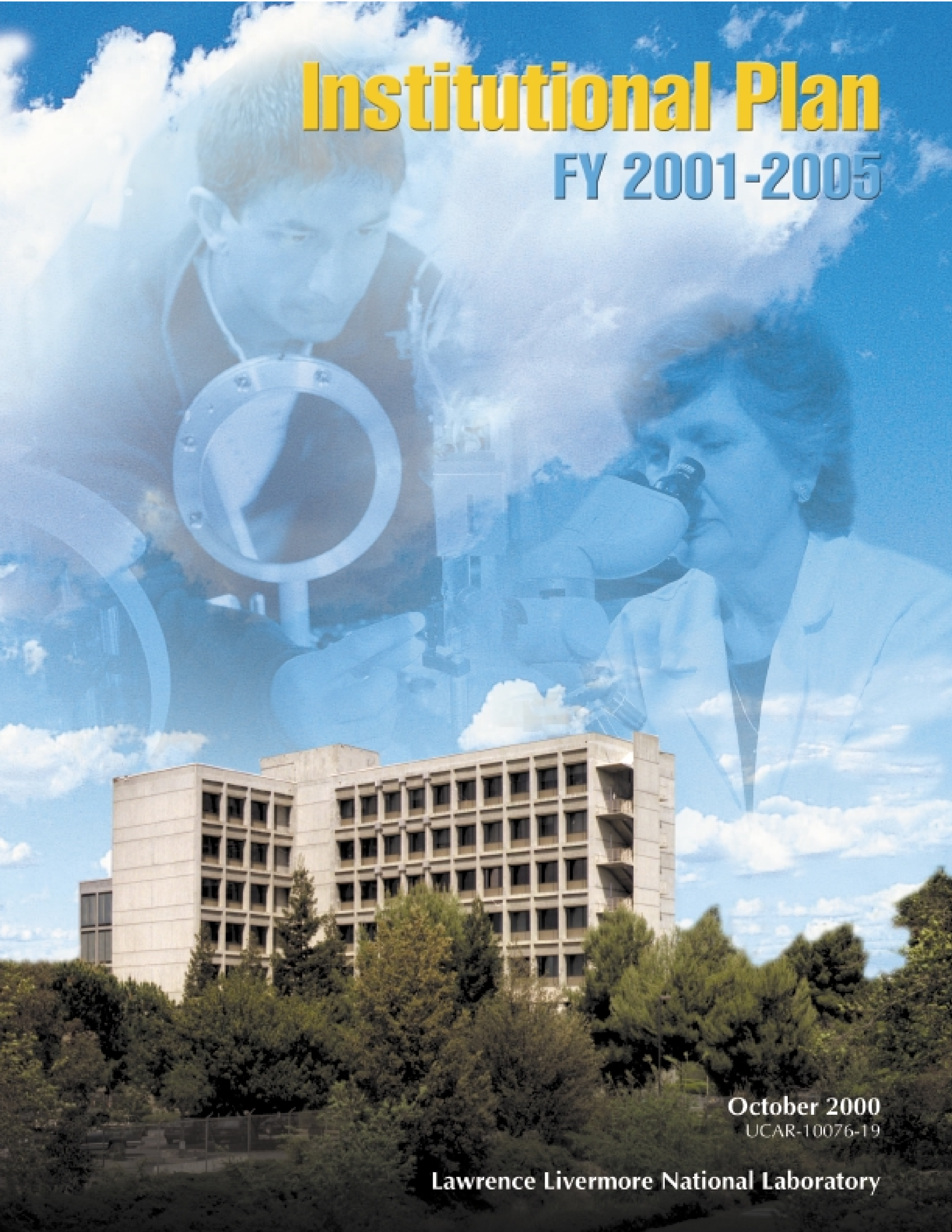


Institutional Plan

FY 2001-2005

October 2000

UCAR-10076-19

Lawrence Livermore National Laboratory

About the cover and divider pages

From physicist to microtechnologist, chemist, biologist, quality assurance specialist, protective service officer—Lawrence Livermore National Laboratory's diverse staff strives to set a standard of excellence among high-technology applied research and development institutions. We work to contribute to our fullest, continuing to add value to our role in meeting the nation's important technological challenges.

The cover and divider pages of this year's Institutional Plan salute our people—our most important asset. Examples of our work are shown in the following photos.

Director's statement: developing a knowledge base of signatures from organisms likely to be used in biowarfare.

Section 1: working as a part of the Joint Genome Institute to sequence the human genome.

Section 2: characterizing unknown objects in waste drums through the use of advanced robotics.

Section 3: developing and testing an ultrashort-pulse laser with the highest irradiance ever recorded, used for exploring plasmas similar to that in the interiors of stars and understanding materials under extreme pressures and temperatures.

Section 4: collaborating with the Russians to provide a more efficient method of preparing plutonium for immobilization.

Section 5: developing know-how and facilities to manufacture advanced diffraction gratings for our Petawatt laser, which has led to our expertise in diffractive optics that is recognized world-wide.

Section 6: investigating whether magnetic lenses for focusing beams of high-energy protons in an advanced radiography probe can be used to monitor aging nuclear weapons in the nation's stockpile.

Acknowledgments

Scientific Editor: Paul L. Chrzanowski
Publication Editor: Sue Stull
Designer: George Kitrinos
Compositor: J. Louisa Cardoza
Proofreader: Elaine Price

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

U.S. Government Printing Office: 683-051-80045

Institutional Plan
FY 2001–2005

Lawrence Livermore
National Laboratory

Department of Energy
University of California

October 2000
UCAR-10076-19

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 to meet enduring national needs—in energy, earth and environmental sciences, bioscience and biotechnology, and fundamental science and applied technology.

Section 4: Laboratory 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

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

Section 6. Appendices

- Program Resource Requirement Projections: Resource data for FY 2001–2005.
- Livermore Organization Chart.
- References for this Institutional Plan.

CONTENTS

Institutional Plan FY 2001–2005

Department of Energy
Lawrence Livermore National Laboratory

Director's Statement

Director's Statement

Director's Statement

C. Bruce Tarter
Director

Events over the past two years have presented major challenges to both our programs and the way we operate at the Lawrence Livermore National Laboratory. Among other actions, we restructured our approach and greatly improved safety and security at Livermore; we developed validated plans that rebaseline a major construction project, the National Ignition Facility; and we had many significant programmatic and technical achievements. The Laboratory is emerging from this turbulent period strengthened to meet our important commitments to our sponsors. Our actions lay the foundation for this *Institutional Plan FY 2001–2005.*

Livermore's technical accomplishments make clear our role as a Department of Energy (DOE) national laboratory. We are striving for major scientific and technical advances toward DOE's goals in national security, energy resources, environmental quality, and science. We are also working to set a standard of operational excellence that is to be expected of a premier national laboratory.

National security is our defining responsibility, and we are part of the newly created National Nuclear Security Administration (NNSA) within DOE. The Laboratory is a vital contributor to the nation's extraordinarily demanding program to maintain a safe and reliable U.S. nuclear weapons stockpile in the absence of underground nuclear testing. It is our responsibility, together with the Los Alamos and Sandia national laboratories, to provide accurate assessments of the safety, security, and reliability of each weapon system. These assessments support a process of annual certification of the stockpile.

We also attend to the immediate needs of the nuclear weapons stockpile, such as our work to extend the lifetime of the W87, the Air Force's most modern ICBM warhead. Livermore developed refurbishment plans based on a combination of laboratory experiments and computer simulations—the same approach we use for assessment of weapons performance and safety. To address the more challenging issues that will arise as the nation's nuclear weapons stockpile continues to age, we will depend on more powerful experimental and computational tools, which we must acquire.

The National Ignition Facility (NIF) is a major new tool that is under construction at the Laboratory. NIF, the world's largest laser, will provide the means for investigating the thermonuclear physics of primaries and secondaries in nuclear weapons. Since the project began, we have achieved the necessary tremendous advances in laser technologies that make NIF possible. However, in FY 1999, significant issues arose about the project, particularly the method for assembling the lasers. In FY 2000, the NIF Project team rebaselined the project, developing a new schedule and cost estimates, which were reviewed and approved by the Energy Systems Acquisition Advisory Board. Subsequently, the Secretary of Energy submitted his certification of the NIF Project baseline together with his recommended funding plans to Congress. These new NIF plans and the appropriation of funds by Congress have resulted in a renewed and strengthened project.

In addition, in FY 2000, Livermore took delivery from IBM of the world's currently most powerful supercomputer, capable of over 12 trillion operations per second. Delivery of the Option White machine is the latest milestone in DOE's Accelerated Strategic Computing Initiative (ASCI), an effort to obtain from U.S. industry successively more powerful computers that improve our ability to simulate the performance of the aging stockpile and conditions affecting weapon safety. In parallel with these acquisitions, we are improving simulation models and developing tools to manage and visualize the vast amount of data generated. We have also begun construction of the Terascale Simulation Facility to house the next major supercomputer at Livermore.

The Laboratory'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. We are working with DOE and other organizations to provide technical support for U.S. arms control and nonproliferation policy, analyze weapons activities worldwide, and develop improved capabilities to thwart WMD threats. Livermore is making significant progress in technologies to secure weapons-usable fissile materials, to monitor and analyze proliferation-related production activities, and to detect the use of biological agents. Our future programs and plans are further described in this Institutional Plan.

Our multidisciplinary approach to problem solving and special facilities enable us to respond to a broad range of vital national needs. For example, Livermore's scientific computing capabilities offer the potential of unprecedented levels of understanding in climate modeling, environmental management, materials science, fusion energy, molecular biology, astrophysics, and many other areas.

These research interests demonstrate our focus on the enduring missions of the DOE and program areas that reinforce our national security work. Our work on alternative sources of energy, carbon management, climate modeling, and groundwater cleanup benefit from broad technological expertise and extraordinary computational capabilities. In addition, we will be extending our efforts in nuclear materials management—a long-term mission of DOE—including work in specific areas, such as the Yucca Mountain project for nuclear-waste storage. In biosciences and biotechnology, we will build on the successes of the Joint Genome Institute, which completed a "working draft" of three chromosomes in 2000. We continue our DNA sequencing efforts and are developing programs in functional and structural genomics as well as computational biology.

Increasingly, our major program activities are executed in partnerships with other laboratories, U.S. industry, and universities. External partnerships have been important to the Laboratory since our establishment as part of the University of California, and we are pleased that DOE intends to negotiate an extension of the management and operating contract with the University. Many of our research activities are strengthened through the participation of faculty, postdoctoral fellows, and students. Our various partnerships with industry include a particularly significant ongoing effort as part of an industry–laboratories consortium to develop extreme ultraviolet lithography (EUVL) technologies for manufacturing the next generation of computer chips. Other highly successful industrial collaborations range from environmental remediation to the development of advanced medical technologies.

Our external interactions and research programs must be conducted in a safe and secure manner. To stay at the cutting edge, we must engage the broad scientific and technical community. At the same time, we must remain vigilant about security, which is a particular challenge in an age of electronic information and international science and technology. Science and security are both central to our mission. We must operate in a manner that protects scientific inquiry as we strengthen security to address new threats.

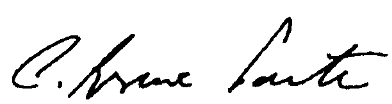
Over the past two years, we worked expeditiously to improve all aspects of security at Livermore—physical security, cyber security, and personnel security (including counterintelligence). As an outgrowth of these efforts, our overall security performance was rated Satisfactory (the highest grade) when it was reviewed in FY 2000. We continue to make upgrades in security to address identified issues and any perceived weaknesses.

Our focus on security improvements in FY 2000 was complemented by actions to ensure that we meet high operational standards in safety. To improve safety and ensure that it stays a top priority, we successfully implemented DOE's Integrated Safety Management System (ISMS). Through the extraordinary efforts of Livermore's ISMS implementation team, we were well-prepared for DOE's final verification in September 2000, which entailed the inspection safety procedures at 25 facilities across the Laboratory and the review of over 700 supporting documents. All employees now pay a higher level of attention to working safely, and we have already begun to see improvements in safety performance.

Successful programs and quality operations demand that the Laboratory continue to recruit and retain an exceptional workforce, without which our achievements would not be possible. In FY 2000, we faced stiff competition for skilled workers in the Northern California job market, additional restrictions on interactions with foreign nationals, limitations on spending for internal research and development, and negative headline-grabbing news about the DOE national security laboratories. It was not a good year in terms of these people issues, but we believe much of the bad news is now behind us. A major focus of senior management in FY 2001 will be on workforce issues—how to best attract and retain the talented people that Livermore needs to sustain its tradition of scientific excellence.

This Institutional Plan describes our strategic plans and ongoing planning efforts, our current program accomplishments, and our new initiatives. 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 in the early part of the 21st century.

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



SECTION 1

Laboratory Overview

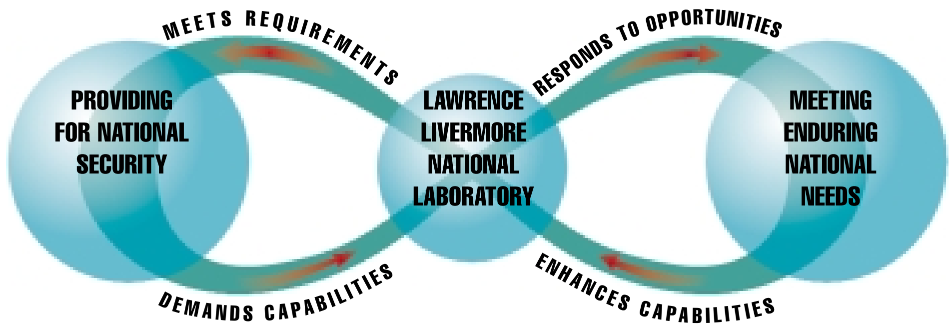


Figure 1-1. The Laboratory's mission. We meet requirements to provide for national security. This mission demands capabilities at the Laboratory that are also used to respond to opportunities to meet enduring national needs through projects that enhance our capabilities.

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

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 (DOE). 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 innovation, which is essential to sustained scientific and technical excellence. As a DOE laboratory with security and science central to its purpose, Livermore has an essential and compelling core mission and the capabilities to solve important, difficult, real-world problems.

As this *FY 2001–2005 Institutional Plan* highlights, it is a time of tremendous programmatic and operational challenges for the Laboratory.

- **Livermore programs must meet important commitments and deliver major products.** We are responsible for bringing into operation and applying significant new capabilities required for nuclear weapons stockpile stewardship, most notably the National Ignition Facility and ASCI White, a 12-trillion-operations-per-second supercomputer that is part of the Accelerated Strategic Computing Initiative (ASCI). In addition, we are committed to other major efforts for sponsors that lay the foundation for future activities at the Laboratory.
- **The Laboratory is taking substantial steps to improve security and safety.** Recent events have reinforced the prime importance of security at the DOE nuclear weapons laboratories. Working closely with the Secretary of Energy and other DOE senior managers, Livermore staff are expeditiously working to improve security. Specific actions have been taken to provide even greater protection of critical assets, implement state-of-the-art cyber security, and expand the Laboratory's counter-intelligence program. We also have successfully implemented DOE's Integrated Safety Management System to improve safety performance and management at Livermore.

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 the U.S. government and a partner with industry and academia. (Figure 1-1.)

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.

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 continue to 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 arms control and arms reduction.

The realization of a world with no nuclear testing—but with remaining dangers that keep nuclear deterrence and nonproliferation central elements of U.S. security strategy—presents the Laboratory with significant challenges. As part of an integrated national effort,

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.

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

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

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

we must make major advances in science and technology to maintain confidence in the U.S. nuclear weapon stockpile without nuclear testing. 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 prevent the proliferation and 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

At the Laboratory, investments are being made 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 are shaping 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 will seek such challenges where Laboratory efforts can lead to dramatic benefits for the nation.

We will focus on the 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, 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 and proteomics, disease susceptibility and prevention, and improved health care 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. Increasingly, our accomplishments will be achieved through effective partnerships with others.

Focused 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. Our programmatic achievements would not be possible, however, without the dedicated, outstanding efforts of all employees, and we must attract and retain high-quality staff for future achievements.

Safe, Secure, and Efficient Operations

Livermore's scientific and technological achievements will be made possible by safe, secure, and efficient operations and sound business practices. The Laboratory is committed to providing every employee and the community with a safe and healthy environment in which to work and live. We are also taking specific steps to provide even greater protection of critical assets at Livermore, enhance cyber security, and expand the Laboratory's counterintelligence program.

1.2 Critical Capabilities

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

1.2.1 An Extensive Science and Technology Base

Livermore programs are supported by a large technical base with nearly 3,000 scientists and engineers serving as career or term employees. 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 wide-ranging 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.

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 nearly 50 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 generation. 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 the 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 DOE 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 meeting design and construction goals for the National Ignition Facility. 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 (Figure 1-2).

High-Performance Scientific Computing. Over the 1994–2004 decade, we are acquiring successively more powerful computers with the goal of increasing computational speed and data capacity by a factor of 100,000. In July 2000, we took delivery from IBM of a 12-teraops computer (12 trillion operations per second), 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 advanced computing capabilities. These capabilities can potentially revolutionize scientific discovery and

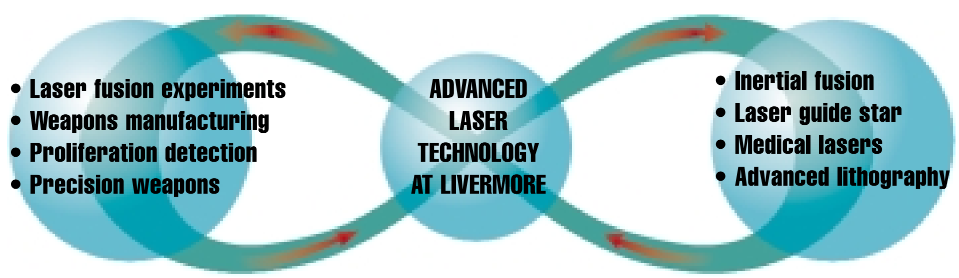


Figure 1-2. Expertise in advanced lasers and associated technologies—necessary for the National Ignition Facility and other major projects for national security—provides program opportunities in inertial confinement fusion, advanced lithography, and other scientific and industrial applications.

lead 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 Laboratory programs, such as environmental cleanup, nuclear waste disposal, and atmospheric modeling. In addition, we develop nanoengineered multilayer materials and other exotic materials, such as aerogels. These advances meet programmatic needs for highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

1.2.2 Specialized Research Capabilities and Facilities

Many specialized research capabilities and facilities 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

Principal Research Capabilities and Facilities at Livermore

Center for Accelerator Mass Spectrometry—most versatile spectrometry capability in the world.
Chemistry and Materials Science Environmental Services Laboratory—wide-ranging chemical and radiochemical characterizations of environmental samples.
Conflict Simulation Laboratory—state-of-the-art, interactive, entity-level conflict simulations.
Electron Beam Ion Trap Facility—unique facility for the study of highly ionized atoms at rest.
Engineering Technology Centers—cutting-edge research in Centers for Complex Distributed Systems, Computational Engineering, Microtechnology, Nondestructive Evaluation, and Precision Engineering.
Falcon Laser/Linac—facility for developing a source of ultrafast-pulse x-rays.
Flash X-Ray/Contained Firing Facility—versatile hydrodynamic testing facility currently undergoing upgrades.
Forensic Science Center—world-leading forensic analysis and instrumentation.
Genome Center—facility for high-throughput genome sequencing and study of functional genomics.
Hardened Test Facility—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.
Long-Term Corrosion Test Facility—comprehensive evaluation service for corrosion on various candidate metals for nuclear waste containers.
National Atmospheric Release Advisory Center—real-time emergency predictions of hazardous substance releases.
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—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—near-atomic-level chemical and structural analyses and images of complex materials.
Tritium Facility—activities to support target fabrication and decommissioning and recycling in inertial confinement fusion.
Two-Stage Gas Guns—phase-change predictions through experiments with metallic hydrogen.
Ultrashort-Pulse Laser—capability for equation-of-state, opacity, and other stockpile stewardship experiments.
Uranium Manufacturing and Process Development Facility—research facility for casting and forming processes.

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.

1.2.3 Multiprogram Support for DOE

As a consequence of the Laboratory's extensive science and technology base and its many special research capabilities, we provide multiprogram support to the DOE. This important relationship between the capabilities that Livermore has developed to fulfill its national security mission and its ability to make unique and valuable contributions in other DOE mission areas is a central feature of Livermore's mission statement (see Figure 1-1).

For example, with outstanding capabilities in laser science and technology, we support stockpile stewardship, pursue inertial confinement fusion physics, develop lasers for biotechnology and advanced manufacturing applications, and apply advances in laser technology to make breakthroughs in areas of basic science (see Figure 1-2). Our expertise in bioscience and bioengineering has applications in genomics research, bioremediation, environmental risk reduction, and biological warfare agent detection. Advanced scientific

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."

computing at Livermore supports stockpile stewardship, atmospheric modeling for emergency response and global climate prediction, computational biology, modeling for radioactive waste disposition and the movement of contaminants in groundwater, materials science modeling, and many other scientific areas (Figure 1-3).

1.3 Strategy Development and Alignment

1.3.1 Development of a Strategy—The DOE Strategic Plan

In September 2000, the DOE completed the development of a new strategic plan that builds on the *U.S. Department of Energy Strategic Plan* (September 1997) and planning activities within the Department that have occurred since 1997. Like the previous document, the new plan articulates the Department's mission, vision for the future, core values, and strategic goals in Corporate Management and its four businesses: National Nuclear Security, Energy Resources, Environmental Quality, and Science. The general goals identified in DOE's Strategic Plan are:

• **National Nuclear Security.** Enhance national security through the military application of nuclear technology and reduce the global danger from weapons of mass destruction.

• **Energy Resources.** Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.

• **Environmental Quality.** Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.

• **Science.** Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

• **Corporate Management.** Demonstrate excellence in the Department's environmental, safety, and health practices and management systems that support our world-class programs.

1.3.2 Strategy Development and Identification of Key Milestones

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* continues to reflect 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.

As an extension to *Creating the Laboratory's Future*, in February 1999 Laboratory senior managers identified specific key milestones to meet by 2001. These milestones, which constitute the Director's "A list," provide a set of important objectives for all Laboratory employees.

The Laboratory's Strategic Councils. The five Strategic Councils—created by the Laboratory Director in 1996—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 on issues pertaining to the scientific and engineering base at the Laboratory. In addition, there is a Council on Strategic Operations. The councils provide a key link for ensuring that the Laboratory's program plans and deliverables match the plans and needs of the DOE and other customers (Figure 1-4).

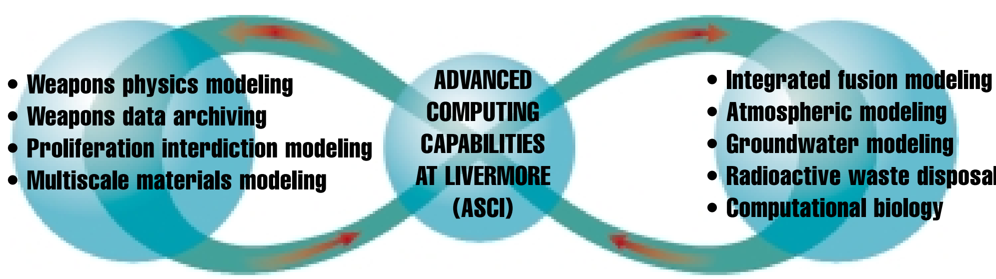


Figure 1-3. The Accelerated Strategic Computing Initiative (ASCI) and Livermore's advanced scientific computing capabilities, required for stockpile stewardship, enable us to respond to other program opportunities.

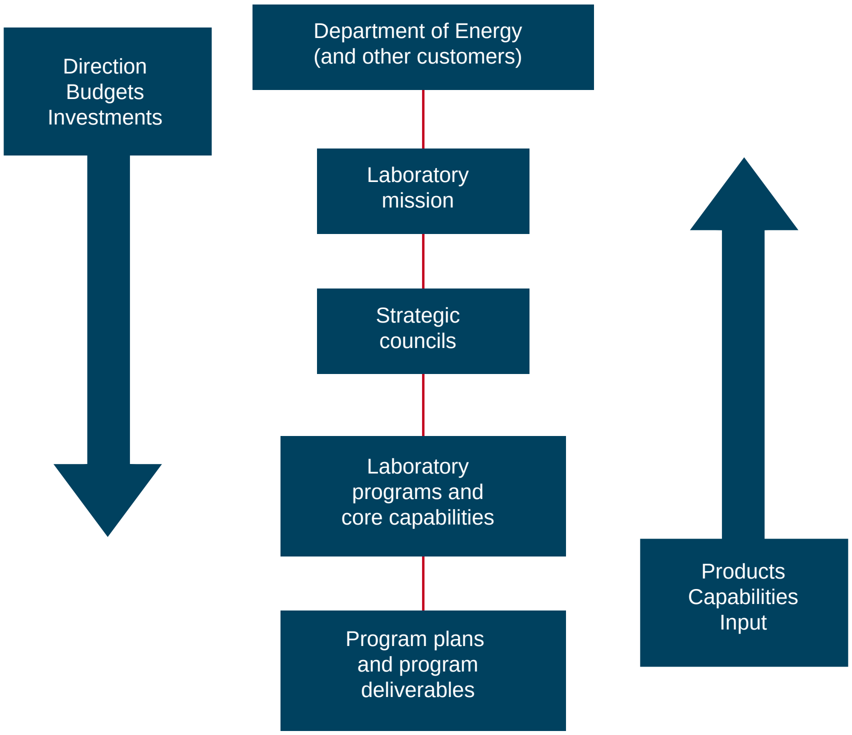


Figure 1-4. Development and alignment of Livermore's strategic plans are highly interactive processes involving the Department of Energy (as well as other customers) and the Laboratory's programs and strategic councils. Strategic direction and major new investments at Livermore, which flow down from the Department of Energy, are based on recognition of the Laboratory's capabilities, responsibilities, and current deliverables.

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 also developed planning materials for *Creating the Laboratory's Future* and ensure that the strategic direction of planned actions and initiatives align with the strategic plans of the Department of Energy (and other customers).

In addition, the councils are responsible for developing materials about plans and programs that are used at annual senior management offsite meetings, during which priorities are established. The senior management offsite in 1999 established goals for 2001 (discussed below), while the meeting in 2000 focused on very near-term programmatic and operations issues.

Livermore's Strategy Document. *Creating the Laboratory's Future* describes Livermore's roles and responsibilities as a DOE national laboratory and sets the foundation for decisions about Laboratory programs and operations. It presents the Laboratory's mission, vision, and goals (Section 1.1); work projects and initiatives in support of them; the science and technology strengths of the Laboratory that support our missions (Section 1.2); the management of operations at the Laboratory (and operations initiatives); and steps we are taking to prepare for the future.

Milestones for 2001. A product of the Laboratory senior management offsite in February 1999 was a list of goals, or milestones, for Livermore to achieve by January 2001. The 12 milestones (Figure 1-5), updated for the *FY 2000–2004 Institutional Plan*, represent goals for the Laboratory as a whole—other important objectives for specific programs are not included. The accomplishments represented by the 2001 milestones include: progress on several new initiatives; in some cases, the completion of programs already under way; and in other cases, progress toward completion. Our achievement of these milestones helps to define long-term well-defined roles in program areas that are of national interest and importance.

1.3.3 Alignment with DOE Strategy and Needs

Livermore's Principal Responsibilities and Major Programs. The Laboratory's mission statement—and essentially all the supporting material in *Creating the Laboratory's Future*—highlights the important interaction among Livermore's primary (national security) mission, the scientific and technical capabilities at the Laboratory, and programs to meet other enduring national needs. The direction of the Laboratory's national security

programs—evident from the milestones for 2001—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 the 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.

As the 2001 milestones demonstrate, we are able to make selected advances in many of DOE's mission areas, in part 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 engineering capabilities and success in developing 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 1-5. Twelve Milestones for Livermore to Meet by January 2001

1. The Stockpile Stewardship Program is proceeding as planned, and the Annual Certification has been completed for the fifth time with no need for nuclear testing identified.
2. The Laboratory has made significant gains in improving safety and is now viewed as a leader in the DOE complex. Livermore's operational record in counterintelligence and physical security continues to be viewed as excellent, and the Laboratory has made state-of-the-art advances in cyber security.
3. The National Ignition Facility building complex is completed in 2001, and laser support equipment is being installed.
4. The 12-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing.
5. The Laboratory is providing technology and capabilities to protect the United States from nuclear, chemical, biological, and other emerging threats to national security.
6. Livermore has become the leading DOE laboratory in industrial partnering, with extreme-ultraviolet lithography being one of the largest DOE successes to date.
7. The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology.
8. Livermore has expanded initiatives in nuclear materials stewardship, environmental clean-up technologies, and global climate modeling.
9. The workforce and management reflect an ability to attract and retain a high-quality and diverse staff.
10. The Laboratory's science and technology contributions are recognized by prizes, awards, and front-page publicity.
11. The Long-Range Strategy Project has successfully completed its work with a visionary and compelling description of the Laboratory's future.
12. The Laboratory is increasingly recognized as integral to the state of California through increased involvement with the University of California, particularly at the Davis and (new) Merced campuses, and as a partner of the state's broad education initiatives.

(Figure 1-2) and advanced scientific computing (Figure 1-3).

Alignment with the DOE Strategic Plan. Continuing interactions of Livermore programs with DOE sponsors and 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 2000). 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 our programs and strategies align with those of DOE (Figure 1-6). Figure 1-7 illustrates how Livermore's 2001 milestones are aligned with objectives defined in the *DOE Strategic Plan.*

Self-Assessments of Planning Success. 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:

• Successful Programs and Partnerships. Sustained support for Livermore program activities 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, our 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 makes it possible for us to be very responsive to changing needs.

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

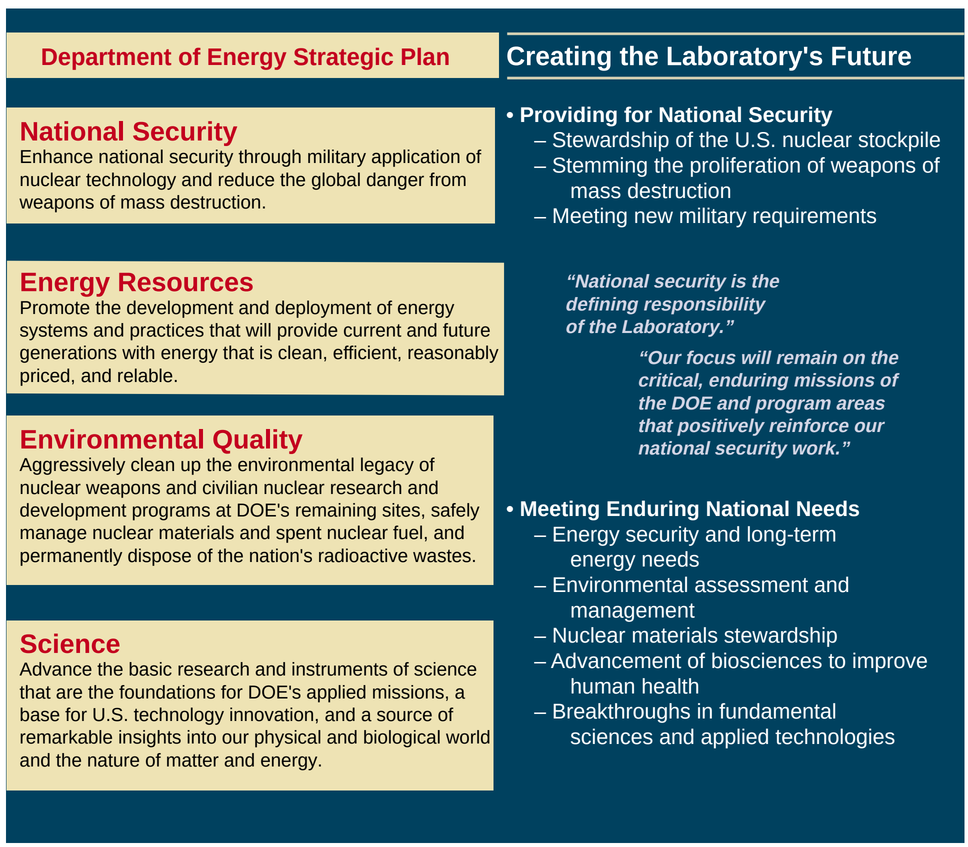


Figure 1-6. The missions and goals identified in the Laboratory's strategy document, *Creating the Laboratory's Future*, closely align with the strategic goals identified in the *U.S. Department of Energy Strategic Plan* (September 2000).

Figure 1-7. Alignment of Livermore's 2001 Milestones with the DOE Strategic Plan (September 2000)

DOE Strategic Plan Objectives	Livermore's Supportive Milestones
National Nuclear Security	
NS1: Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.	1,3,4
NS2: Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapon components under the nuclear testing moratorium.	1,3,4
NS3: Ensure the vitality and readiness of DOE's national nuclear security enterprise.	1,3,4,9,11
NS4: Reduce the global danger from the proliferation of weapons of mass destruction (WMD)	5,8
NS6: Ensure that the Department's nuclear weapons materials, facilities, and information assets are secure through effective safeguards and security policy, implementation, and oversight.	2
Energy Resources	
ER3: Increase the efficiency and productivity of energy use, while limiting fuel supplies.	6,8
ER5: Cooperate globally on international energy issues.	8
Environmental Quality	
EQ1: Safely and expeditiously clean up sites across the country where DOE conducted nuclear weapons research, production, and testing or where DOE conducted nuclear energy and basic science research. After completion of cleanup, continue stewardship activities to ensure that human health and the environment are protected.	8
EQ2: Complete characterization of the Yucca Mountain site and, assuming it is determined suitable as a repository and the President and Congress approve, obtain requisite licenses, construct and, in FY 2010, begin acceptance of spent nuclear fuel and high-level radioactive wastes at the repository.	4,8
Science	
SC1: Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation's quest for clean, affordable, and abundant energy.	8
SC2: Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences.	4,8
SC3: Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature, spanning scales from the infinitesimally small to the infinitely large.	7.10
SC4: Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE's science mission; and support our nation's leadership in the physical, biological, environmental, and computational sciences.	3,4,6,7,9,10,11,12
Corporate Management	2,12

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, participate in the national dialogue on important science issues, and be broadly recognized as a scientific leader.

Focused Internal Investments. We 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 scientific and technical horizons, and create important new capabilities so that the Laboratory can 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.

The Long-Range Strategy Project. One of the steps the Laboratory took to better define future directions for the Laboratory was the Long-Range Strategy Project (LRSP). In April 1998, the Laboratory Director initiated the LRSP to explore science and technology opportunities and national needs in the 2010-to-2020 time frame. The project was launched with the recognition that the Laboratory's prospects 10 to 20 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 national debate.

The project entailed the efforts of 22 younger to middle-career scientists and engineers from disciplines and programs across the Laboratory. Team members devoted 20 to 25% of their time to the project while continuing to fulfill their scientific and management responsibilities. They were guided by the Laboratory Director, and administrative support and leadership was provided by the Office of Policy, Planning, and Special Studies. The project was also supported by a resource group consisting of selected senior Laboratory leaders.

The principal activities of the LRSP were carried out through two sets of subgroup studies conducted sequentially and focused on selected topics. Each topic group was composed of five or six project members (including a selected leader or co-leaders) together with a senior member from the resource group. Project participants also met with an array of leaders from diverse fields and enterprises and had in-depth discussions with Associate Directors and other senior Livermore scientists and engineers. The LRSP concluded in January 2000 with a final briefing to senior management. A summary report, *2020 Foresight: Forging the Future of Lawrence Livermore National Laboratory*, synthesizes the results of the nine subgroup study projects. The report highlights principal points raised by the individual subgroups and ties them together with an overall set of conclusions and recommendations.

The LRSP concluded that the nation will continue to rely on a nuclear deterrent, but it is likely that the perceived importance of nuclear weapons and funding allocations for their stewardship will decline over the 10- to 20-year time horizon. However, it is also likely that other threats, both new and already emerging, will require innovative technical countermeasures. The group believes that the Laboratory's best strategy is to evolve consistent with changes in national priorities. Founded as a nuclear weapons laboratory, the future Laboratory envisioned by the group will still be focused on national security with a small set of core programs in three principal areas:

- Nuclear weapons.
- Other national security programs to meet emerging threats.
- Work to safeguard the nation's future (e.g., fusion energy, nuclear materials management, integrated environmental observation, civilian biosciences).

For the foundation of these core program areas, Livermore must strategically focus its R&D investments. The LRSP identified several such areas of particular interest: bioscience, scientific simulation, and lasers. Investments in these areas would build on existing strengths, offer exciting research opportunities, and contribute to the Laboratory's national security.

The LRSP found that some of the most urgent challenges facing Livermore are tied to the Laboratory's culture and the way it operates. Success in the future will require effective staff recruitment, improved means for nurturing early-stage research, greater use of partnerships, flexible business practices, and more open operations.

The project provided an opportunity for a diverse group of technical staff, who will be making important decisions about Livermore's programs and their direction over the coming decades, to get to know each other and the many issues that the Laboratory faces. Their report is just one of the important products of the project. *2020 Foresight* will be one of the principal building blocks for the Laboratory's next strategic plan, the planning cycle of which is expected to begin in 2001.

1.4 Evaluation of Performance

Livermore is one of three national laboratories managed and operated under a contract between the Department of Energy and the 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 current contract extension strengthens the performance-based management system introduced in 1992.

In October 2000, Secretary Richardson announced a decision to restructure the current contract to address security and management issues. The Department will also commence negotiations with UC that, if successful, would lead to additional performance requirements and a three-year extension of the contract.

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 UC with 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 1-8, since the inception of performance assessment system in FY 1993, the Laboratory has achieved very high ratings in science and technology and has markedly improved ratings in administration and operations since the first year. Our performance evaluation in FY 1999 was "excellent" in science and technology and "excellent" in administration and operations.

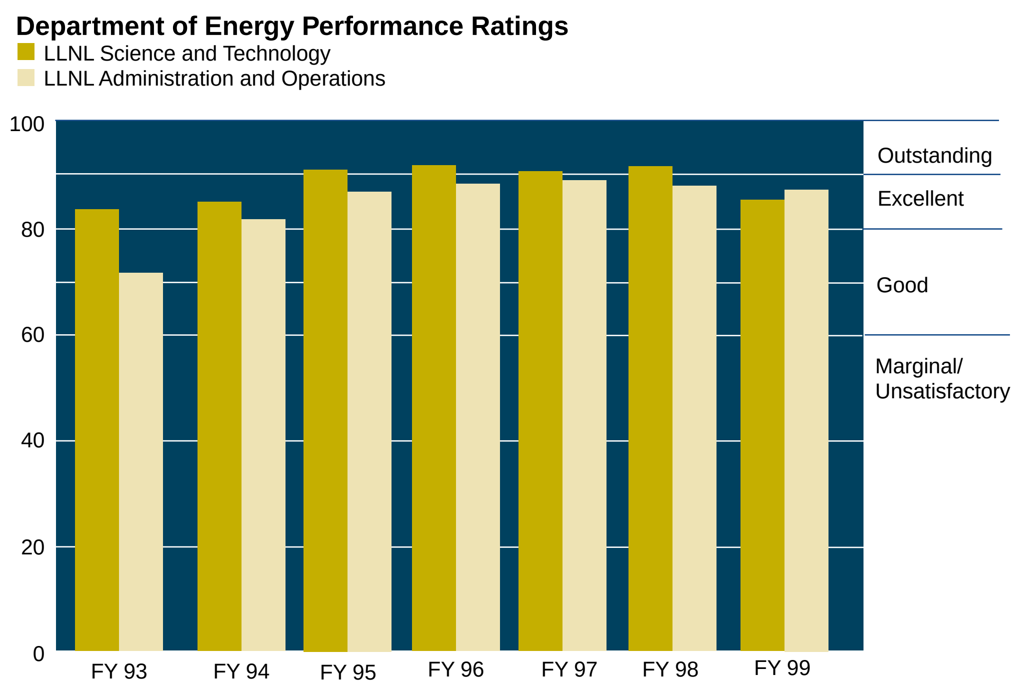


Figure 1-8. Overall, Livermore's Science and Technology (S&T) and Administration and Operations (A&O) were deemed "excellent" as measured by performance criteria defined in the performance-based management contract between the Department of Energy and the University of California.

SECTION 2

Institutional Plan FY 2001–2005

Laboratory Science and Technology
National Security

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. and its allies—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.

The Laboratory's national security programs align directly with the National Security Business Line General Goal in the September 2000 *DOE Strategic Plan* to "enhance the national security through the military application of nuclear technology and reduce the global danger from weapons of mass destruction."

Livermore is one of the three DOE national security laboratories that are part of the new National Nuclear Security Administration (NNSA) within the Department. Created through Congressional legislation enacted in 1999, the NNSA formally began operation in March 2000. The NNSA brings together DOE's national security functions and gives them a clear focus.

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. As part of the NNSA, Livermore plays a key role in the Stockpile Stewardship Program for maintaining the nation's nuclear weapons stockpile in the absence of nuclear testing. Bringing into operation new experimental facilities and accelerating and expanding the use of high-performance computing and simulation tools are fundamental to the success of the effort. Success also critically depends on maintaining expert judgment about nuclear weapons. We must pay particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel.

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, there is growing concern related to terrorist acquisition and use of WMD. Livermore is addressing the problem of WMD proliferation through a wide spectrum of analysis and technology development activities. Our efforts are supported by the NNSA Office of Defense Nuclear Nonproliferation and other sponsors.

Meeting Other Important National Security Needs

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and nonproliferation missions, we develop advanced defense technologies for the Department of Defense (DoD) to enhance the effectiveness of U.S. military forces. Livermore technologies are also increasingly being applied to domestic national security issues such as 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.

As a Collaborative Effort. Our work takes place within the context of the national security community—the three DOE national security laboratories, the production facilities and the Nevada Test Site, the DoD, and the U.S. intelligence community. Many of our 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.

Bolstered by Internal Investments. We also target Laboratory Directed Research and Development (LDRD) investments to enhance our ability to meet challenging, long-term national security mission objectives and other national priorities. These investments reinforce our core strengths, expand the Laboratory's scientific and technical horizons, and create new capabilities, such as technologies for remote sensing and detection. 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 3.3.2.

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 2 Laboratory Science and Technology—National Security	
2.1 Stockpile Stewardship	• The Stockpile Stewardship Program is proceeding as planned, and the Annual Certification has been completed for the fifth time with no need for nuclear testing identified.
2.2 Countering the Proliferation and Use of Weapons of Mass Destruction	• The National Ignition Facility building complex is completed in 2001, and laser support equipment is being installed.
2.3 Meeting Other National Security Needs	• The 12-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing.
	• The Laboratory is providing technology and capabilities to protect the U.S. from nuclear, chemical, biological, and other emerging threats to national security.

2.1 Stockpile Stewardship

DOE's Stockpile Stewardship Program is 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 for refurbishing nuclear weapons. The DOE Office of Defense Programs (DP), part of the new NNSA, is leading its three national security laboratories, the Nevada Test Site, and the production facilities that are part of the weapons complex in the execution of the program. A comprehensive stockpile stewardship implementation plan, referred to as the "Green Book," is updated on an annual basis.

In October 1999, Secretary of Energy Bill Richardson directed DOE Under Secretary Ernest J. Moniz to undertake a comprehensive internal review of the Stockpile Stewardship Program, to be completed within 30 days. The report resulting from the study team's efforts, the *U.S. Department of Energy Stockpile Stewardship Program 30-Day Review* (November 23, 1999), provides a broad overview of the program, its status and accomplishments, and major issues it faces. The review found that the program's structure is "on track" and that "science-based stockpile stewardship is the right path." However, one important finding of the review was that "despite the many accomplishments, the program is under stress."

One source of stress is the large set of investments that must be made. The Stockpile Stewardship Program's ambitious goals include having in place within about a decade a set of vastly improved scientific tools and manufacturing capabilities: 100-teraops supercomputers; advanced radiography capabilities to take three-dimensional images of imploding mock primaries; a high-energy-density research facility, the National Ignition Facility, for studying the thermonuclear physics of primaries and secondaries; and efficient, flexible, and modern manufacturing facilities. Concurrently, there have been greater-than-anticipated needs for direct stockpile support to meet Department of Defense requirements, and investments are needed to meet new security requirements. These are extraordinary demands on program resources and on the people in the program.

Program Priorities and Activities at Livermore

Livermore's efforts support the three objectives identified in the *DOE Strategic Plan's* National Nuclear Security Business Line that are related to stockpile stewardship:

Objective 1: Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.

Objective 2: Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapon components under the nuclear testing moratorium.

Objective 3: Ensure the vitality and readiness of DOE's national nuclear security enterprise.

To meet these objectives, the Stockpile Stewardship Program is organized into three focus areas: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and Facilities. These focus areas, which are described in greater detail below, provide an organizational structure for Livermore's stockpile stewardship activities. Priorities for these activities 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 effort involves projects such as the W87 Life Extension Program, surveillance, and baselining of the current stockpile systems to support Annual Certification and the planning for future life extension programs. These activities fully make use of advanced computing capabilities and simulation tools, physical databases, and experiments at the DOE weapons complex'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 (Accelerated Strategic Computing Initiative), construction of the National Ignition Facility, and development of advanced radiography technologies and facilities that conduct high-explosive experiments on mock weapon primaries.

• **To further develop the underlying science and technology** critical to future stockpile assessment and 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** for use when the current stockpiled systems must be refurbished or replaced.

The Growing Challenge

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 as staff retire. This experience base—and the emerging new tools needed to resolve stockpile issues—must be passed on to the next generation of stockpile stewards.

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. Management challenges stem from the need to both integrate and balance the many elements of the program while working within tight budget constraints. In addition, the Laboratory must attend to mandated security upgrades (see Section 5.2).

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. The *30-Day Review* specifically identified the challenges of workforce recruiting and the need to attend to morale issues arising from new security requirements, budget uncertainty, and reduction of resources to support innovative scientific inquiry. Workforce recruiting and retention of top-quality staff both benefit from the Laboratory's LDRD Program (Section 3.3.2) and various ties to universities (Section 3.4.3). These efforts, together with the Science and Technology Education Program (Section 3.4.4), 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 facilities, and the Nevada Test Site. DOE's detailed implementation plan, the Green Book, undergoes annual revision. It 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 coordinating assessments of stockpile performance and modifications.

Program Thrusts

Annual Assessment. Livermore is a key participant in two formal review processes for assessment of weapon safety and reliability—the 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 this process, we collect, review, and integrate all available information about each stockpile weapon system, including physics, engineering, 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, DOE has been conducting a Dual Revalidation of the W76 SLBM warhead. Now concluding, the Dual Revalidation examined the warhead design in detail over a three-year period. In the future, rather than dual revalidation, the laboratories will be conducting a set of less comprehensive baselining studies to archive and update technical analysis of each system over a five-year period. With DoD, we are also establishing new procedures for conducting life-extension refurbishment programs.

Improved Program Alignment and Integration. For the Stockpile Stewardship Program to succeed, it is crucial that the activities at the three laboratories, the Nevada Test Site, and the production facilities be a unified effort with integrated goals, milestones, and schedules. To this end, DOE's Office of Defense Programs undertook a major shift in program management strategy in FY 1999, working closely with the three national security laboratories throughout the planning process. The *Stockpile Stewardship Program 30-Day Review* (November 1999) concluded that the changes substantially improved program's organizational structure and management.

The revised program management strategy is responsive to a number of demands on the Stockpile Stewardship Program. The revision recasts major elements of the Stockpile Stewardship Program into a set of activities that more clearly describe program goals and budget priorities and that help to identify program risks if there are budget shortfalls. The integrated program activities include:

- **Directed Stockpile Work.** Directed Stockpile Work supports the readiness of weapons and includes activities to meet current stockpile requirements. It involves production activities and research and development that directly apply scientific understanding and engineering capabilities to the assessment, refurbishment, and certification of the weapons stockpile. The effort includes weapon maintenance, comprehensive surveillance, weapon baselining, assessment and certification, supporting research and development, and scheduled weapon refurbishments. It also includes other stockpile commitments, such as dismantlement and information archiving.
- **Campaigns.** Campaigns are directed at making the scientific and technological advances necessary to assess and certify weapon performance now and over the long term without nuclear testing. Campaigns are focused, technically challenging, multifunctional efforts that address critical capabilities needed to achieve certification of stockpiled weapons. They develop and maintain specific critical capabilities that are needed to sustain a viable nuclear deterrent. Each campaign has milestones and specific end-dates designed to focus advanced basic and applied science, computing, and engineering efforts on well-defined deliverables related to the stockpile. The current set of eighteen campaigns—eleven of which focus on scientific activities at the three laboratories—provides a planning framework for the program's research and development activities.
- **Readiness in Technical Base and Facilities.** Readiness in technical base and facilities ensures that necessary investments are made to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. Readiness includes the fixed costs and the investments of the Stockpile Stewardship Program. Readiness depends on (1) exceptional, motivated people in the program with the needed skills and training; (2) a well-maintained, modern infrastructure to support the activities of these people and to operate in a safe, secure, and environmentally responsible manner; and (3) special experimental and computational facilities for future stewardship activities in the absence of nuclear testing.

In conjunction with this revised approach to managing program activities, a rigorous planning process was established to clearly define programmatic milestones to be achieved within each program element. The Stockpile Stewardship Program is now defined by a series of five-year plans, one for each program element, describing goals and objectives. The five-year plans—developed with the participation of the laboratories, plants, and the test site—are accompanied by annual implementation plans with detailed milestones.

2.1.2 Directed Stockpile Work

Directed Stockpile Work supports the readiness of weapons. It includes weapon maintenance, comprehensive surveillance, weapon baselining, assessment and certification, supporting research and development, and scheduled weapon refurbishments. The effort also includes other stockpile commitments, such as dismantlement and information archiving.

Situation and Issues

Stockpile Requirements. On an annual basis, the President issues the Nuclear Weapons Stockpile Plan, which is first prepared by the Nuclear Weapons Council and reviewed by the Secretaries of Defense and Energy. The Plan sets the requirement to maintain a safe and reliable nuclear weapons stockpile, and it specifies the number of weapons of each type to be in the stockpile. Among its other responsibilities, DoD establishes military requirements, which are incorporated into the President's plan. These requirements drive the Directed Stockpile Work workload for DOE, particularly in the resource-intensive area of refurbishment activities and life extension programs.

One of the findings in the *30-Day Review* is that the requirements process between DoD and DOE should be improved through more vigorous efforts at prioritization. "Requirement" means different things to the two departments, and refurbishment program drivers that are "must do's" need to be distinguished from those that are "should do's" or "could do's."

Livermore-Designed Weapons and Responsibilities. 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. These systems are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 is already doing that. The Laboratory has special responsibilities for these systems, including surveillance, performance and safety assessments, and refurbishment. We are developing comprehensive plans to extend the stockpile life of the Livermore-designed systems.

We have also begun working closely with Los Alamos and the production facilities on issues related to the W80 cruise missile warhead. In addition, the Laboratory has broader responsibilities to develop assessment capabilities, technologies, and processes that contribute to maintaining the safety and reliability of all stockpiled weapons.

Assessments. Assessments provide the foundation for formal certification of stockpile performance and for refurbishment decisions. 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.

The Stockpile Stewardship Program includes a comprehensive set of assessment 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 options for new production and fabrication processes and materials. Modification actions must then be certified.

Stockpile Surveillance. Our stockpile surveillance activities focus on Livermore designs in the stockpile. These efforts include developing improved monitoring capabilities and building the scientific base to better understand aging effects in all stockpiled weapons (see Enhanced Surveillance Campaign in Section 2.1.3). With a better understanding of aging, we can better predict changes in the stockpile and conduct systematic refurbishment and preventative maintenance activities to correct developing problems. We also perform surveillance testing of the detonator systems on the Livermore-designed weapons.

Weapon Refurbishment. 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.

Activities to improve the manufacturing of weapons components are part of the W87 Life Extension Program as well as the Advanced Design and Production Technologies (ADaPT) Campaign discussed in Section 2.1.3. We are working closely with the production plants to integrate the development of replacement components with the development of new materials and manufacturing processes. By making use of modern production technologies and incorporating major technical advances that have occurred since the weapons were first manufactured, we are able to lower the cost of weapon refurbishment and reduce the environmental impact.

Program Thrusts

A Strategy to Improve Assessment Capabilities. The expectation that more challenging stockpile issues will arise as weapons continue to age is driving the program's campaign strategy (see Section 2.1.3) and investments in more capable experimental facilities (see Section 2.1.4). These investments include the National Ignition Facility (NIF) and the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos. 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 and eventual operation of NIF.

W87 Life Extension. A principal program thrust at Livermore is the W87 Life Extension Program (LEP). The objective of the LEP is to enhance the 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. The W87 LEP is a success story—we achieved all planned major milestones. We have completed all development activities—including flight testing, ground testing, and physics and engineering analyses—and production processes have been finalized. Final ground testing of production units will be completed in autumn 2000; successful completion will be followed by formal certification of the refurbished weapons. The first refurbished unit was completed in February 1999, and the final production unit is scheduled for completion in 2004.

Improved Surveillance of the Stockpile. Using the experience and data we have gathered, we are working with the Albuquerque Operations Office on plans for revising the surveillance program for Livermore systems so that it is even better attuned to understanding behavior of an aging stockpile. We are undergoing a general review and revision of our surveillance work to document design requirements, redefine attributes to be measured, redefine sampling plans, introduce new diagnostic tools, and improve analysis methods. For example, we are working on strategies that combine the benefits of random and targeted sampling directed at specific weapons system issues.

In addition, as our contribution to the Enhanced Surveillance Campaign (see Section 2.1.3), we are improving the sensors and techniques used to inspect weapons. For example, Livermore is introducing into surveillance service solid-phase micro-extraction technologies for nonintrusively collecting and analyzing chemicals in sealed weapon components, completing development of high-resolution x-ray tomography for imaging weapon pits, and continuing development of high-energy neutron radiography for nondestructively detecting small voids and structural defects in weapon systems. Working with Y-12, AlliedSignal, and Savannah River, we are also pursuing micro-sensors for evaluating material degradation and corrosion in weapon systems.

Improved Production Technologies. Working in conjunction with the W87 LEP, 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. The network will help to foster greater integration of work throughout the weapons complex. 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 LEP activities.

For a possible production option for the W87 LEP, we have built and delivered to the Y-12 Plant a production-worthy Laser Cutting Workstation. It has general applicability to several stockpile systems and refurbishment programs. We also demonstrated a laser system designed as a safe and precise tool for cutting high-explosive materials. The Pantex Plant is very interested in further development of laser cutting for high-explosive applications. Other production technologies are being pursued as part of Livermore's contribution to the ADaPT Campaign.

Directed Stockpile Work Workload Planning. With the W87 LEP under way, we are 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. We are also working with Los Alamos and the production facilities on W80 LEP issues.

DOE and DoD must work together effectively to arrive at realistic work plans—including budgets and schedules—for future refurbishment activities for each system in the enduring stockpile. We need to develop a range of well-defined options that then must be weighed according to risks and benefits. Balancing benefits and risks in a highly constrained budget environment will be difficult. Near-term affordability issues—together with the prospect of better definition of which components should be replaced and the possibility for improved design options—argue for tackling the more challenging refurbishment actions later if they are not yet “must-do’s.” However, that decision could lead to later workload balancing issues at the plants. It would also increase the burden on future stockpile stewards, who will face the more challenging issues without the experience base of the current staff.

2.1.3 Stockpile Stewardship Campaigns

Situation and Issues

The Stockpile Stewardship Program Campaigns are directed at making the scientific and technological advances necessary to assess and certify nuclear weapon performance now and over the long term. They integrate experiments, simulation development, and assessment activities and focus on achieving specific needed capabilities. Eighteen campaigns are being pursued.

Each campaign has a specific end-date and is designed to achieve a quantifiable end-state associated with a specific stockpile stewardship goal. As they progress, the campaigns will achieve scheduled interim objectives relevant to stockpile needs. For each campaign, the resource needs have been determined together with an assessment of program risks if funding is not adequate. In addition, a set of cross connections with other elements of the program has been identified.

Significant Accomplishments. In 1999, Livermore achieved a number of significant accomplishments in its campaign activities, such as:
- The first-ever three-dimensional simulation of a nuclear weapon primary explosion.
- The Oboe subcritical experiments using confinement vessels for rapid turnaround of test results.
- Progress in understanding the aging of key materials in weapons through a variety of laboratory experiments and modeling efforts.
- Experiments using the Omega laser yielding data for the comparison of radiation transport models.

These and other accomplishments are described in more detail in Livermore’s *Annual Report, Science and Technology Review* (the Laboratory’s monthly publication), and *National Security Review* (the Laboratory’s quarterly classified journal).

Program Thrusts

The current set of eighteen campaigns is briefly described. Teams from across the DOE weapons complex work together to focus and optimize their combined resources to achieve overall milestones and end-states. Livermore’s role in each campaign varies, and our major contributions are highlighted in Table 2-1.

In general, we are primarily focused on the eight campaigns to improve the scientific understanding of weapons performance. We also work in close partnership with the production facilities on the three applied-science and weapons-engineering campaigns, and in selected areas, we provide development support to the seven campaigns to sustain the manufacturing base.

The following eight campaigns are aimed at providing the scientific understanding needed to certify the nuclear weapons stockpile in the absence of nuclear testing and to support required weapon modernization in life-extension programs.

Primary Certification Campaign. This campaign focuses on developing and implementing the tools required to certify the performance and safety of any rebuilt or aged primary. Primary performance must be understood within a certain margin of error. Among the many activities supporting this campaign are efforts to develop validated models of high-explosives denotation, boost physics, and primary burn.

Dynamic Materials Properties Campaign. The goal of this campaign is to develop data and accurate, experimentally validated models that describe the behavior of materials at the level of accuracy needed for certification of weapon performance. One area of special emphasis is determination of the equation of state and constitutive properties of plutonium (e.g., strength, spall, ejecta) as well as organic materials and deuterium–tritium gas mixtures.

Advanced Radiography Campaign. This campaign aims to provide three-dimensional dynamic radiographic images of imploding surrogate primaries as well as associated analytical capability applicable to the certification of rebuilt primaries. After nuclear testing, advanced radiography is the most important experimental tool that we have to maintain an aging nuclear stockpile. This campaign includes completing and operating the DARHT facility, developing advanced simulation and analysis capabilities, and providing a technical basis for deciding the next step on the path to more advanced radiography capabilities.

Table 2-1. Livermore contributions to the DOE Defense Program Campaigns.

Campaign	Major Livermore Technical Efforts
1. Primary Certification	High-fidelity modeling and experiments: with plutonium at NTS (JASPER gas gun and subcriticals), high explosives at the High-Explosives Applications Facility (HEAF) and Site 300, hydrotests at the Flash X-Ray/Contained Firing Facility and DARHT; calculational model development.
2. Dynamic Materials Properties	Subcritical and gas-gun experiments (Pu); HE experiments at HEAF and Site 300; NIF experiments (deuterium and tritium equation of state); model development.
3. Advanced Radiography	Linear induction accelerator (LIA) work for DARHT-2; lead for LIA technology demonstration facility; materials research.
4. Secondary Certification & Nuclear Systems Margins	Opacity, transport, and interaction experiments at Omega and NIF; physics model development.
5. ICF Ignition & High Yield	NIF construction and operation; target design and fabrication; experiments and diagnostics.
6. Certification in Hostile Environments	Nuclear weapon outputs and environments; weapon vulnerability and hardness, including experiments at Omega and NIF.
7. Defense Applications & Modeling	ASCI applications development; data visualization; platform integration; validation and verification.
8. Weapon System Engineering Certification	Experiments to validate models; system-level confirmatory experiments.
9. Enhanced Surety	Development of advanced initiation, safing, optical, and high-explosives technologies.
10. Enhanced Surveillance	Aging (and accelerated aging) of pits, canned subassemblies, and high explosives; lab experiments; modeling.
11. Advanced Design & Production Technologies	Development of materials and production process technologies
12. Seven Production Readiness Campaigns	Development of production processes.

Secondary Certification and Nuclear System Margins Campaign. This campaign examines the performance of secondaries to identify the minimum factors necessary to produce a militarily effective weapon. The objectives of this campaign include (1) developing a validated predictive computational capability for each system in the stockpile; (2) quantifying, through simulation and experiments, our understanding of primary radiation emission and energy flow; and (3) determining the performance of nominal, aged, and rebuilt secondaries. In the past, our less-than-complete understanding of these issues required nuclear tests to establish performance "margins." Without such tests, aging and remanufacturing issues require a more rigorous predictive capability.

Inertial Confinement Fusion (ICF) Ignition and High-Yield Campaign. The long-term goal of this campaign is to achieve ICF ignition implosions in the National Ignition Facility (NIF). Material conditions that can be reached in NIF, together with the diagnostics available, will allow the experimental study of thermonuclear burn and important regimes of high-energy-density science. Understanding physical phenomena at star-like temperatures and pressures is critical to understanding how nuclear weapons work.

Certification in Hostile Environments Campaign. The goal of this campaign is to develop certification tools and microelectronics technologies to ensure that refurbished weapons meet stockpile-to-target-sequence (STS) requirements for hostile environments. Technical objectives include developing a suite of validated computational tools for radiation-hardened design and certification using nuclear environments generated with pulsed-power and laser-based facilities, reevaluating nuclear-weapon hostile environments, and demonstrating certification technologies on the W76 life-extension program. The development of computational models will reduce reliance on laboratory tests.

Defense Applications and Modeling Campaign. This campaign focuses on the shift from nuclear-test-based methods to computation-based methods to certify the safety, reliability, and security of the stockpile. The capabilities coming online through the Accelerated Strategic Computing Initiative (ASCI) make possible three-dimensional, high-fidelity, full-system simulations. The goal is to develop the simulation software required for engineering, safety, and performance analyses of weapons in the stockpile.

Weapon System Engineering Certification Campaign. The intent of this campaign is to establish engineering certification methods that quantify performance and uncertainties of weapon systems at a reduced cost. Predictive engineering computational models for stockpile life-extension program activities will be developed and validated through fewer, smarter, system-level confirmatory experiments. The goal is to greatly increase the information gained from each fielded experiment so that we can increase weapons understanding while we reduce the number of tests and associated costs.

The following three campaigns focus on applied science and weapons engineering. They provide specific tools, capabilities, and components in support of weapon maintenance, modernization, and refurbishment, as well as certification of weapon systems.

Enhanced Surety Campaign. The goal of this campaign is to increase nuclear safety and surety. Main efforts include developing advanced capabilities in micro, optical, and solid-state technologies that improve nuclear warhead safety, as well as enhancing use-control and use-denial technologies. A critical factor is to qualify surety solutions for planned stockpile life-extension refurbishment activities while maintaining flexibility to respond to surprises encountered during refurbishment.

Enhanced Surveillance Campaign. This campaign will provide a validated basis to certify aged components, specify when components must be replaced, and determine when new manufacturing facilities are needed. It will provide the first science-based assessment of the lifetimes of pits, high explosives, organic materials, and canned secondary subassemblies and furnish quantitative bases for future stockpile life-extension activities. One of the goals is to minimize or eliminate unnecessary refurbishment costs.

Advanced Design and Production Technologies (ADaPT) Campaign. This campaign aims to develop improved modeling and simulation tools and information management technologies so that refurbishment products are high in quality and are delivered cheaply and quickly. The campaign will enable full-scale engineering development for weapon component refurbishment with minimal hardware prototyping and paperless monitoring of production activities.

The final seven campaigns support readiness by focusing on sustaining the manufacturing base within the weapons complex.

Pit Manufacturing Readiness Campaign. The goal of this campaign is to reconstitute pit manufacturing within the DOE nuclear weapons complex, including the reestablishment of the technical capability to manufacture pits for the enduring stockpile at a capacity of 20 pits per year.

Secondary Readiness Campaign. This campaign will ensure that future manufacturing capabilities are in place, including the reestablishment of special materials processing, replacement of antiquated technologies, maintenance of workforce competencies, and development of component certification and recertification techniques for weapon secondaries.

High-Explosives (HE) Manufacturing and Weapon Assembly/Disassembly Readiness Campaign. This campaign is focused on ensuring future manufacturing capabilities for high-explosives fabrication and weapon assembly.

Nonnuclear Readiness Campaign. This campaign will ensure that future manufacturing capabilities for nonnuclear components are available.

Materials Readiness Campaign. This campaign includes activities to support the construction of a new highly enriched uranium (HEU) storage facility at Y-12.

Tritium Readiness Campaign. The focus of this campaign is to develop a source of tritium for meeting future stockpile needs. A commercial light-water reactor is the primary technology option under consideration, with a linear accelerator (linac) option as a backup.

Transportation Readiness Campaign. This campaign ensures that there will be improved transportation equipment and proper personnel training to meet anticipated threats and the needs of DOE and DoD for safe and secure transportation of nuclear weapons, nuclear components, and related cargoes.

2.1.4 Readiness in Technical Base and Facilities

Readiness in technical base and facilities calls for investments in people and their supporting infrastructure to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. The Stockpile Stewardship Program success depends on the presence of well-trained, motivated people together with a well-maintained, modern infrastructure that is operated in a safe, secure, and environmentally responsible manner. Success also requires bringing online the special experimental and computational facilities that are especially needed in the absence of nuclear testing.

Situation and Issues

A Quality Workforce. We face the absolutely crucial challenge of maintaining expert judgment about nuclear weapons issues. That challenge has been recognized from the onset of the Stockpile Stewardship Program, and it was very carefully considered by the Commission on Maintaining United States Nuclear Weapons Expertise (the "Chiles Commission"). The Commission correctly pointed out the need for a sustained recruiting and training effort at the laboratories to supplement our veteran workforce.

Retirement age is nearing for a significant fraction of the Laboratory's career workforce with "critical skills" that support of the Stockpile Stewardship Program and related activities. About 37% of Defense-Programs-funded engineers, scientists, technicians, and their managers are over 50 years old. Only about 17% of the "critical skills" career-employee population at Livermore is 40 years old or younger. Retention of the current staff and recruitment of new scientists, engineers, and technicians are vitally important for the continuing health of the Stockpile Stewardship Program.

Unfortunately, events over the last year have made workforce management more challenging. As noted in the *30-Day Review*, morale and employee recruitment and retention are being impacted by new security requirements (e.g., restrictions on foreign nationals and interactions with them), by budget and program uncertainties, and by the reduction of resources that support innovative scientific inquiry.

The Need for NIF. The National Ignition Facility (NIF) is a cornerstone of the Stockpile Stewardship Program. Understanding high-energy-density physics phenomena is critical to understanding how nuclear weapons work. NIF will be the only facility capable of well-diagnosed experiments to examine fusion ignition and burn and the thermonuclear properties of primaries and secondaries in nuclear weapons.

NIF experiments are needed to study a number of important issues that can affect an aging or refurbished stockpile. In addition, the facility will be used to better understand critical elements of the underlying science of nuclear weapons and nuclear weapon effects. Advanced computer models being developed for stockpile stewardship need to be improved and validated by tests in the physical conditions that only the NIF can provide. NIF also will attract and help train the exceptional scientific and technical talent required to sustain stockpile stewardship over the long term. A more detailed discussion of the need for NIF is provided in DOE's *The National Ignition Facility and Stockpile Stewardship*.

ASCI and Future Facility Needs. The Accelerated Strategic Computing Initiative (ASCI) is a program to dramatically advance our ability to computationally simulate the performance of an aging stockpile and the conditions affecting weapon safety (e.g., the Defense Applications and Modeling Campaign and others, above). The initiative is designed to deliver at a steady pace significant new capabilities to support 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. In summer 2000, the Laboratory took delivery of a supercomputer capable of 12 trillion operations per second (12 teraops). Planned expansion of Livermore's computing power beyond the 12-teraops platform will require a new facility, the Terascale Simulation Facility.

Key Stockpile Research Facilities at Livermore. Livermore has special responsibilities in the Stockpile Stewardship Program because of our special skills and capabilities and because unique user facilities at Livermore must be maintained. In addition to a number of important but smaller science and engineering facilities, these include:

• The High- Explosives Applications Facility (HEAF). The most modern facility for high-explosives research in the world, HEAF is a center for the study of chemical high explosives. It combines all the capabilities needed to synthesize, formulate, and test new explosive compounds. High explosives can be safely detonated in specially designed vessels in quantities up to 10 kilograms. Experiments are supported by state-of-the-art diagnostic equipment that includes high-speed, rotating-mirror streaking and framing cameras, electronic image-converter cameras, optical interference velocimeters, and image-forming x-ray machines.

• The Flash X-Ray/Contained Firing Facility at Site 300. This modern hydrodynamic test facility is capable of conducting "core punch" experiments that record a detailed digital image of a mock weapon primary when it is highly compressed. The experimental area is being upgraded to contain the debris from tests. When completed in FY 2001, the Contained Firing Facility will be a 2,700-square-meter indoor explosives testing facility at Site 300 that houses the newly upgraded Flash X-Ray (FXR) machine. The containment addition includes a reinforced firing chamber, a support staging area, and additional diagnostic space for testing up to 60 kilograms of explosive materials. Emissions to the environment will be drastically reduced, and hazardous waste, noise, and blast pressures will be minimized. The facility, now shut down during construction, will be reactivated in FY 2001.

• The Secure and Open Computing Facilities. This facility assists our programs and serves as a testbed for development of high-performance computing hardware and software. Livermore Computing maintains two computing facilities, one for classified work (the Secure Computing Facility) and the other for unclassified work (the Facility for Advanced Scalable Computing Technology).

• The Superblock. Housing modern facilities for special nuclear materials research and engineering testing, the Plutonium Facility, in particular, is engaged in activities to prepare and monitor accelerated-aging plutonium samples. The facility is also used to prepare plutonium samples for Livermore's subcritical tests, to investigate technologies for the remanufacture of plutonium parts in Livermore-designed weapons, and to conduct other fundamental physics and engineering experiments using plutonium. In addition, as part of the DOE's nonproliferation efforts, the Superblock is central to the multilaboratory Plutonium Immobilization Program to develop means for disposing excess U.S. plutonium.

Program Thrusts

The Laboratory's future workforce and facilities are areas of considerable attention. The steps we are taking in workforce recruitment and retention are discussed in Section 5.3. Some of our activities that particularly pertain to recruiting are highlighted below. Section 5.2.1 presents a comprehensive summary of Livermore's facility plans and resource requirements. Here we briefly discuss two major construction items.

Recruitment for Defense Programs Activities. New employees recruited into the Defense and Nuclear Technologies Directorate at the Laboratory come from a number of sources, all of which require Laboratory outreach, particularly to academic institutions. Recruitment measures include: on-campus recruiting, relationships established through collaborative research activities, postdoctoral fellow programs at the Laboratory, contacts made at professional scientific and engineering society meetings, advertisements in professional journals, and position postings on the World Wide Web.

Through a variety of activities, we have developed a wide range of academic collaborations on physics and computational topics relevant to the needs of the Stockpile Stewardship Program. Two prominent examples are the University of California Research Institutes (five of which are located at Livermore, as discussed in Section 3.4.3) and the Academic Strategic Alliances Program (ASAP), which is part of the Accelerated Strategic Computing Initiative (ASCI). These academic alliances are discussed in Section 4.1.2.

NIF Construction. The National Ignition Facility (NIF), currently under construction at Livermore, will be a 192-laser-beam facility capable of achieving fusion ignition and energy gain in the laboratory for the first time. NIF is the only facility in the Stockpile Stewardship Program that can achieve fusion ignition and obtain temperatures and pressures approaching those in an exploding nuclear weapon. While significant technical accomplishments have been realized with respect to NIF, major project cost and schedule issues emerged in 1999. In September 1999, Secretary Richardson responded to these problems by issuing a six-point plan to "*bring NIF back on track*." As a result, a number of extensive and in-depth reviews of the technology and project management were conducted. The reviews of the NIF science and technology determined that the project design and engineering are sound. However, significant management deficiencies were identified, and the planned method of assembling and integrating the laser was significantly underestimated. To address the project management deficiencies, the lines of authority and communication were restructured at DOE, the University, and the Laboratory. Plans were revised to take advantage of relevant industrial experience and expertise during the assembly and integration of the laser.

A weeklong independent Rebaseline Validation Review and a separate, parallel Independent Cost Review of the entire rebaselined NIF project were held in August 2000. The new NIF baseline schedule provides first light to the target chamber in June 2004 and all 192 beams commissioned in September 2008. The NIF rebaselined cost and schedule were approved by the Energy Systems Acquisition Advisory Board (ESAAB), which allowed the Secretary to submit his certification of the NIF Project baseline along with his recommendations for FY 2001 and out-year funding plans to Congress by September 15, 2000, as required. The acceptance of the new NIF baseline cost and schedule and the appropriation of funds by Congress will result in a renewed and strengthened project consistent with the needs of the overall Stockpile Stewardship Program.

Terascale Simulation Facility. Expansion of Livermore's computing power beyond the 12-teraops platform will require construction of the Terascale Simulation Facility (TSF). A Conceptual Design Report for TSF has been approved. Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers. 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. The construction project was initiated with an FY 2000 line-item authorization.

Laboratory Initiatives

- National Ignition Facility (DP)
- Terascale Simulation Facility (DP)
- Accelerated Strategic Computing Initiative (DP)

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 its 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.

The proliferation 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 Defense Nuclear Nonproliferation. 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, detection and reversal, response, and avoiding surprise. In addition, our Center for Global Security Research brings together the technology and policy communities to explore ways in which technology can enhance national and international security. The Laboratory's activities support an objective identified in the DOE Strategic Plan's National Nuclear Security Business Line that pertains to proliferation of weapons of mass destruction (WMD):

- **Objective 4:** Reduce the global danger from the proliferation of weapons of mass destruction (WMD).

2.2.1 Proliferation Prevention and Arms Control

Situation and Issues

The best way to stop nuclear weapons proliferation is at the source, through the protection and control of weapons-usable nuclear materials. The security of these materials in Russia is of particular concern, given that country's dire economic straits and its inability to support the Soviet-legacy nuclear infrastructure. In contrast, proliferation of chemical and biological weapons 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 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 and START agreements; the Limited, Threshold, and Comprehensive Test Ban treaties; the Chemical and Biological Weapons conventions; and others.

Program Thrusts

Technical Support of Arms Control and Treaty Monitoring. Livermore assesses for the U.S. government the impact of proposed treaty provisions in terms of our 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 support joint DoD and DOE transparency and verification efforts for a wide range of warhead dismantlement and fissile material activities, including warhead dismantlement transparency, Mayak (Russian) Storage Facility Transparency, International Atomic Energy Agency (IAEA) inspections, highly enriched uranium (HEU) purchase transparency, the Plutonium Production Reactor Agreement, the Processing and Packaging Implementing Agreement (PPIA), and excess fissile material storage under the Trilateral Initiative (U.S., Russia, and IAEA). A major challenge to dismantlement transparency is the need for technologies that reveal enough information to verify that the inspected contents are of weapons origin without revealing sensitive design information. We have developed such a method and successfully demonstrated it to the Russians and the IAEA.

We are also responding to the challenge of improving U.S. technical capabilities to monitor nuclear testing in regions of specific national security interest. Effective worldwide monitoring is important to access proliferation activities and to monitor the Comprehensive Test Ban Treaty (CTBT) should it enter into force. Monitoring must take place against a background of tens of thousands of benign events each year and requires the gathering and analysis of regional seismic signals. Livermore is part of a multilaboratory effort to provide the U.S. government with the technical capabilities, data, and algorithms needed to meet national CTBT monitoring goals. Lawrence Livermore, Los Alamos, and Sandia are working together to construct the "knowledge base" that contains the data and event-location and identification corrections for regions of concern. At Livermore, our efforts are focused on seismic R&D for the Middle East, North Africa, and Russia.

This past year, we validated our seismic event location technique using aftershock sequences in the Caucasus, the Gulf of Aqaba, and Morocco, among others. Our tests show that, using our wave propagation corrections, we can locate seismic events from sparse regional networks to within an area of 1,000 square kilometers (the on-site inspection requirement of the CTBT). For seismic event identification, we have developed (in conjunction with Los Alamos) a technique that dramatically improves the separation between the explosion and earthquake populations. Our results suggest that in certain regions, we can achieve false alarm rates and missed violation rates of less than 5%.

International Nuclear Material Safeguards. The security of Soviet-legacy nuclear materials and weapons is critical to U.S. security. Livermore is helping various Russian sites improve the protection of their fissile materials through the DOE Material Protection, Control, and Accounting (MPC&A) program. We have the lead at Chelyabinsk-70 (one of the former Soviet nuclear weapons design laboratories). We are also working with the Northern and Pacific Fleets of the Russian Navy and with the Murmansk Shipping Company's Icebreaker Fleet to improve the protection of fresh, highly enriched reactor fuel for their nuclear-powered vessels. In September 1999, MPC&A upgrades were completed and formally commissioned at one of the Northern Fleet dockside sites and on two refueling support ships (one for the Navy, the other for the Icebreaker Fleet). Work at other Russian Navy sites is proceeding at a rapid rate.

Also for the MPC&A program, Livermore has the lead in developing, with the Russians, a database that will enable Minatom and the Government of Russia to track nuclear material within their nuclear complex. Within three years, we expect that this database system will be routinely collecting nuclear material accounting information from about 70 Russian nuclear sites.

As part of DOE's Second Line of Defense program, we are working with the Russian customs service to detect and intercept the illicit transport of nuclear materials into and out of Russia. Particularly vulnerable border crossings are being outfitted with radiation detection equipment. A port on the Caspian Sea and Moscow's Sheremetyevo International Airport complex were equipped in late 1998, and work is under way to equip seven additional sites in Russia, including several possible transit points to Iran or North Korea. We are also developing a radiation-detection-equipment training manual that will guide the work of more than 30,000 front-line Russian customs officials.

Plutonium Immobilization. Plutonium from dismantled U.S. weapons is slated for disposition either via immobilization and disposal in a geologic repository or by burning as mixed oxide (MOX) reactor fuel. Livermore has been tasked by DOE to develop pit disassembly and plutonium conversion techniques that reduce worker radiation exposure and waste streams, produce a plutonium oxide product acceptable to the immobilization or MOX fuel fabrication plants, and are suitable for a production plant environment. We have developed a chipless method for bisecting weapon pits and a dry hydride/oxidation (HYDOX) method for converting plutonium metal into plutonium oxide. The HYDOX process can be applied to all U.S. excess pit types, and the plutonium oxide product meets the feed material requirements for both immobilization and MOX fabrication without additional processing. We are in the process of automating the HYDOX process to further reduce worker radiation exposure.

Livermore is the technical lead for DOE's Plutonium Immobilization Program. Titanate-based ceramic has been selected as the plutonium-immobilizing waste form. Prototype hardware for ceramic fabrication has been assembled and is undergoing cold testing prior to testing with plutonium. The viability of the can-in-canister concept was recently demonstrated in terms of the ability to fill a canister containing cans of ceramic with glass in tests using surrogate materials. Also this past year, we completed the design-only conceptual design review for a ceramic production plant, which should lead to the start of detailed design in FY 2001 and plant operation in FY 2008.

The Laboratory also leads the DOE effort to engage Russia in plutonium immobilization activities. This is a difficult task because the Russians consider plutonium a valuable national resource and have been extremely reluctant to even consider the immobilization option. As a result of patient and persistent Livermore negotiations, based on solid technical arguments, at the November 1999 U.S.–Russian Excess Weapons Plutonium Disposition Bilateral Agreement meetings, Minatom offered to immobilize a portion (1 million tons) of its weapons-grade plutonium. Technical efforts have focused on the needs of the Russian plutonium production industrial sites of Mayak, Krasnoyarsk-26, and Tomsk. Engineering and scientific studies by Russian design organizations, scientific institutes, and the industry sites are under way. The goal is to establish a full-scale plutonium immobilization facility at a Russian industrial site by 2005. Livermore activities focus on supporting the industrial sites' plutonium immobilization requirements and include nonproliferation studies of plutonium in the immobilized forms.

Control of Weapons-Related Expertise. To reduce the proliferation of WMD expertise, it is in the best interests of U.S. national security to help former Soviet weapons scientists develop nonweapons applications for their weapons-related expertise, capabilities, and facilities. Livermore is actively supporting various U.S. government programs designed to create self-sustaining jobs that will provide employment for these WMD experts long after the U.S. government programs have ended. These programs include the State Department's Science and Technology Centers in Moscow and Kiev, which target individual weapons scientists, and the DOE's Initiatives for Proliferation Prevention (IPP), which targets the nuclear design institutes. To date, Livermore IPP projects (completed, under way, and proposed) total 93, employing approximately 1,100 NIS scientists; a key metric is the 30:1 ratio of NIS to LLNL scientists supported by the IPP.

Livermore has taken a central role in implementing the DOE's Nuclear Cities Initiative, the goal of which is regional market and job creation for the closed cities. For example, we are leading a medical technology development project with the Avangard Electromechanical Plant (the equivalent of Pantex) at Sarov. In March 2000, Avangard and Livermore signed the first contracts that pave the way for a manufacturing center at Avangard. The facility will eventually employ several hundred former weapons builders in the daily production of parts for dialysis machines and ultimately the fabrication of complete dialysis systems. These contracts are a major milestone in U.S. government efforts to engage a Russian serial production facility.

Laboratory Initiatives

• Environmental Security (NN).

2.2.2 Proliferation Detection and Defense Systems

Situation and Issues

To reverse weapons proliferation, we must first detect and identify weapons-related activities. Weapons development, testing, and production all have unique indicators that, if detected and characterized, 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; import records; material and personnel movement—to assemble a reliable overall picture. By analyzing the production capabilities of proliferators' weapons of mass destruction (WMD), we can identify likely chemical signatures of proliferation activity, which we can then use as the basis for developing various sensing and detection technologies. In addition, working with the military services, we are developing tools to help protect forces in the field.

Program Thrusts

Remote Monitoring. We are developing several long-range standoff sensors capable of measuring trace amounts of airborne effluents that are indicative of the processes occurring within a suspect facility. This past year, we conducted high-altitude flight tests of our hyperspectral infrared imaging spectrometer (HIRIS). In three flight campaigns, the system successfully demonstrated the collection of hyperspectral data under the extreme environmental conditions present in the open bomb bay of NASA's WB-57B aircraft at 60,000 feet, including data collection against blind tests.

We have also developed continuously tunable mid-wave infrared (MWIR) lidar instruments for the multilaboratory Chemical Analysis by Laser Interrogation of Proliferation Effluents (CALIOPE) program. We flight tested a state-of-the-art, solid-state tunable laser transmitter and receiver on the U.S. Air Force's Argus KC-135 aircraft, successfully demonstrating the instrument's ability to perform stand-off chemical sensing measurements of controlled releases from the Remote Sensing Test Range at the Nevada Test Site.

The Metis Program, a follow-on to CALIOPE, began in October 1999. The goal of Metis is to develop a hybrid active/passive sensor for remote chemical detection. We are conducting a technical evaluation to determine the optimal sensor suite for the system. Current analysis indicates that the combination of a MWIR active sensor with a passive long-wave infrared (LWIR) sensor will yield the optimal sensor package. This sensor suite is being pursued experimentally with our existing CALIOPE and HIRIS systems.

Ballistic Missile Lethality. We are exploring the use of the echelle grating spectrometer (EGS) for acquiring optical signatures to determine the type of incoming warhead (nuclear, chemical, or biological) following the intercept of a hostile missile. Our goal is to develop real-time characterization of impact and debris to provide battle commanders with a rapid identification of enemy warheads that have chemical or biological agents and with source terms to track those agents. We are studying the optical signatures that might be accessible to remote sensing instruments. In early field tests of this concept, the EGS performed flawlessly and returned useful booster plume and thruster signature information.

We also analyze the capability of various interceptor systems to defend against and negate the effects of ballistic-missile-delivered WMD. Through a combination of calculation and experiment, we assess the damage and probability of kill resulting from given impacts of a kinetic-energy interceptor onto an incoming ballistic missile.

Technology to Support Military Operations. We provide U.S. policy makers and military planners with tools and information needed to evaluate the implications of various actions. For example, Livermore's Counterproliferation Analysis and Planning System (CAPS) is a powerful tool for end-to-end process analysis of a proliferator's WMD production capabilities and for assessment of interdiction options and corresponding consequences. CAPS is as easy to use as a Web browser, with its powerful and complex science (spectral analysis, toxic release modeling, etc.) invisible to the user. CAPS is widely accepted by the military's mission planners, as evidenced by the Secretary of Defense's announcement in this year's Defense Planning Guidance that CAPS is the preferred counterproliferation planning tool to be used by the nation's armed services. In March 1999, CAPS supported the Navy's Fleet Battle Experiment–Echo, providing real-time plume dispersal models associated with simulated chemical and biological attacks by terrorists.

More than 20 years of Laboratory experience in conflict simulation have culminated in the Joint Conflict and Tactical Simulation (JCATS). The entity-level conflict simulation code allows training, planning, and tactics analysis from the campaign level (hundreds of square kilometers) down to individuals fighting inside a multistory building. JCATS is currently used by more than 50 organizations, including U.S. military commands and services, the State Department, the Secret Service, and DOE's site-security function. For urban conflict simulations, JCATS has become the Marine Corps' tool of choice, having provided real-time virtual interplay during the Urban Warrior exercise, held March 1999 in the San Francisco Bay Area. In April 2000, JCATS supported the Navy's Fleet Battle Experiment–Golf, held in Italy, where it provided a virtual battlefield context for the live exercise.

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. Terrorists are exhibiting an increasing desire to cause indiscriminate mass casualties (witness the 1998 bombings of the U.S. embassies in Africa), and thus terrorist use of weapons of mass destruction is a growing threat. 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 and first-responder organizations, 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

Incident Response. Our Nuclear Credibility Assessment program provides technical, operational, and behavioral evaluations of WMD extortion threats. It also assesses cases of illicit trafficking of alleged nuclear materials. 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. Upon request of the FBI, we also furnish emergency response personnel and equipment for such high-visibility events as the Olympic Games and provide forensic analyses beyond the capabilities of the Bureau's own laboratories.

Biological Detection. A limiting factor in the nation's ability to protect against a biological terrorist attack is the current state of biodetector technology. As part of DOE's Chemical and Biological Nonproliferation Program, we are developing two classes of biodetectors: immunofluorescence-based sensors (miniature flow cytometers) and DNA-recognition instruments (based on the polymerase chain reaction, or PCR). When used in combination, these two independent, complementary assays afford the highest level of accuracy that can be achieved today.

This past year, we delivered two 10-chamber (10-sample parallel analysis) advanced nucleic acid analyzers (ANAA), one each to the Naval Medical Research Institute and the U.S. Army Medical Research Institute of Infectious Diseases. We also built and field-tested the first handheld PCR instrument, the handheld ANAA, or HANAA. With four silicon thermal-cycling chambers based on an improved design, HANAA's performance equals or exceeds that of the ANAA.

Biodetectors depend on unique antibodies or DNA sequences to identify and characterize biological pathogens. We are developing a comprehensive array of such signatures to support a wide range of biological detection capabilities. We are working closely with the Center for Disease Prevention and Control (CDC) to validate the signatures. Once validated, these signatures and appropriate analysis protocols can be distributed by the CDC to the network of public health laboratories across the country. We are also working with the FBI, CDC, DoD, and U.S. intelligence agencies to develop detailed biological "fingerprints" and data to support forensic analysis of any act of biological terrorism.

Counterterrorism. Urban first responders and local emergency managers play a critical role in countering and mitigating acts of WMD terrorism in the U.S. Livermore and Los Alamos are jointly developing the Biological Aerosol Sentry and Information System (BASIS) to provide biodefense for special events such as governmental assemblies, dignitary visits, or major sporting events. The system is designed specifically for the "detect to treat" mission—detecting a bioterrorism incident within a few hours of attack, early enough to mount an effective medical response.

BASIS uses a network of distributed sampling units located in and around potential target sites. Each sampling unit continuously collects, stores, and time-registers aerosol samples. The samples are retrieved and brought to a field laboratory for analysis. If a bioagent is detected, authorities are notified and provided with information as to agent type, time, and location of "hot" samples, estimated aerosol concentrations, hazard zones, and medical case-load estimates. To ensure that BASIS supports real-world operational needs, it is being developed in close cooperation with the public health agencies (federal, state, and local) responsible for emergency response and medical operations in the event of a bioterrorist attack. BASIS will be ready for deployment in early 2002.

Forensic Science and Analysis. Our Forensic Science Center develops new technologies for detecting and characterizing the source of weapons materials. We also develop microanalytical forensic techniques, new field instruments, and sample collection techniques for use by federal and local law enforcement agencies (see Section 2.3). The center has continuing partnerships with the U.S. military, FBI, other government agencies, and industry.

We are responding to increased requests that make use of our unique sample collection and analysis technologies for a variety of intelligence, emergency, and non-emergency field applications. For example, our solid-phase microextraction (SPME) collection kits and thin-layer chromatography (TLC) analysis kits were developed to perform rapid, efficient, and on-site detection of chemical signature species indicative of WMD, high explosives, propellants, and illegal drugs. The TLC technology has been adopted by the U.S. Army for remote characterization of propellant instabilities within munition storage depots. The field-portable gas chromatograph-mass spectrometer, delivered as a prototype to the FBI last year, has been transitioned to industry for commercialization.

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). We also review export license requests for the U.S. Department of Commerce and provide technical support and assistance to the U.S. intelligence community.

Program Thrusts

We conduct all-source analyses and research related to foreign development and deployment of nuclear weapons and other weapons of mass destruction. Although most of this program deals with foreign nuclear, biological, or chemical weapons, in recent years growth has occurred in activities to evaluate cyber threats. We also analyze patterns of cooperation among foreign WMD programs. Early-stage foreign technology development and acquisition programs are of particular interest as cooperation among proliferant countries has grown to include a full spectrum of weapons technologies.

We evaluate nuclear proliferation risks in world "hot spots," focusing on threshold states with difficult or hostile relations with the U.S. and those located in politically unstable regions. Nuclear programs in Iran, Iraq, North Korea, India, and Pakistan are of major concern. We also analyze the status of nuclear weapons and weapon materials in Russia and China. Both countries pose concerns related to nuclear proliferation; each may be the source of nuclear materials or technology, whose transfer could accelerate indigenous WMD programs. Russia's economic and political instabilities put severe stress on existing and future controls for safeguarding nuclear material and weapons inventories. China is of concern because of its uneven history related to arms control and nonproliferation and its often-strained relations with the U.S.

The Laboratory's experience and capabilities in nuclear weapons development, testing, and stewardship as well as in biological and chemical science provide the critical foundation for our assessments of WMD proliferation. The technical details of weapons information provide our analysts with the necessary information to evaluate scale and time sensitivity of proliferation threats in an integrated manner. The ability to do integrated assessments is essential because nuclear, chemical, and biological weapons programs are interrelated in some countries of concern, while other countries are pursuing chemical and/or biological weapons in lieu of more costly and more complex nuclear weapons.

Livermore assessments are based on and evaluated against the immutable laws of weapons science and provide reality checks of policy makers' understanding of foreign WMD programs. Our assessments of foreign weapons programs provide important input to policy makers and diplomats as they develop strategies for U.S. responses to events affecting national and international security.

Laboratory Initiative

• Sensitive Compartmented Information Facility (IN).

2.2.5 Center for Global Security Research

Situation and Issues

Technical challenges comprise only a portion of the nonproliferation and counterterrorism issue. The Center for Global Security Research (CGSR) brings together diverse expert communities to learn how science and technology can enhance national and international security by better understanding the policy–technology interface through exploration of new and sensitive issues, multidisciplinary studies, and international outreach.

Program Thrusts

The center focuses on four areas related to the intersection of technology and policy: reduction of threats associated with WMD, security implications of emerging technologies, anticipation of threats to national and international security, and the future role of military forces.

The center collaborates with organizations engaged in similar work, including the University of California, other security research centers in academia, U.S. government agencies, and private institutions worldwide. Activities of the last year include: a study conducted with the International Institute of Strategic Studies on the Y2K issue as an example of a specific threat to critical infrastructures; a series of workshops (one chaired by the Honorable Donald H. Rumsfeld, former Secretary of Defense and chair of the Rumsfeld Commission on Missile Proliferation) on missile proliferation and U.S. policies for dealing with this threat; and a futures conference entitled "Beyond Moore's Law: Opportunities and Threats from Future, Ubiquitous, High-Performance Computing." The center also supports CGSR fellows to study such complex issues at the nexus of technology and policy.

2.3 Meeting Other National Security Needs

Livermore works with the Department of Defense (DoD) and other government agencies to leverage the Laboratory's capabilities and provide long-term research and development support to meet future national security needs.

2.3.1 Department of Defense

Situation and Issues

The focus of future U.S. defense efforts has been the subject of a number of studies completed by the Joint Chiefs of Staff and the military services in addition to the Quadrennial Defense Review and the Alternate Force Structure Assessment. The vision emerging from these studies is of a U.S. "military of the future" that exploits technological superiority to win quickly, decisively, and with minimum casualties on all sides.

Livermore has experience and expertise in many areas of science and technology directly relevant to this military of the future, including missile defense, solid-state lasers, armor/anti-armor materials and munitions, conflict simulation, micro- and nanofabrication, remote sensing, and sensors and sensor networks. In addition, many of the Laboratory's proliferation detection tools and technologies are also applicable to battlefield situations. Livermore also has a long-standing history of collaboration with the DoD. For example, for more than a decade, we have been engaged in a DOE–DoD advanced conventional munitions technologies program for which we have developed new energetic materials and computer tools for design and analysis of munitions. As a result of this partnership, for example, the Livermore-developed high explosive, LX-14, is now used in the TOW and Hellfire missiles; and our CHEETAH code is widely used by the DoD to predict the performance of propellants and explosives and to evaluate formulations of new energetic materials.

Program Thrusts

The DOE laboratories are working to establish ways to further increase the effectiveness of the support provided to the DoD. For example, in response to FY 1998 Congressional authorization language, we helped prepare a pilot proposal for a hardened and deeply buried target-defeat program that would facilitate effective teaming between the DOE laboratories, DoD, and defense industry to meet important military needs. By applying Livermore's special expertise, we will contribute to meeting identified DoD needs in four 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 (e.g., the use of Livermore's Atmospheric Release Advisory Capability, ARAC, as discussed in Section 3.1.3). Livermore is using its demonstrated strengths and capabilities to provide these specialized technologies.

Precision Weapon Systems. Livermore contributes 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 pursues 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. For example, Livermore researchers are investigating for DoD sponsors a variety of concepts for more advanced theater missile defense and for national defense against ICBMs (see also Section 2.2.2).

In support of the Army's Space and Missile Defense Command, the Laboratory is working with industrial partners to develop a 100-kW average-power, solid-state laser to be deployed on a mobile battlefield platform. High-power laser systems are leading candidates for an enhanced air-defense capability. In 1999, we developed 1.5- and 10-kW prototypes and tested their effectiveness in damaging selected materials. We plan to deliver the 10-kW prototype to the High-Energy Strategic Test Facility (HELSTF) at White Sands Missile Range in 2001.

We are also collaborating with Los Alamos, Naval Surface Warfare Center, and U.S. Army Soldier and Biological Chemical Command to develop the Joint Biological Remote Early Warning System (JBREWS). Sponsored by the DoD's Joint Project Office for Bio-Defense, JBREWS is a portable and flexibly deployable network of sensors and communication links used to rapidly alert troops in the field of an attack with biological agents. In April 2000, JBREWS began its final demonstration at West Desert Test Site (Dugway Proving Grounds).

Efficient Operations. Livermore's conflict simulation capabilities are being applied to logistics issues for efficiently supplying equipment, which can make a decisive difference early in a military operation and dramatically reduce overall costs. For example, our Joint Conflict and Tactical Simulation (JCATS) allows training, planning, and analysis from the campaign level to fights between individuals inside a multistory building and is being used by more than 50 organizations (see Section 2.2.2).

2.3.2 Critical Infrastructure Protection

Situation and Issues

Presidential Decision Directive 63, issued in May 1998, addresses the need to better protect the nation against attacks on its critical infrastructures. Livermore is contributing through developing technologies for critical infrastructure protection and through sharing insights into the overall problem. Success in this arena depends on the formation of effective partnerships between law enforcement, private industry, and the technical community, including the DOE laboratories.

Program Thrusts

Cyber Security. Cyber security is a critical component of infrastructure protection, for the nation, DOE, and the Laboratory. In spring 1999, the Information Operations Warfare and Assurance (IOWA) Center was created at Livermore by combining several existing capabilities at Livermore: the Computer Incident Advisory Capability (CIAC), the Computer Security Technology Center (in the Engineering Directorate), and information operations capabilities that were the result of a Laboratory Directed Research and Development Strategic Initiative (see Section 3.3.2 on LDRD activities).

The IOWA Center provides a modeling and simulation environment consisting of an integrated suite of network visualization tools, analysis techniques, and assessment methods. Activities are directed at understanding how vulnerable information systems are to attack, determining what actions can be taken to protect systems, and assessing what the consequences would be if systems were attacked. One focus of the IOWA effort is a pilot project to map traffic on Livermore's Open LabNet as a way to better understand network behavior. This mapping project is helping us to determine our vulnerabilities and just which parts of our infrastructure are visible outside the Laboratory so that we can develop or deploy the necessary countermeasures to prevent attacks.

More generally, the suite of software tools being developed by the IOWA Center can be used to assess a wide variety of systems—computing, communications, command and control, energy and power generation and distribution, transportation, chemical production, manufacturing, and economic and financial. Through this project, we are developing the computer and information science foundation, the data representation models, the software components, and the automated analysis methods necessary to make information operations a viable and effective component of the nation's overall defense strategy.

The CIAC, which is now a part of the IOWA Center, was established by DOE at Livermore in 1989 to help maintain the integrity of Department computer systems. CIAC provides on-call technical assistance to DOE and other government sites faced with computer security incidents. CIAC also develops cyber defense and network intrusion detection tools and provides public information about network security threats via its Web site (http://ciac.llnl.gov/). Through close ties with commercial vendors, law-enforcement agencies, other government agencies, CIAC tracks the latest technology trends, product introductions, and system and network security threats and vulnerabilities. CIAC then disseminates information and advice to "client" organizations. In the event of an incident, CIAC assesses the nature of the attack and the extent of damage, produces or coordinates solutions (patches), provides advice on damage control and recovery, and assists law enforcement.

2.3.3 Support to Law Enforcement

Situation and Issues

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

Program Thrusts

Law enforcement can benefit from Livermore technologies that were developed initially for on-site inspection of arms control treaties, detection of WMD proliferation activities, and response to WMD incidents. An example is our 54-pound, portable gas chromatograph–mass spectrometer (GC–MS), a system for quickly analyzing samples at the scene of a crime or accident. Potential law-enforcement uses for this instrument (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 this 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. The instrument was delivered to the FBI in May 1999 (see Section 2.2.3).

Other technologies with potential application to law enforcement include thin-layer chromatography (TLC) and solid-phase microextraction (SPME). Our portable TLC system can simultaneously analyze 100 samples for high explosives and other chemicals. A digital-camera image-capture system interprets the TLC results and provides first responders with a simple readout of the compounds detected. For SPME, we have combined optical fiber technology with ultratrace analysis to create a "chemical dipstick." This technology can be used to collect minute samples indicative of the presence of illegal drugs or other chemicals of law-enforcement interest. SPME samples can be secured (preserving chain of custody) for later analysis or inserted directly into the portable GC–MS for immediate analysis.

SECTION 3

Institutional Plan FY 2001–2005

Laboratory Science and Technology Enduring National Needs

THE Department of Energy has enduring missions that are vital to the national interest. In addition to providing for national security, the Department's other priorities include enhancing the nation's energy security, developing and making available clean energy technologies, cleaning up former nuclear weapons sites, developing effective and timely approaches for nuclear-waste disposal, and applying DOE's research capabilities to advance fundamental scientific knowledge and contribute to U.S. technological innovation.

Lawrence Livermore supports these DOE mission priorities to meet enduring national needs through major research activities in selected areas. We pursue 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 our 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.

Major Research Areas

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. Livermore has programs and plans in three major research areas.

Energy and Environmental Programs. Our energy and environmental programs contribute to providing the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reducing environmental risks. Our efforts focus on critical thrust areas in which the Laboratory can make a difference: nuclear materials management; global energy, carbon, and climate issues; and environmental risk reduction.

Work in these areas draws on and helps to strengthen the special capabilities that the Laboratory needs for its national security mission. The projects benefit from Livermore's multidisciplinary approach to problem solving. We have an ability to achieve a comprehensive understanding of issues through end-to-end analysis, and we have a research approach that includes basic science, computational modeling, laboratory and field experiments, and prototype development.

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. The cross-fertilization of ideas that occurs at a broad-based national laboratory is important to these programs, as is the availability of the latest technologies in physical sciences and engineering.

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. Many of these activities are funded by DOE's Office of Science or are supported by Laboratory Directed Research and Development to extend Livermore's capabilities in anticipation of new mission requirements.

Alignment with DOE's Strategic Plan

Livermore's strengths are well matched to the DOE's needs (and selected special needs of other customers), particularly in areas with high payoffs that entail significant scientific and technical risk. In addition to our national security efforts, we contribute to the strategic goals of other major DOE business lines described in the September 2000 *DOE Strategic Plan*:

Energy Resources. Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.

Environmental Quality. Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.

Science. Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

Partnerships and Collaborations

Much of our work to meet enduring national needs is executed in partnership with industry, academic institutions, and other laboratories. Partnering activities span a wide range—from very large-scale

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 3 Laboratory Science and Technology—Enduring National Needs 3.1 Energy and Environmental Systems 3.2 Bioscience and Biotechnology 3.3 Fundamental Science and Applied Technology 3.4 Partnerships and Collaborations	• Livermore has expanded initiatives in nuclear materials stewardship, environmental clean-up technologies, and global climate modeling. • The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology. • The Laboratory's science and technology contributions are recognized by prizes, awards, and front-page publicity. • Livermore has become the leading DOE laboratory in industrial partnering, with extreme ultraviolet lithography being one of the largest DOE successes to date. • The Laboratory is increasingly recognized as integral to the state of California through increased involvement with the University of California … and as a partner of the state's broad education initiatives.

strategic alliances to licensing of individual technologies, academic research, educational outreach, and support for the small business community. Often partnerships and collaborations are the most cost-effective way for us to accomplish programmatic 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.

3.1 Energy and Environmental Programs

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.

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 in two ways:

• By focusing our energy and environmental programs in research areas that have important national security aspects, such as nuclear materials management. These activities are natural extensions of—and are often tightly connected with—our national security mission. (See Table 3-1.)

• By extending the scale, technical reach, demonstration orientation, and expertise that support Livermore's national security mission. The programs add to the intellectual vitality of the Laboratory and help support the technology base needed to provide for national security. For example, expertise in geophysics and atmospheric science are needed to monitor nuclear test activities worldwide and to model atmospheric releases of hazardous substances.

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 focus on three critical areas in which the Laboratory can make a significant, positive difference.

Table 3-1. General goals of Livermore thrust areas with dimensions in energy, environment, and national security.

Goals in: \ Thrust Areas:	Nuclear Materials Management	Energy, Carbon, and Climate	Environmental Risk Reduction
Energy Use Wisely manage:	Nuclear materials	Improved generation and use	Benefits and risks of energy options
Environment Clean up/reduce:	Nuclear legacy	Fossil-fuel emissions and greenhouse gases	Toxic materials and carcinogens
National Security Reduce:	Nuclear dangers	Dependence on imported oil	Environmental disaster risks

Nuclear Materials Management. Nuclear materials management is a fundamental, compelling, and enduring mission of DOE because the Department will be responsible for a vast array of nuclear materials for generations to come. Livermore is a key contributor to nuclear materials management through our stockpile stewardship and nonproliferation activities. We also support DOE's programs aimed at secure storage, immobilization, and sequestration of radioactive materials. In addition, the Laboratory pursues research and development for fission energy systems, with emphasis on geological repositories—Yucca Mountain and other international sites—and complementary technologies such as safeguards, transportation and packaging, and proliferation-resistant technologies for reactors and their nuclear fuel.

Energy, Carbon, and Climate. 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, and human activities (such as reliance on burning fossil fuels to meet energy needs) continue to increase the atmospheric concentration of CO_2 and other greenhouse gases. Significant, large-scale innovations are needed to provide clean, accessible, non-resource-depleting energy production. In areas where the Laboratory has special expertise, we will selectively pursue advanced energy technologies focused on end-use efficiency, the use of lower-carbon fuels, and CO_2 sequestration. Livermore focuses on important aspects of carbon management and contributes to scientific and technical assessments of carbon-management strategies. We will also develop a better understanding of the environmental consequences of energy generation and use, which will drive technology selection and implementation.

Environmental Risk Reduction. DOE's environmental responsibility, dealing with the legacy of Cold War nuclear weapons production, is a major task. At Livermore, we are developing a better understanding of the underlying science related to the fate, transport, and effect of radionuclides in the environment. We are also developing technologies to characterize and remediate contaminated groundwater faster and more cost efficiently than previously possible. Opportunities exist to accelerate cleanup at DOE contractor sites and to apply the technologies more broadly. In addition, the Laboratory has 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 to bring these technologies to commercial use, and advance the scientific basis for risk assessment and regulatory reform. Moreover, Livermore is capable of providing assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security.

3.1.1 Nuclear Materials Management

Situation and Issues

Need for an Integrated Strategy. Regardless of the future of nuclear weapons or nuclear energy, DOE will be responsible, both internationally and domestically, for nuclear materials for generations to come. Proper management of nuclear materials is an important strategic objective of DOE that is tied the Department's missions in national security, energy resources, and environmental quality. National security concerns give rise to the need to develop proliferation-resistant nuclear energy technologies for international use as well as technologies to better manage and control nuclear wastes. Current environmental and safety issues—waste cleanup, interim storage, and long-term repositories—dominate domestic concerns. There is also a need to explore next-generation nuclear technologies to provide energy security.

Because nuclear materials issues cut across mission areas, DOE would benefit from an integrated approach to ensure secure, safe, and environmentally sound use of nuclear materials throughout their life cycle. The potential direct benefits include 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. In addition, an integrated approach to nuclear materials management will better enable decision makers to focus on the most critical factors, leading to an integrated set of capabilities that the U.S. can use to proactively deal with important nuclear issues in the twenty-first century. Success will also help preserve the option for nuclear power in the U.S. and maintain U.S. leadership in the international nuclear materials arena.

Livermore's Capabilities and Contributions. Livermore is outstanding among U.S. national laboratories in both the scope and focus of nuclear activities. In addition to weapons research and development, we work on aspects of nuclear materials management associated with civilian use. Our activities span national security aspects (materials disposition, waste management, and proliferation-resistant technologies) and energy and environmental concerns (technologies for storage, improved safety and security, transportation, repositories, and clean up). 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

Yucca Mountain Project. Livermore is working 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 and leading in the development and evaluation of waste package materials and designs. We are working to support major project milestones toward site recommendation and license application, and in these efforts, we have placed significant emphasis on achieving high quality assurance. Livermore staff members are the leads for three of the nine Process Model Reports—waste package, engineered barrier system, and near-field environment—that will be the basis for the Secretary's site recommendation to the President. Livermore is also making substantial contributions in the waste-form program area.

Licensing of the Yucca Mountain facility will likely require more scientific tools in modeling and performance confirmation. We are developing an integrated repository systems model that includes water infiltration, thermal effects, and reactive flow of radionuclides. We are also initiating development of an even more complete materials system modeling capability that will include the engineered system of man-made materials as well as the perturbed natural geologic system. This work, which takes advantage of dramatic increases in computational capability at Livermore, will help to optimize and evaluate the technical performance of the repository.

Nuclear Safety and Security Systems. As part of its nonproliferation mission, Livermore contributes to DOE's Material Protection, Control, and Accounting (MPC&A) program to improve the security of weapons-usable nuclear materials in the former Soviet Union (see Section 2.2.1). For example, we participate in DOE's Second Line of Defense Program, through which we are helping the Russian Customs Service install detection equipment to intercept illicit traffic in nuclear materials at Russian border crossings and checkpoints.

We have also developed technologies to improve the physical security and protect sites in the U.S. that contain nuclear material or other top-priority assets. A sophisticated, computerized security system called Argus was designed, engineered, and installed at Livermore. Argus is now being installed at other DOE facilities (Idaho National Engineering and

Environmental Laboratory, Pantex, and Los Alamos) and DoD facilities. A key feature of Argus is planned renewal so that the installed systems are continuously upgraded and therefore never become obsolete. To sustain such renewal, a major element of our program involves improvements to current components and new products to enhance Argus.

In the area of nuclear safety, Livermore's Fission Energy and Systems Safety Program works with the Nuclear Regulatory Commission (NRC) to develop software and computer-system design guidance that it uses to evaluate the design of safety-critical systems for U.S. plant retrofits. Overseas, where new nuclear power plants are being built, regulators and designers are using this state-of-the-art guidance to help ensure plant safety. In addition, Laboratory experts, using sophisticated risk assessment models, work with DOE and the NRC to perform analyses of the transportation of spent nuclear fuel. We also review safety analysis reports for packaging with regard to federal regulations and develop evaluation criteria for the NRC and DOE.

Materials Management. In 1993, the U.S. signed an agreement with Russia to purchase highly enriched uranium (HEU) extracted from Russian nuclear weapons. Under this agreement, the HEU is blended down in Russia to low-enriched uranium (LEU) and then shipped to the U.S., where the LEU is used in making fuel for nuclear power reactors. Livermore is providing comprehensive technical support for transparency measures that serve as a technical basis for assuring each government that the other is abiding by the agreement. With funding from the DOE Office of Defense Nuclear Nonproliferation, our HEU transparency project activities include on-site monitoring using specially designed instrumentation, documentation review, and data analysis.

We also support the DOE Office of Nuclear Energy in their depleted uranium hexafluoride (DUF_6) disposition efforts. We have completed studies that identify alternative uses and disposition paths for DUF_6, and we have prepared detailed studies of the cost of major facilities to convert DUF_6 into alternative forms for use and/or disposal.

Proliferation-Resistant Technologies. New approaches are needed to maintain the future viability and security of nuclear energy. Proliferation-resistant technologies for the widespread use of nuclear energy are receiving significant attention in the U.S. and internationally. We helped in the planning and will be part of a U.S.–Russia program that focuses on proliferation-resistant technologies for nuclear reactor systems. In addition, Livermore is contributing to the planning of a U.S.–Russia collaboration on spent-fuel repository development. We are also continuing development of the Secure Transportable Autonomous Reactor (STAR) concept for a small, proliferation-resistant reactor for developing countries.

Laboratory Initiatives

- Nuclear Materials (Multiple Program Offices)

3.1.2 Energy, Carbon, and Climate

Situation and Issues

The Challenge of Carbon Management. Regardless of steps taken in the near-term, about 80% of global energy use in 2020 is expected to be from fossil fuels. As a result, the concentration of atmospheric carbon dioxide may double in our lifetime. This prospect has the potential of driving major changes in the way energy is generated, stored, and used. An integrated approach to understanding the underlying scientific issues and technical possibilities is needed to help guide public policy and R&D investment decisions. Through our extensive multidisciplinary capabilities and partnerships with many collaborators, Livermore can help to understand the significant issues and develop innovative solutions.

Energy Alternatives. The need for clean, reasonably priced, reliable energy calls for new exploration, production, and utilization methods for hydrocarbon fuels. The Laboratory's strengths in earth and environmental sciences, materials science, engineering, and computational modeling will be applied to develop more efficient coal combustion, energy storage and conversion, renewable resources, and emission separation and sequestration technologies. We are also pursuing fusion energy science as a possible longer-term source of energy (see Section 3.3.1).

Transportation Systems. Transportation systems are a leading contributor to greenhouse gases and increasingly will be 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. Livermore's expertise and programs in advanced materials, systems modeling, alternative fuels (e.g., hydrogen and natural gas), and energy conversion and storage (e.g., fuel cells for stationary and eventually mobile applications) provide the basis for expanded work in this area.

We have completed a number of important computational studies dealing with the combustion of diesel fuels. Our combustion models were used to clarify and validate many of the experimental results obtained at Sandia National Laboratories' Research Center. We also contributed to the study of combustion of oxygenated hydrocarbon fuels in diesel engines and their effectiveness in reducing soot production. In addition, Livermore is contributing to the Integrated Vehicle Electronics Simulations Testbed (InVEST) program and other partnerships to develop next-generation vehicles through both simulation efforts and technology development.

Grand Challenge of Climate Modeling. 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 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 institutional investments that augment DOE's Accelerated Scientific Computing Initiative (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 participant in this planning process. ACPI pilot projects are starting on a limited funding basis in FY 2000. We expect to play a key role 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 has major responsibilities for the Program for Climate Model Diagnosis and Intercomparison (PCMDI), which was established at the Laboratory in 1989. The PCMDI's principal mission is to develop improved methods and tools for the diagnosis, validation, and intercomparison of global climate models and to engage in research on a wide variety of outstanding problems in climate modeling and analysis. Livermore is also responsible for the development of atmospheric physical and chemical models directed at specific critical issues such as ozone, CO_2, and aerosols.

Program Thrusts

Fossil and Geothermal Energy. Through 2050, most of our energy requirements will be supplied by fossil energy. We need to develop technologies to enhance the recovery of oil and gas (currently two-thirds of the oil is left in the ground). The Laboratory participates in DOE's Natural Gas and Oil Technology Partnership, an alliance that combines the resources and experience of the nation's petroleum industry with the capabilities and technologies of the national laboratories. This integration expedites development of advanced technologies for better diagnostics, more efficient drilling, and improved natural gas and oil recovery.

We will also explore other technologies that can lead to significant, large-scale innovations in energy production or that can help manage carbon emissions. These efforts build on the Laboratory's strengths in materials, instrumentation, and computational modeling. For example, the potential uses of methane hydrates are so numerous that we must thoroughly understand them. We are completing preliminary laboratory studies on CO_2 and CH_4 clathrates and are looking to expand these efforts to examine the engineering consequences of recovery options. In addition, with several industrial partners, we are proposing to build a 10-MWe zero-emission power-plant research station on site. It will supply power and allow the testing of new air separation and turbine technologies while sequestering CO_2 in nearby oil wells.

Energy Conversion and Storage and Transportation Technologies. We will expand the existing technology base for integrated alternative-fuels production, fueling, and automotive drive systems.

We will develop technologies for very efficient steam electrolysis, auxiliary energy storage capabilities (flywheel and supercapacitors), and the practical, safe storage of hydrogen fuel onboard a vehicle. For example, we have made significant progress on our high-temperature steam electrolyzer project, which is funded through the Hydrogen Program within DOE/EE/Office of Power Technologies. We have completed a feasibility study of decreasing electricity consumption by using both natural gas and electricity to produce hydrogen. Laboratory researchers also improved manufacturing technologies for electrolysis cell fabrication and developed new electrode materials.

Atmospheric Modeling—from Global to Local Scales. 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. 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. We are working to develop more accurate climate and weather forecast modeling at the regional scale. It is through predictions and measurements on a regional scale that we can observe and better understand the potential impact of human activities on the global climate. Improving climate and weather models requires a much better understanding of the relationships among the atmosphere, ocean, and land systems. Use of these models will facilitate responsible environmental management, reliable climate predictions, and anticipation of and effective response to natural and terrorist environmental emergencies.

As home to PCMDI, Livermore will also continue to provide national and international leadership in the development of a shared climate-modeling infrastructure that includes collected methods and tools for the diagnosis, validation, and intercomparison of global climate models. For an overview of the intercomparison projects currently under way, see http://www-pcmdi.llnl.gov/PCMDItoc.html.

Tera-Scale Model Development. 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. As an adjunct to our parallelization efforts, we are developing better methods for managing and visualizing the vast amount of data generated.

In one area of focus, we will improve modeling of aerosols in the atmosphere (both anthropogenic and natural), aerosol interactions with clouds, and the resultant climate effects. An outgrowth of this work is our participation in NASA's Global Climate Modeling Initiative, using the Laboratory's unique capabilities to analyze the atmospheric impacts of supersonic aircraft. All these activities, as well as steps toward achieving our important future goal of coupled climate and carbon cycle models, depend on effective collaborations with many partners and continuing support from DOE, NASA, and other sponsors.

Ocean Carbon Sequestration. Carbon-dioxide emissions from fossil-fuel use may adversely impact global climate. The oceans naturally absorb about one-third of the carbon dioxide from human-caused emissions, but climate change could be mitigated if a way could be found to accelerate the ocean's absorption of carbon in an environmentally acceptable way. To develop the scientific base needed to make technical and policy decisions, Lawrence Berkeley and Lawrence Livermore national laboratories are codirecting the DOE Center for Research on Ocean Carbon Sequestration. Participating institutions also include Massachusetts Institute of Technology, Rutgers, Scripps, Moss Landing, and PICHTR. The center's goal is to better understand the efficacy and environmental impacts of various ocean sequestration options, including direct injection of carbon dioxide into the deep ocean and fertilization of marine biota. Livermore's role in the center includes leading efforts to numerically simulate ocean carbon sequestration.

Laboratory Initiative

- Accelerated Climate Prediction (KP)

3.1.3 Environmental Risk Reduction

Situation and Issues

Remediation Technologies and Risk Assessment. Livermore's recent innovations in remediation technology and tools to assess the health risk from low-level exposure to toxic materials can be used to significantly reduce the national mortgage of environmental cleanup. In a demonstration of an innovative remediation technology in Visalia, California, more than 150,000 gallons—about 1.2 million pounds—of toxic chemicals have been removed in just 30 months of operation. 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. The technology is now being used for cleanup at Portsmouth, Ohio, and Cape Canaveral, Florida.

The Visalia cleanup activities demonstrate end-to-end capabilities at Livermore: understanding the underlying science, developing and applying state-of-the-art simulations, assessing environmental risks and potential clean technologies, and developing and deploying field-scale systems. Moreover, 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 exposure levels in the environment. This science and technology can greatly improve the effectiveness of remediation strategies in reducing health hazards.

Emergency Response Capabilities. Livermore has assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security. 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.

The National Atmospheric Release Advisory Center is located at Livermore, and we are responsible for the Atmospheric Release Advisory Capability (ARAC). ARAC is a formally recognized national emergency response service for real-time assessment of atmospheric releases involving nuclear, chemical, biological, and natural hazardous materials. ARAC's primary function is to support the DOE and DoD in the event of radiological releases. Under the Federal Radiological Emergency Response Plan, ARAC also assists other federal agencies, and with approval of DOE, it supports local, state, and international agency responses to natural and anthropogenic releases. Since 1979, ARAC has supported more than 900 exercises and over 160 alerts, accidents, and disasters involving radiological and chemical releases. For example, in September 1999, we responded to the criticality accident in Tokaimura, Japan, and provided consequence assessments at local, regional, and global scales.

Program Thrusts

Faster Remediation Technologies. 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 than previous methods. Our strategy will be to target DOE, DoD, and civilian contamination problems as opportunities for technology development and application. 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.

Basic Research on Environmental Cleanup. To reduce the cost of environmental cleanup and make it faster over the long term, DOE is sponsoring projects in basic science related to environmental management through its Environmental Management Science Program. In grants from the program, our work ranges from molecular geochemistry to a large-scale look at contaminant movement at the Livermore site. Through several projects, we are studying the movement of contaminants in the vadose zone, a region between the surface and the water table that protects the water from surface contaminants. Livermore researchers are also developing improved computer algorithms and measurement capabilities for subsurface imaging that can be applied to improve environmental management. In addition, we are examining emission-free, high-temperature means for treating and disposing of nuclear wastes that contain actinide elements (including nuclear materials).

Improvements to ARAC. ARAC functions as an integrated research, development, and operational program at the Laboratory. We continue to modernize ARAC's capabilities to better meet the needs of current and potential new customers and facilitate services to them. For example, we are developing Web-based network communications to the ARAC central system. During an actual event, this Internet Remote Access capability will allow simultaneous access by multiple emergency response agencies to ARAC's incident characterization and assessment products.

In addition, national security concerns have expanded beyond the nuclear threat to include chemical and biological releases. Potential ARAC applications range from accident response to countering terrorism threats. We are coordinating ARAC research efforts with DOE's Chemical and Biological Nonproliferation Program and developing the capability to predict the fate of chemical or biological releases both outdoors and indoors (for example, in buildings and subways). Our focus is on the prediction of airflow and dispersion in difficult-to-model urban environments. In particular, we are developing an ARAC interface to Livermore's very-high-performance computers to provide real-time local meteorological and dispersion forecasts, detailed vulnerability and mitigation assessments, and accurate predictions of the dispersion and fate of chemical or biological agents released into a complex urban environment. Our goal is the capability for planning, training, and, ultimately, emergency-response assessments of urban chemical and biological releases.

Expanded Environmental Security Capabilities. We are working to establish a long-term relationship with DOE and DoD to provide on-demand operational capability and analysis of continuing national and international issues pertaining to the environment, particularly scenarios that would adversely affect regional stability. This 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. We will provide dependable service for emergency, military, and political management of emerging regional and global environmental situations and their relationship to regional security. Working with the DOE and other government agencies, we will promote confidence-building cooperative steps to mitigate environmental stresses on regional security in areas of importance to U.S. strategic interests.

Risk Assessment Consortium. 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 Initiatives

- Environmental Security (NN)
- National Wildfire Prediction Initiative (Multiple Program Offices)

3.2 Bioscience and Biotechnology

Working with academia, government, and industry, we leverage the Laboratory's capabilities in the physical and engineering sciences to conduct bioscience 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 twenty-first 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.

Grand Challenges in the Biosciences. Four challenges have been identified that align with DOE's and the Laboratory's missions and draw upon our existing personnel talents and core competencies.

- **Genomics—**Learning how living systems function and using that information to enhance our nation's security, preserve the environment, and ensure a better quality of life.
- **Biological Nonproliferation—**Providing new, more sensitive tools for the rapid identification, isolation, and characterization of potential pathogens.
- **Disease Susceptibility: Identification and Prevention**—Determining what causes disease, why some people are more susceptible than others, and what we can learn to prevent it.
- **Health Care and Medical Biotechnology—**Developing tools for

cost-effective, high-quality health care 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 Biological and Environmental Research (OBER). More recently, OBER 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 OBER 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 Livermore bioscientists to maintain credibility with their peers. Recent discussions with the University of California (UC) at Davis may result in the creation of the National Cancer Institute "comprehensive cancer center" across the two institutions. Finally, 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.

3.2.1 Genomics

Situation and Issues

Genomics Research. 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 center 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 2003 a substantial fraction of the 3 billion total bases of the human genome. In addition, the genome of several microbes of interest to the DOE will be sequenced, with the initial effort at Livermore.

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 2.3 million arrayed clones, 1.9 million sequences, and over 50,000 mapped cDNAs.

Program Thrust

Joint Genome Institute. We are 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 implemented a strategy for "production mode" DNA sequencing. Central to this production mode is the operation of a DNA sequencing facility in Walnut Creek, California. Continued 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. With the completion of the draft sequencing of three human chromosomes, the JGI is expanding their efforts into comparative and functional genomics.

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

Laboratory Initiative

- Joint Genome Institute (KP)

3.2.2 Biological Nonproliferation

Situation and Issues

With the foundation laid by the Human Genome Project, we are able to quickly respond to the national call for basic and applied research in chemical and biological nonproliferation. Since 1991, we have been researching certain elements of molecular biology with the goal of developing, analyzing, and synthesizing molecular information regarding potential biowarfare agents. Researchers at Livermore have actively focused on the foundational biology needed for this important program.

Program Thrusts

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, and 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.

Technology Development. Livermore researchers have recently joined with colleagues at Los Alamos, Brookhaven, and Sandia national laboratories to develop a five-year research plan that will expand the three laboratories' research in the areas of DNA-based "fingerprint" signatures, structure-based attribution, and molecular epidemiology. Several underlying technology development efforts will support these three general areas. These include (1) rapid identification, isolation, and characterization of unique DNA, (2) characterization of microbial backgrounds, (3) characterization of signatures of genetic engineering and virulence factors, and (4) baseline genomic sequencing of selected pathogens. Each program element is designed to the specific support program objectives of providing warning of any biological warfare attack, characterizing the nature and extent of such an attack, and providing forensic evidence to aid in identifying and prosecuting perpetrators. These same tools will have strong spin-off benefits for the development of vaccines, drugs, and other medical treatments, as well as for environmental bioremediation.

Laboratory Initiative

- Microbial Genomics (KP)

3.2.3 Disease Susceptibility Identification and Prevention

Situation and Issues

Disease and Genes. 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 are drawing upon 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

Gene Identification. 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 on the basis of 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 through 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 computational 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)
• Computational Biochemistry (KP)

3.2.4 Health Care and Medical Biotechnology

Situation and Issues

Cost-Effective Technologies. Affordable, accessible health care 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 health-care technologies. Projects exploring improved or new health-care 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 multi-disciplinary and often involve external collaborators. We work closely with health-care deliverers and industry to develop and demonstrate novel health-care technologies, such as high-tech tools to aid stroke treatment. Increasingly, industry is expressing interest in partnering with 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

Device and Method Developments. 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 diagnosed each year 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 pursue fundamental science and provide capabilities that enable the U.S. to maintain its world leadership in science. The Department must also advance the science and technology that is required to support DOE's primary missions in national security, energy resources, and environmental quality. It is widely recognized that the nation's advances of fundamental knowledge and technological 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, the work is sponsored by DOE's Office of Science or other customers who take advantage of the unique research capabilities and facilities present at the Laboratory. In other cases, the work is supported by Laboratory Directed Research and Development funding and extends Livermore's capabilities in anticipation of new mission requirements.

The Laboratory's scientific advances—and technologies developed in pursuit of fundamental science—have important spinoff and spinback applications, such as:
• Livermore-developed adaptive optics technologies that are being installed as part of a laser guide star system on the 10-meter-diameter Keck II Telescope on Mauna Kea, Hawaii, to correct for atmospheric turbulence and significantly improve the quality of images. Adaptive optics is also a critical, enabling technology for the National Ignition Facility.
• The discovery of fluid metallic hydrogen—a new state of matter—which contributes to planetary science and generates new knowledge about the properties of hydrogen that is needed for Laboratory programs.
• Livermore's ultra-short-pulse lasers, which enable physics experiments never before possible and also have precision cutting applications for advanced manufacturing in stockpile management and broader applications. In addition, technologies developed to build these lasers are enabling revolutionary advances in flat-panel displays.
• Materials synthesis and materials engineering at the atomic level, which have led to the development of an

aerogel dielectric and new materials that will help improve the performance of integrated circuits. These developments have also led to multilayer optics that enable mapping the x-ray spectrum of the sun in incredible detail and provide extraordinary images of its surface.

• Recent progress, with the U.S. Geological Survey, in understanding methane clathrate EOS stability at various temperatures and pressures. This study may lead to future exploitation of methane clathrate as an energy source and of a clathrate from carbon dioxide. Like methane, carbon dioxide also forms clathrates in the deep sea. If carbon dioxide proves to be relatively stable as a clathrate in the deep sea or in deep-sea sediments, it could be a promising option for deep-sea carbon sequestration.

Science and Technology at the Laboratory

The tight coupling of science and technology at Livermore is reflected in our mission focus and the use of Laboratory Directed Research and Development to prepare for future mission requirements. And, as discussed in Section 3.4, below, we depend on effective partnerships with other laboratories, academic institutions, and industry to be successful in our endeavors.

Application of Mission-Directed Science and Technology. As an institution with stable mission responsibilities and program continuity, the Laboratory has developed a strong science and technology infrastructure. We focus our unique capabilities and research facilities on problem solving to meet the demands of DOE's national security business line. This science and technology base also enables us to meet other important national needs and respond to new challenges. These national needs align with DOE's business lines in energy resources and environmental quality (see Section 3.1 Energy and Environmental Programs) and science (see Section 3.2 Bioscience and Biotechnology and Section 3.3.1 Application of Mission-Directed Science and Technology).

Laboratory Directed Research and Development. We sustain and strengthen the Laboratory's science and technology base through effectively managed internal investments in 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.

Alignment with the DOE Strategic Plan

The strong interrelationship of science and technology at the Laboratory means that technology development is integral to our programmatic activities and serves as a principal tool for achieving mission success. This approach is reflected in the *DOE Strategic Plan*, which does not specifically identify "technology" as one DOE's four main business lines; instead, technology is appropriately distributed throughout the Department's missions. "Science" is a DOE mission, but it also is a tool for achieving mission success in other business lines. Accordingly, some of the Laboratory's fundamental science activities are supported by DOE's Office of Science. Other activities—particularly in national security areas—are embedded in programmatic work, and yet other activities are supported by Laboratory Directed Research and Development.

DOE's science mission is to "advance the basic research and instruments of science that are the foundations for the Department's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy." Activities at the Laboratory address the four objectives of the science business line:

Objective 1: Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation's quest for clean, affordable, and abundant energy. See Sections 3.1.1 Nuclear Materials Management and 3.1.2 Energy, Carbon, and Climate.

Objective 2: Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences. See Sections 3.1.2 Energy, Carbon, and Climate and 3.1.3 Environmental Risk Reduction.

Objective 3: Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature spanning scales from the infinitesimally small to the infinitely large. See Sections 2.1 Stockpile Stewardship, 3.2 Bioscience and Biotechnology, and Section 3.3.1 Mission-Directed Science and Technology.

Objective 4: Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE's science mission and support our nation's leadership in the physical, biological, environmental and computational sciences. This objective is addressed by almost all of our activities. Some of our activities for DOE's Office of Science are especially emphasized in Section 3.3.1 Mission-Directed Science and Technology.

3.3.1 Application of Mission-Directed Science and Technology

Situation and Issues

Livermore has special capabilities for meeting some of the nation's broader challenges in fundamental science and applied technology. These capabilities and facilities 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.

Program Thrusts

Our special capabilities are being applied to meet the nation's challenges in fundamental science and applied technology, including:

Astrophysics and Space Science. In partnership with many other scientific institutions, we make important advancements in astrophysics and space science by applying the Laboratory's special expertise in high-energy-density physics, nuclear fusion, and scientific computing. Livermore researchers participate in a wide range of observational, experimental, and theoretical activities—from the creation of supernova-like instabilities using powerful lasers to the sighting of the most distant radio galaxy and the discovery of a quasi-stellar object with one of the most luminous starbursts ever.

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 has led to other advances, such as development of a revolutionary camera system and its use to discover massively compact halo objects (MACHOs). Our work on adaptive optics has enabled the Keck II telescope to take images of Neptune and Titan of unprecedented quality, and Livermore's multilayer optics are yielding extremely detailed x-ray images of the surface of the sun.

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 was part of the three-laboratory effort that designed and built the B-Factory at the Stanford Linear Accelerator Center (SLAC). Working with SLAC and Berkeley, we contributed across a broad range of disciplines, ranging from particle physics to precision machining. As part of an international collaboration that includes the same tri-laboratory team, Livermore is now pursuing research and development for the Next Linear Collider. Important national security applications of our accelerator expertise include the further development of an advanced hydrodynamic testing capability.

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. Our expertise in thin-film processing and microfabrication technology is leading to many applications in lithography, semiconductor processing and process modeling, electronics packaging, communication and computing systems, and biotechnology. Advances have made possible microtools for health care, portable biological agent detectors, and diagnostics for the National Ignition Facility.

Advanced Materials and Materials Science. 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 includes work for the Office of Basic Energy Sciences (OBES) in areas such as interfaces and grain boundaries and their role in the behavior of metals and the superplastic deformation of metals and intermetallics. We also conduct fundamental research on in situ characterization of welding processes. Furthermore, OBES supports work to better understand heterointerfaces using photoelectron spectroscopy and holography, and it supports efforts in which double polarization spin measurements are used to characterize magnetic structure at the atomic level.

Through fundamental science research activities, we have also developed an improved understanding of material deformations and radiation effects on materials. In addition, we are working to develop a basic, yet detailed, understanding of the mechanical properties of metals through the development of a multiscale model of metals that is validated by experiments. The goal is to understand dislocation dynamics that affect the strength of materials at the micrometer scale. Multiscale modeling uses the Laboratory's supercomputers and involves simulations at three length scales (atomistic, micro, and meso) with information passing from the shorter- to longer-length scales.

High-Performance Scientific Computing. With the arrival of successively more powerful supercomputers at Livermore through the Accelerated Strategic Computing Initiative, we have unparalleled capabilities in scientific computing that offer the potential of revolutionizing scientific discovery as the machines become increasingly capable. A key is their effective utilization—improvements are needed in scientific software, data management, and visualization tools. Through various collaborative efforts and for sponsors that include DOE's Office of Science, we conduct basic research in computational science in areas that support programmatic objectives. Areas of focus include high-performance computing, computational physics, numerical mathematics, algorithm development, scientific data management, and visualization.

Fusion Energy Science. Livermore conducts inertial fusion experiments and pursues advanced magnetic confinement fusion schemes using the Omega laser at the University of Rochester and, in the future, the National Ignition Facility. We seek to identify and make progress along the most promising path to full-scale deployment of fusion power. To establish the scientific basis of energy production from nuclear fusion is a long-standing goal at Livermore.

Our goal in inertial confinement fusion (ICF) is to demonstrate for the first time in a laboratory fusion ignition and energy gain in the National Ignition Facility (NIF), which is now under construction at Livermore. 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. In particular, for DOE's Office of Science, we are working closely with Lawrence Berkeley National Laboratory to assess and advance the technology for heavy-ion accelerators as ICF drivers for commercial fusion power generation. We are also working with the University of Rochester Laboratory for Laser Energetics on advanced technologies for laser drivers.

In the area of magnetic fusion research, the tokamak concept has been used to advance the science of high-temperature plasmas. Livermore collaborates in experimental studies centered on advanced performance and power handling for the tokamak using the DIII-D tokamak at General Atomics. In the DIII-D program, we have the lead role in the critical area of power handling (and divertor physics in general), and we contribute importantly to the study of advanced operating scenarios.

We are also focusing attention 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 has built and is conducting tests using a 1-meter spheromak. The Sustained Spheromak Physics Experiment (SSPX) facility was dedicated in January 1999. The SSPX aims to demonstrate modest heat containment in the presence of dynamo action, achieve a significant plasma temperature in the few-hundred-electronvolt range, and examine issues of magneto-hydrodynamic stability. Beyond these experiments, a new facility will be required.

In addition, we provide leadership in the use of large-scale simulation of plasmas as a very cost-effective way of carrying out fusion research. We have developed the CORSICA code, which couples various computational models (such as power input, heat loss, and magnetohydrodynamic equilibrium and stability) that proceed on very different time scales. We are building on the capabilities of CORSICA to take advantage of greatly expanded computational power becoming available through ASCI. As our resources permit, we will move toward ASCI-compatible integrable code structures for magnetic fusion.

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.

Our expertise in lasers also has exciting scientific applications. An important breakthrough in physics of laser–matter interactions was reported by Livermore researchers in 1999—nuclear fusion driven by an ultrafast “tabletop” laser. The approach entails generating fusion reactions in small clusters of heavy hydrogen gas that are superheated suddenly by short, extraordinarily intense laser pulses. Tabletop fusion may offer a promising avenue for future production of compact, economical sources of neutrons. These sources could be useful for neutron radiography and in studying neutron damage to materials.

Manufacturing Technologies. The Laboratory has considerable capabilities in advanced manufacturing technologies, ranging from laser machining to precision manufacturing and manufacturing control. One major project is work with the U.S. Army on the Totally Integrated Munitions Enterprise (TIME) program to improve munitions manufacturing. We are applying agile manufacturing technologies, developed earlier under DOE’s Technologies Enabling Agile Manufacturing (TEAM) program, that include our Open Modular Architectural Controller software. This “intelligent” controller works with “smart” sensors and actuators to enable production lines to shift rapidly (within days) from one product to another. The benefits include greater flexibility, increased efficiency, high product quality, faster turnaround time, and less waste than previous controller systems.

Major Initiatives

• Materials Studies and Surface Characterization (ER)
• Accelerator Technologies (Multiple Offices)
• Computational Materials Science and Chemistry (Multiple Offices)

3.3.2 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. R&D that expand the horizons of science and technology are 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 2000, LDRD at Livermore was funded at the allowed annual level of 4%, with a budget of $35 million. The 4% level directed by Congress in FY 2000 constituted a significant reduction of the LDRD program, which had been 6% in recent years. The reduction was a significant loss.

A report prepared by a panel of the Laboratory Operations Board noted that “…the size of the LDRD program at 6% is marginally acceptable…” although “…6% is below the industry average for the research and development ratio in high-technology industries. The 4% level fails any reasonable comparison test.” The LDRD Program not only advances science and technology in support of our national security mission, but it is also an important vehicle for bringing new talent to Livermore through collaborative research and postdoctoral opportunities.

A Mission Focus. 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 are evaluated against Congressional requirements regarding support of national security programs. Our assessments for the past four years and an estimate of the FY 1999 portfolio show national security sponsors of work at Livermore receive an LDRD return than far exceeds the 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 Thrusts

Livermore’s LDRD Program has three major components: Strategic Initiatives, Exploratory Research, and the Laboratory-Wide Competition. About 26% of the funding is invested in Strategic Initiatives, about 67% in Exploratory Research, and about 7% in the Laboratory-Wide Competition.

Strategic Initiatives. 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. 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.

Laboratory-Wide. 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. The program continues to provide many far-reaching scientific and technical accomplishments, which are described in detail in the Laboratory's LDRD annual reports (UCRL-LR-113717-99 for FY 1999).

National Security Support. The Laboratory's national security mission—stockpile stewardship of U.S. nuclear weapons and countering the 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). Representative highlights from the FY 1999 LDRD program include:

- Proton Radiography Research. A Livermore team, in collaboration with Los Alamos scientists and engineers, made significant progress in demonstrating the feasibility of using high-energy protons for dynamic radiography of thick objects that are of interest to the Stockpile Stewardship Program. They have also successfully identified a cost-efficient path leading to the timely development of a proton radiography experimental test-bed that would provide three-dimensional views of objects undergoing hydrodynamic testing.
- Modeling and Simulation for Critical Infrastructure Protection. Using LDRD funding, we are developing a modeling and simulation environment for critical infrastructure protection. This Information Operations, Warfare, and Assurance (IOWA) initiative is leading to an integrated suite of simulation engines, computer visualization tools, analysis techniques, and assessment methods for understanding and evaluating information operations issues. IOWA is to be used to determine how information systems may be vulnerable to intrusion, what actions can be taken to successfully defend against these intrusions, and what are the consequences if intrusions occur.

Awards and Recognition. Laboratory scientists and the research funded by LDRD continue to garner national recognition. For example, in an invited talk at the centennial meeting of the American Physical Society in March 1999, Laboratory researchers reported that they produced antimatter and stimulated nuclear fission by focusing the world's most intense and powerful laser on a thin target. The recent discovery of element 114 by researchers from Livermore and the Joint Institute for Nuclear Research in Dubna, Russia, was also supported by LDRD.

In addition, many patents and R&D 100 Awards from *R&D Magazine* have been earned for innovative technologies developed through LDRD-funded research. In FY 1999, 45 of the Laboratory's 84 patents were LDRD-based, and in FY 1999, three of the six R&D 100 Awards given to Livermore scientists by *R&D Magazine* were based on their LDRD research:

- A high-powered diode-pumped solid-state green laser—for industrial material processing, such as laser machining.
- Gamma watermarking—a revolutionary method of identifying and authenticating material objects.
- PEREGRINE™ radiation treatment—a three-dimensional Monte Carlo dose calculation system for accurate radiation therapy dosage (licensed to NOMOS Corp.).

Student Support. The participation of 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. LDRD projects provide valuable support for student and postdoctoral research—60 students and 95 postdoctoral fellows in FY 1999; however, there were only 25 students and 71 postdoctoral fellows in FY 2000 because of the reduction in DOE funding. A continuing restriction on this important pipeline would damage our ability to bring talented new employees into the Laboratory.

Long-Term Benefits. Because of the nature of research, many years might pass before the full impact of an R&D project is realized. Several recently funded LDRD activities achieved major successes that have been broadly reported in the scientific communities as major scientific accomplishments:

- Research leading to extreme ultraviolet (EUV) lithography. LDRD-funded research in the 1980s provided much of the basic capabilities to enable the Laboratory to be a major player in a $250-million cooperative research and development agreement (CRADA) with the leaders in semiconductor manufacturing.
- Biological weapon agent detection and identification. In a terrorist attack or on the battlefield, lives may depend on a quick determination of whether a biological agent has been used. LDRD-funded research led to the development of two highly portable and extremely sensitive technologies that are currently undergoing further development under DOE programmatic sponsorship.
- Environmental cleanup technologies. For many years, LDRD has funded research projects to identify better methods for cleaning up soil and groundwater contamination. The program contributed to the development of two technologies, dynamic underground stripping and hydrous pyrolysis/oxidation, which have been very successfully demonstrated in Visalia, California. These technologies are now being used for site cleanup at two major DOE facilities, the Portsmouth Gaseous Diffusion Plant in Ohio and the Savannah River site in South Carolina.

3.4 Partnerships and Collaborations

Many Livermore research and development activities are executed in partnership with industry, academic institutions, and other laboratories. Partnerships and collaborations are often the most cost-effective way to accomplish our programmatic 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.

Program Thrusts

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 continue to 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. We also work with others to share expertise and make available research capabilities.

Effective Academic Collaborations and Science Education Programs. As a part of the University of California and as 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 unique facilities 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 all educational levels.

3.4.1 Partnerships with Industry

Situation and Issues

Livermore is committed to promoting partnerships with U.S. businesses and industries. We anticipate that the Laboratory's partnerships and alliances with industry will continue to grow. We work with U.S. companies for various reasons and use a variety of partnering mechanisms. Most importantly, we form partnerships with industry—often through procurements—to acquire mission-critical capabilities. Other partnerships, such as our participation in a consortium to develop advanced technologies to manufacture computer chips, enhance critical capabilities at the Laboratory that are needed for our national security mission. Finally, the areas of environmental remediation and health care provide examples where we "spin off" for public benefit Laboratory-developed technologies through mechanisms such as cooperative research and development agreements (CRADAs) and licensing. See Table 3.2, Laboratory Interactions with Industry, FY 1994–2000. During FY 1999, Livermore had 90 active licensing agreements, reported

163 inventions, applied for 109 patents, and was issued 78 patents.

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 it negotiates the contracts that govern these relationships.

Ongoing Process Improvements. Livermore continually strives to balance the need for streamlined partnering processes against the need for adequate controls to ensure a well-managed program. We strive to achieve partnerships that will meet the needs of both the Laboratory and its partners while operating within the structures and policies of DOE and the University of California and complying with the laws governing technology transfer.

An Intellectual Property and Industrial Partnering Issues (IPIPI) Committee was formed in January 1997 to resolve important issues associated with the Laboratory's partnerships with industry. We have since revised the Laboratory's policies regarding distribution of income generated by licensed inventions and the acceptance of equity as partial compensation for licensing intellectual property. In addition, a Conflict of Interest Review Committee makes sure that related Laboratory policies are clearly articulated, widely understood, and followed. Following recommendations of the IPIPI Committee, an intellectual property management process has been formalized with important controls. Each month, formal invention disclosure prioritization reviews are held as a means of ensuring that disclosures selected for patenting are considered within a framework of the Laboratory's strategic objectives.

In addition, over the last few years we have focused on improving our agreement processes. In addition to DOE's modular CRADA, we use model agreements for consistency in language and structure in other technology transfer agreements. Detailed process checklists also ensure appropriate coordination and consistency. Within the IPAC office, licenses are peer reviewed by at least two business specialists and by the Managers for Partnership Development and Contract Compliance prior to the formal legal review. We are also vigilant about export control reviews. For example, if an export control issue surfaces during the review process, the industrial partner is sent a letter stating that the technology is export controlled and that it is the partner's sole responsibility to obtain the appropriate export licenses.

We have begun implementing the 18 process improvements recommended by a recent University of California Task Force. For example, to ensure the licensee's understanding of its responsibility for obtaining all necessary regulatory approvals, additional communication steps are being added to the licensing process. Greater emphasis is placed on this issue because, on account of our mission obligations, technical assistance cannot be guaranteed in our licenses. When requests are made for technical assistance, follow-up actions are carried out through a formal agreement. In addition, a process is being established to survey CRADA partners and licensees annually and incorporate appropriate improvements into the Laboratory's procedures, and an ombuds program is being established to provide an informal process for resolving disputes. Furthermore, a module on industrial partnering has recently been included in

Table 3-2. Laboratory interaction with industry, FY 1994–2000.

Type of interaction	FY 1997	FY 1998	FY 1999	FY 2000	Totals
Licenses of Laboratory patents and copyrights					
Number issued	65	36	35	41	177
Royalties ($M)	2.4	2.3	2.2	3.2	10.1
DOE (TTI) CRADAs					
Number active	55	15	6	1	–
DOE funding ($M)	19.5	5.0	2.5	0.1	27.1
Lab-funded CRADAs					
Number active	24	19	24	19	–
Lab/DOE funding ($M)	4.4	3.4	3.2	2.3	13.3
Industry-funded CRADAs					
Number active	34	28	33	30	–
Industry funds-in ($M)	17.8	29.2	34.5	21.2	102.7
Work-for-others projects with industry					
Number active	85	90	113	99	–
Industry funds-in ($M)	3.4	9.1	8.1	14.5	35.1
Lab SBIR Projects					
Number of awards made	3	5	2	0	10
Industry funds-in ($M)	0.2	0.2	0.5	0.0	0.9
Start-up companies (number)	4	3	1	3	11

the Laboratory's Supervisory Training Course. IPAC-developed courses on various aspects of industrial partnering and intellectual property can be given upon request.

Partnering Mechanisms and Activities

Partnerships through Procurement. 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.

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 here and transferred to a commercializing partner or developed by the company to meet our requirements in order to generate a production-scale source of equipment, instrumentation, or components for some of our larger experimental facilities.

Similarly, in the Accelerated Strategic Computing Initiative (ASCI), DOE Stockpile Stewardship computational requirements are driving computer advancements and refinements of prototype machines. The laboratories are acquiring increasingly powerful supercomputers from U.S. industry and, in turn, helping these companies ready their new products for the wider marketplace. Table 3-2 shows our interactions with industry for 1994 through 1999.

Partnerships through CRADAs and Work for Others. 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 evolved to the DOE's Technology Transfer Program (TTP). As the program winds down, Livermore's CRADAs are increasingly either Laboratory-funded (cooperative efforts on technologies we vitally need) or funds-in projects (industry backing for cooperative efforts). In addition, we engage in industrial work-for-others (WFO). These agreements provide non-DOE organizations with access to highly specialized or unique DOE facilities, services, or technical expertise.

One major funds-in CRADA is a project to develop technologies to produce smaller, more powerful computer chips. Researchers from the Livermore, Sandia, and Berkeley national laboratories have formed a Virtual National Laboratory that is working with an industrial consortium including Intel, AMD, Motorola, Micron, and Infineon as major partners. Our work focuses on the use of extreme ultraviolet lithography (EUVL) as a means for etching ultrathin patterns into silicon chips. EUVL technology relies on Livermore expertise in multilayer coating technology and ultraprecision optics metrology.

In 1999, the Laboratory announced the selection of NOMOS Corporation of Sewickley, Pennsylvania, to commercialize PEREGRINE™, an improved dose-calculation system for extremely precise planning and application of cancer radiation treatment. In addition to issuing a license, we are assisting NOMOS' commercialization efforts under a WFO agreement. In September 2000, NOMOS received clearance from the Food and Drug Administration to produce and market PEREGRINE™ systems to the medical community.

We currently have active CRADAs and WFOs in fields as diverse as medical devices, advanced manufacturing, and microtechnologies. Our small-business activities also include CRADAs, technical assistance, and participation in the Small Business Innovative Research Program (SBIR) and the Small Business Technology Transfer Program (STTP).

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, exceptionally effective environmental cleanup results were achieved using the Laboratory's dynamic underground stripping technology to clean up groundwater contamination at a Southern California Edison site previously used to treat power poles with preservatives such as creosote. Dynamic underground stripping and important auxiliary technologies were licensed to SteamTech Environmental Services to perform the cleanup operations. The process has removed or destroyed in place well over 1 million pounds of contaminants, an amount that would have required more than 1,000 years with traditional pump-and-treat methods. Because of this success, the technology has subsequently been licensed to Integrated Water Resources Inc., and the process is being applied to contaminated DOE sites at Portsmouth, Ohio, and Savannah River, Georgia. A number of other public and private sites are evaluating the technology as well.

Recent highlights from our licensing efforts include:

- PolyStor Corporation, founded in 1993 by former Livermore employees, has emerged as a leading U.S. manufacturer of high-performance lithium–ion batteries for the next generation of portable and wireless products.
- In 1997, the PowerStor company was spun off from PolyStor to concentrate on developing advanced capacitors, called supercapacitors or ultracapacitors, using Livermore's carbon aerogel technology for pulsed-power and electronic circuitry applications in multibillion-dollar battery and capacitor markets.
- In 1997, Cepheid obtained a license for specific applications of Lawrence Livermore patents covering work on microfabricated chemical reaction chambers. In July 2000, the company announced its initial public stock offering. The Department of Defense currently uses a product based on the Livermore technology to detect and identify potential biowarfare and bioterrorist agents.
- MiniMed, Inc., a leader in infusion systems for the delivery of insulin and continuous glucose monitoring, has been working with Livermore to adapt laser technology used for fusion research and to develop an advanced glucose sensor to continuously indicate the sugar level in diabetic patients. When used with an implanted pump, the two devices would essentially become an artificial pancreas. Livermore has collaborated with MiniMed since 1995 in three successful CRADAs, and we are now licensing a Livermore-developed technology to MiniMed.

Honors and Awards. From 1999 through 2000, we were recognized for several technology transfer activities:

- We won six R&D 100 Awards in 1999 and one in 2000. The awards are given annually by *R&D Magazine* for the top 100 technological achievements that promise to improve people's lives through breakthrough products and processes. Winning entries are selected on criteria that include proof of product.
- In both 1998 and 1999, we won two Federal Laboratory Consortium Awards for "outstanding work in the process of transferring a technology to the commercial marketplace."
- In March 2000, *Fortune Magazine* recognized retired Livermore employee Jim Bryan as one of the "heroes of U.S. manufacturing" for work in precision engineering done at the Laboratory in the 1980s. Hundreds of companies worldwide use versions of Bryan's adaptation of an old British invention to quickly test machine tool performance, and the instrument has become a national standard in precision engineering.

3.4.2 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 many other projects described throughout Sections 2 and 3.

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.

3.4.3 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 FY 2000.

The University Relations Program. The Laboratory's University Relations Program encourages and expands research collaborations between Livermore and universities and other research organizations. 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 that help solve complex problems of importance to the nation.

The University Relations Program also oversees the Laboratory's science and technology education efforts (see Section 3.4.4). We help train the nation's next generation of scientists and engineers through our outreach programs that span all educational levels. 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.

Livermore–University of California Research Institutes

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 Electron Beam Ion Trap (EBIT), the Positron Microprobe, and Livermore's high-pressure shockwave and diamond-anvil-cell facilities.

Table 3-3. (will be updated for final report) Laboratory–university collaborations FY 1997–1999.[a]

Type of collaboration	FY 1997	FY 1998	FY 1999
Laboratory and University of California			
Total number	461	499	419
UC faculty	164	202	175
UC research staff	65	87	79
UC students	232	210	165
Laboratory and other California universities			
Total number	75	78	85
Faculty	33	32	51
Research staff	12	10	12
Students	30	36	22
Laboratory and non-California universities			
Total number	385	415	537
Faculty	201	204	314
Research staff	57	63	118
Students	127	148	105

[a]University and college faculty, research staff, and students involved in collaborative work programs with the Laboratory at Livermore, at their home institutions, or both. Numbers for FY 2000 will be available after January 2001.

Other University Interactions

Department of Applied Science (DAS). A part of the College of Engineering at the University of California, Davis, DAS has facilities at both Davis and Livermore. It offers a limited number of temporary positions to selected UC Davis graduate students who then work in one of the Laboratory's major research facilities while conducting thesis research related to the programmatic research. In 1998, after a comprehensive review of the UC Davis DAS program, the Livermore student fellowship program was broadened beyond applied science and computer science to include all relevant UC Davis departments.

University of California Directed Research and Development (UCDRD). Other collaborative activities among the three UC-managed DOE national laboratories are supported by two funds established by the UC/DOE management contract. The UCDRD fund 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 Complementary and Beneficial Activities (CBA) Fund was established specifically to support collaborative research efforts through the Campus–Laboratory Collaborations (CLC) Program.

Lawrence Livermore Fellowships. Among the research opportunities offered by the Laboratory is the Lawrence Livermore Fellowship, a distinguished postdoctoral program established in 1998. The Fellows 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 of the Laboratory.

University of California, Merced

The University of California is developing plans to open a tenth campus in Merced, California, in 2004. The new campus, which will eventually serve 25,000 students, is expected to have a close affiliation with Lawrence Livermore. UC Merced planners meet with senior Livermore managers on a wide range of issues. We are helping to establish this new campus by: contributing to the definition of scientific and engineering programs at the campus, consulting on the physical plant (e.g., energy efficiency, waste management), helping plan the programs for UC Merced's Sierra Nevada Research Institute, and serving on search committees for senior staff. Once the new campus is in operation, UC Merced and the Laboratory expect to collaborate on research projects, student internship programs, and joint appointments that will provide opportunities for Livermore personnel to teach. Over time, we expect UC Merced to become an important source of future employees for the Laboratory.

In particular, a collaboration between environmental programs at Livermore and the Sierra Nevada Research Institute at UC Merced offers great potential for strengthening environmental expertise at the Laboratory as we provide regional technical assistance on a broad range of problems related to population growth and development: water and watershed, air quality, fire ecology, biodiversity, and resource management. Other potential focus areas include computer and information science (supercomputing and bioinformatics), engineering (bioengineering and other advanced technologies), and optical science/laser science and applications.

3.4.4 Science and Technology Education Programs

The Laboratory's Science and Technology Education Program (STEP) serves as the Laboratory's primary resource to students and teachers by

- Educating future scientists through research internships for students entering careers important to Livermore's national security mission.
- Increasing the interest in and quality of science education through science outreach and K–14 educator partnerships with nearby schools.

The common theme of our science education effort is the integration of education, research, and career options at all school levels—pre-college, undergraduate, and graduate school—through Livermore-sponsored projects. STEP's "school-to-career" education projects make an important long-term contribution to national security. The program further benefits the nation by helping the U.S. to compete successfully in the world marketplace and remain a major economic power.

STEP is organized around the three school levels to reflect the recommendation of the Task Force on Education of the Secretary of Energy Advisory Board (SEAB) in the December 1998 Final Task Force Letter Report (http://vm1.hqadmin.doe.gov:80/seab/educ.html). The long-standing goals of Livermore's science and technology education efforts also align with the dual goals set by the Task Force on Education. For further updates of STEP activities, see the Website at http://education.llnl.gov.

Student Research Internships

STEP facilitates partnerships and collaborations with the education community to help ensure a highly skilled, diverse workforce for the science and technology challenges of DOE's national security mission. Stockpile-stewardship internships are funded directly through DOE Defense Programs. Individual internship projects support the specific recruiting needs of Laboratory programs, such as our terascale simulation program, which supports DOE's Accelerated Strategic Computing Initiative (ASCI).

Internships engage college students within the disciplines defined by the report of the Chiles Commission (established by the Congress under the National Defense Authorization Acts of 1997 and 1998). The report recommends specific strategies for recruiting and retaining scientific, engineering, and technical personnel needed to maintain a safe and reliable nuclear weapons stockpile without nuclear testing. STEP's internship projects attract, place, and recruit students in the four recommended major critical-skill disciplines: computer science and math, physics, chemistry and materials science, and engineering. In addition to the four recommended disciplines, the internship program will add a fifth discipline, DOE/DoD partnerships, in FY 2001.

During FY 2000, STEP placed 78 college interns in our stockpile stewardship programs in six projects (Table 3-4) and 34 interns in various other national security research programs.

Science Outreach and K–14 Educator Partnerships

Through local and regional education partnerships, STEP leads the Laboratory's education efforts to stimulate greater interest in science and technology among teachers and school administrators and to encourage students to pursue scientific and technical careers after high school. The science outreach and educator projects are funded by the Laboratory's General and Administrative (G&A) Distributed Budget.

Pre-college science literacy activities play an important role in the creation of future scientists, engineers, and technicians by enlightening students about potential careers in science and technology, especially those of special interest to the Laboratory. STEP's K–14 partnerships with the education community align with new science standards of the State of California. The science outreach and educator projects during FY 2000 engaged over 9,000 students and 900 teachers, some in one-day workshops or events.

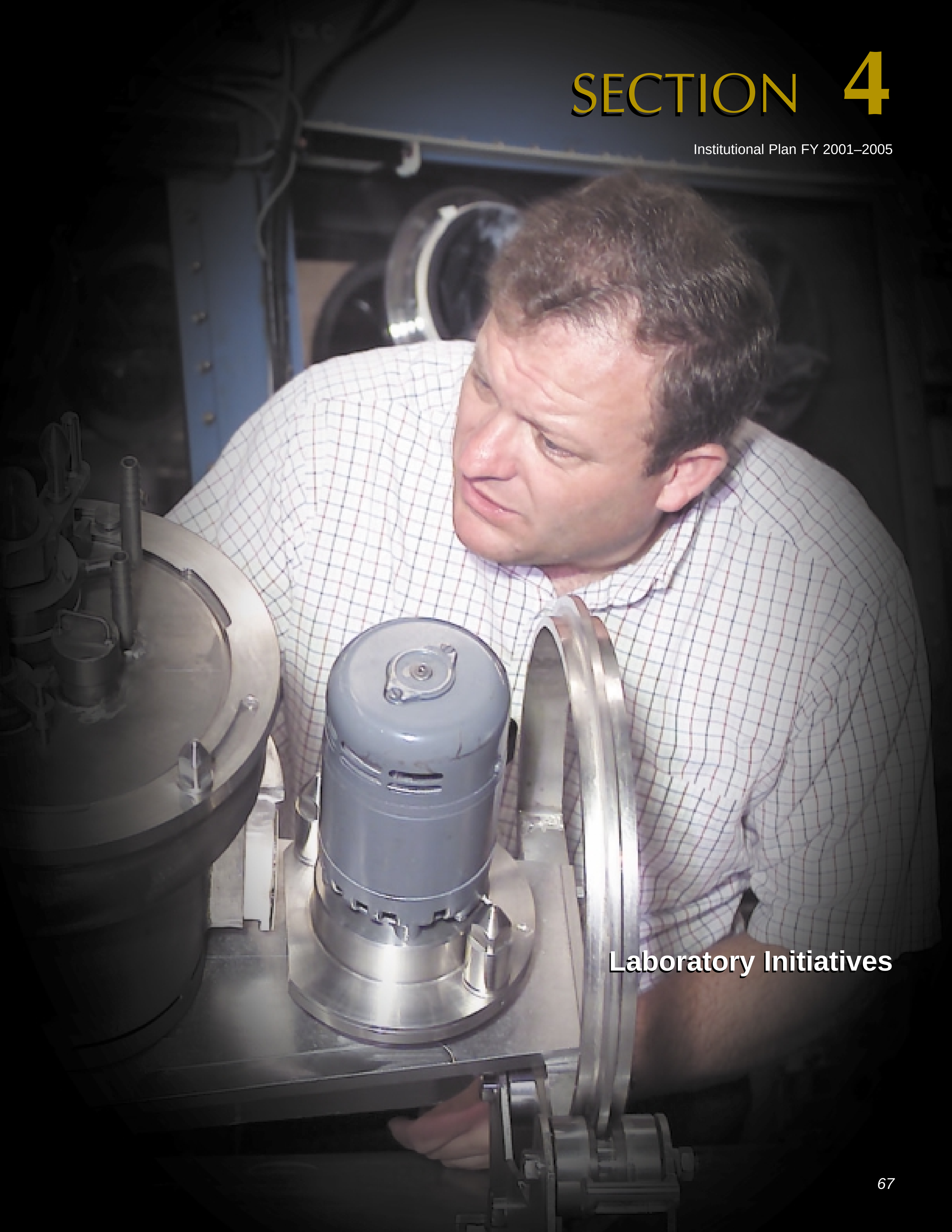
By providing a continuous school-to-career "roadmap" for pre-college, undergraduate, and graduate students interested in science and technology, STEP will continue to offer intriguing opportunities to further students' careers in science research through hands-on internships, projects, and partnerships.

In FY 2001, STEP will continue exploring—with the UC Davis and UC Merced campuses—a partnership to support the California Subject Matter Projects, a UC-administered network of discipline-specific professional development projects for K–12 teachers. The California Subject Matter Projects provide summer workshops and institutes and additional support during the academic year. Such a partnership would elevate science education in Central California by aggregating dedicated professionals, enriching educational and scientific resources, and providing access to research scientists and world-class facilities.

Table 3-4. College interns placed in Livermore national security projects during FY 2000.

National security project	Number of interns
Stockpile stewardship programs:	
Actinide Sciences Summer School	8
ASCI pipeline at:	
Northern Arizona University	7
Cal-State University Hayward	4
San Jose State University	2
University of the Pacific	1
Graduate Interns for Nuclear Technologies	6
Internships in Terascale Simulation Technology	23
Military Academic Research Associates:	
Military Academies	19
ROTC	4
System Administration Computer Support	4
Other national security research programs	34
Total interns placed	112

SECTION 4



Laboratory Initiatives

THE following initiatives are proposed as major additions to existing programs or as new directions within our missions. We have also included information about three major, ongoing Stockpile Stewardship initiatives—the National Ignition Facility, the Accelerated Strategic Computing Initiative, and the Terascale Simulation Facility.

For new initiatives, the programs and budget figures are provided for consideration by the Department of Energy. The detailed Program Resource Requirements tables (Section 6.1) do not reflect the growth in resource requirements needed to pursue the initiatives. Their inclusion in this Institutional 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 Office of Defense Programs

4.1.1 National Ignition Facility (DP)

The National Ignition Facility, currently under construction at Livermore, will be a 192-laser-beam facility capable of achieving fusion ignition and energy gain in the laboratory for the first time. NIF will support national security, energy, and scientific goals. A critical element of the Stockpile Stewardship Program, NIF is designed to maintain the safety and reliability of the country's remaining nuclear weapons without full-scale nuclear testing. It is the only facility in the program that can achieve fusion ignition and obtain temperatures and pressures approaching those in an exploding nuclear weapon. Experiments on NIF will also evaluate the scientific feasibility of inertial fusion energy, which has been a long-standing program goal within DOE. In addition, NIF will provide nuclear environments for studying weapons effects and will allow laboratory astrophysics studies under conditions similar to those found in stars.

The NIF builds upon the extensive experience gained at Livermore using a series of large lasers built over the past 30 years. The NIF design provides 1.8 megajoules of ultraviolet laser light in 192 beams directed into a 10-meter-diameter target chamber. NIF will deliver 60 times more energy than the Nova laser. Many of the key technical features of NIF were tested using the Beamlet Laser at Livermore, which operated between 1994 and 1998. Features included the multi-pass amplifiers; large-aperture optical switches; large frequency-conversion crystals; deformable mirrors for adaptive

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 4 Initiatives DOE Program Sponsors: 4.1 Assistant Secretary for Defense Programs 4.2 Office of Nonproliferation and National Security 4.3 Office of Intelligence 4.4 Office of Science 4.5 Assistant Secretary for Energy Efficiency 4.6 Multiple Program Offices	• The National Ignition Facility building complex is completed in 2001, and laser support equipment is being installed. • The 12-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stockpile stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing. • The Laboratory is providing technology and capabilities to protect the U.S. from nuclear, chemical, biological, and other emerging threats to national security. • The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology. • Livermore has expanded initiatives in nuclear materials stewardship, environmental clean-up technologies, and global climate modeling.

optics; power conditioning, capacitor, and flashlamp systems; and high-fluence, large-area optics. The NIF facility consists of a laser and target area building nearly 300,000 square feet in size with adjacent support facilities for cleaning and assembling the optical components of the laser, target diagnostics, and experimental support and a number of test facilities for integrated systems development, prototyping, and qualification.

A series of milestones have occurred on the NIF Project, beginning with Key Decision Zero in January 1993, which established mission need. The most recent high-level milestone of the project was Critical Decision Three (March 1997), the approval to begin construction.

Although significant technical accomplishments have been realized with respect to NIF, major project cost and schedule issues emerged in 1999. In September 1999, Secretary Richardson responded to these problems by issuing a six-point plan to "*bring NIF back on track*." As a result, extensive and in-depth reviews of the technology and project management have been conducted by the Secretary of Energy Advisory Board (SEAB) Task Force on the NIF Project, the Energy Systems Acquisition Advisory Board, the University of California, the General Accounting Office (GAO), the Laboratory Director's Office, and the NIF Programs Review Committee. The reviews of the NIF science and technology have determined that the project design and engineering are sound. However, significant management deficiencies were identified, and the planned method of assembling and integrating the laser was significantly underestimated.

To address the project management deficiencies, the lines of authority and communication were restructured at DOE, the University, and the Laboratory. Plans were revised to take advantage of relevant industrial experience and expertise during the assembly and integration of the laser. In August 2000, DOE approved the award of an Integration Management and Installation (IMI) contract to an industrial engineering firm having extensive experience in building high-technology facilities in the semiconductor and pharmaceutical industries. This IMI contractor is responsible for installing and commissioning all of the NIF beampath infrastructure in partnership with the Laboratory. Livermore remains responsible for the procurement, installation, and commissioning of most of the components comprising the NIF laser, such as optical assemblies, amplifiers, etc.

A weeklong independent Rebaseline Validation Review and a separate, parallel Independent Cost Review of the entire rebaselined NIF project were held in August 2000 and involved some 100 individuals from DOE, the DP labs, the DOE Office of Science labs, and private industry. The review teams' findings concluded:

- There are no show stoppers within the NIF Project.
- The NIF Project can be completed successfully within the cost and schedule defined.
- The NIF Project management team is capable of bringing in the project successfully.
- The NIF Project objectives can be met with current technology. Technical improvements to make optics more resistant to laser damage will improve future operating costs and availability.
- NIF is a frontier project. The contingency appears appropriate at this stage.

The NIF rebaselined cost and schedule were found to be acceptable and soundly based by the Level 0 Baseline Change Control Board, which is part of the Energy Systems Acquisition Advisory Board (ESAAB) chaired by the Deputy Secretary of Energy. The new NIF baseline schedule calls for first light to the target chamber in June 2004 and all 192 beams to be commissioned in September 2008. The ESAAB approval of the new NIF baseline allowed the Secretary to submit his certification of the NIF Project baseline along with his recommendations for FY 2001 and out-year funding plans to Congress by September 15, 2000, as required. The acceptance of the new NIF baseline cost and schedule and the

Table 4-1. Resources required for the National Ignition Facility ($M; BA in FY 2001 dollars after FY 2000).[a]

Fiscal year	Construction costs (TEC)	Total project cost
Prior years	651.3	790.4
2000	247.2	253.0
2001	209.1	215.1
2002	245.0	246.4
2003	187.2	188.1
2004	150.0	150.0
2005	130.0	130.0
2006	130.0	130.0
2007	130.0	130.0
2008	15.1	15.1
Total	**2094.9**	**2248.1**

[a] FY 2001 NIF construction amount is now $199.1M after the passage of the FY 2001 Energy and Water Appropriations Bill.
NIF construction amounts for FY 2002 and beyond reflect the funding profile for the new NIF baseline approved by DOE and submitted to Congress on September 15, 2000.

appropriation of funds by Congress will result in a renewed and strengthened project consistent with the needs of the overall Stockpile Stewardship Program and fully supported by all three national security laboratories.

Table 4-1 details the resources required for the NIF as approved by the ESAAB and Level 0 Baseline Change Control Board.

To Readiness in Technical Base and Facilities, see Section 2.1.4.

4.1.2 Accelerated Strategic Computing Initiative (DP)

The Accelerated Strategic Computing Initiative (ASCI) is a program that greatly extends the computational capability of DOE Defense Programs (DP). The initiative's goal is to provide a robust simulation-based capability for assuring the safety, reliability, and performance of the U.S. nuclear stockpile in an era without nuclear testing. ASCI simulation capabilities will integrate 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. In FY 2000, the Laboratory's operating and maintenance costs in support of ASCI are over $280 million.

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 now beginning to emerge 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 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; and training a new generation of experts in the process.
- Establishing and following a collaborative acquisition path to systems with computing power much greater than 12 trillion floating-point operations per second (12 teraops) and the necessary infrastructure of utilities, storage, networks, and visualization.
- Supporting access to advanced ASCI computers by designers at all three laboratories.

In addition to simulation code development and verification and validation efforts, Livermore, working with Sandia and Los Alamos, is developing Problem-Solving Environments (PSEs) to accelerate the development and application by our weapon scientists of the new ASCI simulation codes to the problems of stockpile stewardship. Much of this research to improve visualization and data management tools is being conducted in collaboration with ASCI's university alliance partners. Key elements of the problem-solving 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, possibly as large as many trillions of bytes from an overnight run, 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 called Data and Visualization Corridors (or DVCs). We are combining high-performance storage and networking with a visualization architecture that allows interactive exploration of large quantities of data. Tools are being developed to interactively navigate the generated data and select subsets to analyze. Improved visualization of ASCI-generated data is offered by Livermore's Assessment Theater, a user interface of the DVC that began operation in 1999. The theater includes state-of-the-art projectors to achieve extremely high resolution and superior image quality on a screen 6,400 × 3,072 pixels (enlarged from its original size of 3,840 × 3,072 pixels in FY 2000). The Assessment Theater is connected to the Livermore Computing complex via the Laboratory's fiber-optics infrastructure. The theater provides 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. The next step in the visualization strategy is to expand use of the technology into the offices of individual designers.

A central component of ASCI is the accelerated development of highly parallel, terascale computers in partnership with the U.S. computer industry. In October 1999, our Laboratory and IBM dedicated the

3.9-teraops Blue Pacific ASCI supercomputer and celebrated its "coming of age." Developed and delivered in several stages over the past three years, Blue Pacific has matured into a powerful tool for stockpile stewardship. Acquired as part of an ASCI partnership with IBM, the machine exceeded contractual performance requirements when it was first operated in September 1998, and delivery of the hardware was completed six months ahead of schedule. The machine is a hyper-cluster of 1,464 nodes hooked together by a multiple-stage hierarchical network. Each node is a four-way shared memory multiprocessor with its own operating system and local disk. The system includes 17.1 terabytes of local disk memory and 62.5 terabytes of global disk memory.

The next major delivery in the partnership with IBM was the 12-teraops system delivered to Livermore in summer 2000. This machine, ASCI Option White, is based on the next-generation IBM processor, node, and switch technology and constitutes another dramatic leap in performance. This machine also exceeded its performance requirements by showing up with a 12.3-teraops capability—23% greater than its contractual requirement and three times faster than the recorded speed of any other computer. Besides the high peak computation rate, the machine will feature 4.0 terabytes of main memory. In addition, the system has 10.0 terabytes of local disk memory and 142.5 terabytes of global disk memory. The initial capability demonstration of this system has been completed. Option White was installed in Building 451, formerly home for the National Energy Research Supercomputer Center. Necessary modifications to the facility included a doubling of the power to the building, replacement of air conditioning units, and extension of the computer floor space by 8,000 square feet. Further increases in capability beyond Option White will require a new computer facility at Livermore, the Terascale Simulation Facility (TSF), described in Section 4.1.3.

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 is working with universities through the Academic Strategic Alliances Program (ASAP), a $250-million initiative to assist the three DOE national security laboratories in meeting ASCI computational science and simulation goals. ASAP is engaging the best minds in the U.S. academic community to help accelerate the emergence of new unclassified simulation science and methodology and associated supporting technology for high-performance computer modeling and simulation. Universities participate in research projects funded at three levels:

- Level One Strategic Alliances. Major centers have been established at Stanford University, California Institute of Technology, University of Chicago, University of Utah, and University of Illinois. Personnel from Livermore are working with their counterparts at each center. The centers are engaged in long-term, large-scale, unclassified, integrated multidisciplinary simulation and supporting science and computational mathematics representing ASCI-class problems. They have a five-year funding commitment, starting at approximately $3.7-million per year with planned growth to about $5 million per year, subject to contract renewal in the third year. These centers collectively have access to up to 10% of the ASCI-class computing resources.
- Level Two Strategic Investigations. These investigations establish smaller discipline-oriented projects working in computer science and computational mathematics areas identified as critical to ASCI success. The projects are each targeted for three years, with funding ranging from $200,000 to about $600,000 per year. Like Level One Alliances, these investigations are selected by an open, peer-reviewed solicitation process.
- Level Three Individual Collaborations. These projects are initiated by individual ASCI researchers and focus on near-term ASCI-related problems. Typically, these projects range from $50,000 to $100,000 per year, and they are funded from the Laboratory's ASCI budget allocation.

To Stockpile Stewardship, see Section 2.1.2.

4.1.3 Terascale Simulation Facility Initiative (DP)

The Terascale Simulation Facility (TSF) is 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 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 12-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 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 management, transmission, and comprehension of the vast data sets (referred to as Data and Visualization Corridors) that are generated. Plans for a TSF have been developed, and a Conceptual Design Report has been approved. The construction project was initiated with a FY 2000 line-item authorization.

Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers. The approved Conceptual Design Report for the TSF included plans for 48,000 square feet of machine room, between 6 and 8 megawatts to run the computer, and an additional 4 to 5.5 megawatts for cooling, which is needed because the air in the machine room must be exchanged several times per minute. The total cost of such a facility is $89 million.

As conceived, 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.

See Table 4-2 for the Terascale Simulation Facility resource requirements.

Table 4-2. Resources required for the Terascale Computing Facility Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating and maintenance cost
2000	2.0
2001	5.0
2002	32.0
2003	25.0
2004	23.0
2005	2.0
Total	89.0

To Readiness in Technical Base and Facilities, see Section 2.1.4.

4.2 Office of Defense Nuclear Nonproliferation

4.2.1 Environmental Security Initiative (NN)

Environmental issues, like water resources, pollution, and earthquake mitigation, can significantly affect regional security. Fortunately, many of these issues are amenable to technical mitigation and can thereby serve as vehicles for regional cooperation. The DOE and its national laboratories have formulated a regional Environmental Security Initiative to address issues where the U.S. has a national security interest. Activities and ongoing work include:

• Providing expertise in hydrology and relevant modeling capabilities to foster collaboration between Jordan, Israel, and the Palestinian Authority to develop water-management strategies for the aquifers and surface water resources in the region.

• Discussing seismic monitoring and earthquake simulation technology with states of the Middle East, North Africa, and Eastern Europe to augment their capabilities to monitor earthquakes in those regions, mitigate their effects, and prepare for emergency response.

• Interacting with Russia to identify ways of disposing of spent fuel and nuclear waste from decommissioned submarines to avoid any further contamination of the Arctic Ocean north of Russia.

To Proliferation Prevention and Arms Control, see Section 2.2.1.

4.3 Office of Intelligence

4.3.1 Sensitive Compartmented Information Facility Initiative (IN)

A new Sensitive Compartmented Information Facility (SCIF) building will provide a modern facility for all-source intelligence analysis, reduce maintenance and special security costs, and consolidate Livermore's national security programs, enhancing our ability to execute those projects. The Building 261 SCIF, constructed nearly 40 years ago, cannot accommodate all of the people who must work in an SCI facility or the modern communications and computer equipment and capabilities (information management, networking, data storage and retrieval, and real-time secure communications) required to interface with the U.S. intelligence community.

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 about 125 people in some 110 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 workroom 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 $24 million. This estimate was confirmed upon completion of a Conceptual Design Report and project validation in May 1999. This past year, we updated the CDR and project data sheet. We also completed the project's environmental assessment (NEPA determination), performed a risk analysis review, and prepared the project execution plan.

To International Assessments, see Section 2.2.4.

4.4 Office of Science

4.4.1 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 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.

As 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 with 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 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. Table 4-3 shows 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.

To Environmentally Clean Energy Carbon, and Climate, see Section 3.1.2.

4.4.2 Spheromak Fusion Reactor Initiative (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 and 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 1999, we began operating the Sustained Spheromak Physics Experiment (SSPX). In FY 2000, the physics and experimental efforts are being funded by the Laboratory's LDRD Program, and operations are funded by the DOE Office of Fusion Energy Sciences. In FY 2001, we expect that almost all spheromak research will be funded by DOE. The Livermore program benefits from collaborations with Los Alamos, UC Berkeley, UC Davis, and the University of Washington. We expect to add new collaborations with UC San Diego and the California Institute of Technology starting in FY 2001. See Table 4-4 for resource requirements to continue spheromak research.

The overall goal of SSPX is to understand and optimize energy confinement in the spheromak. In the early phases of the project, the research team focused on learning how to form clean deuterium plasmas using formation and sustainment capacitor banks and to debug diagnostic instruments. 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.
- Comparing performance with standard

Table 4-3. Resources required at Livermore to support the Accelerated Climate Prediction Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	ACPI operating	ACPI capital	Total costs	Direct FTEs
2000	6.0	1.5	1.0	8.0	4
2001	6.5	3.0	2.5	11.1	8
2002	7.0	4.5	3.0	14.5	12
2003	7.0	4.5	3.0	14.5	12
2004	7.0	4.5	3.0	14.5	12
2005	7.0	4.5	3.0	14.5	12

Table 4-4. Resources required for the Spheromak Fusion Research Initiative ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	2.4	0.0	2.4	8
2001	2.8	0.0	2.8	8
2002	3.5	0.0	3.5	9
2003	4.0	0.0	4.0	12
2004	4.0	0.0	4.0	12
2005	10.0	0.0	10.0	30

and partial flux-core magnetic configurations using a new set of bias field coils installed at the end of FY 2000.

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.

To Application of Mission-Directed Science and Technology, see Section 3.3.1.

4.4.3 Joint Genome Institute Initiative (KP)

In recent years, the goals of Livermore's 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 1997 formation of a Joint Genome Institute (JGI) for the Department of Energy. 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 completion of draft sequencing, mapping of the mouse genome equivalent region to human chromosome 19, improving throughput and lowering costs in a production sequencing environment, and management structures for the JGI. The Livermore team has taken the lead in developing shotgun sequencing methodology, microbial sequencing, sequence quality standards, and informatics infrastructure. Construction is near completion on the second of two buildings at the JGI Production Sequencing Facility in Walnut Creek, and we have completed the move to that facility, with over 50 employees working at that location.

In April 1999, the DOE funded the JGI to sequence five microbial organisms of interest to the DOE community for their energy and bio-remediation programs. This work was carried out at Livermore for the JGI and has just moved to the Sequencing Facility.

Table 4-5. Resources required for the Joint Genome Institute Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	20.1	0.2	20.3	80
2001	20.6	0.0	20.6	82
2002	21.6	0.0	21.6	82
2003	22.7	0.0	22.7	82
2004	23.8	0.0	23.8	82
2005	25.0	0.0	25.0	82

Looking further ahead, we plan to move our focus back to the functional aspects of genomic research. This work had 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 Livermore, 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 4-5.

To Genomics, see Section 3.2.1.

4.4.4 Disease Susceptibility: Functional and Structural Genomics Initiative (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 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 a 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 4-6 shows resource requirements for this initiative.

To Disease Susceptibility Identification and Prevention, see Section 3.2.3.

Table 4-6. Resources required for the Disease Susceptibility: Functional and Structural Genomics Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	20.1	0.2	20.3	80
2001	20.6	0.0	20.6	82
2002	21.6	0.0	21.6	82
2003	22.7	0.0	22.7	82
2004	23.8	0.0	23.8	82
2005	25.0	0.0	25.0	82

Table 4-7. Resources required for the Computational Biochemistry Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	1.2	0.0	1.2	8
2001	1.3	0.0	1.3	8
2002	2.3	0.0	2.3	9
2003	2.4	0.0	2.4	9
2004	2.5	0.0	2.5	9
2005	2.6	0.0	2.6	9

4.4.5 Computational Biochemistry Initiative (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 goals are 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, such as the study of normal and chemically modified DNA to support the BBRP's DNA repair and disease susceptibility research and the Laboratory-wide studies of corrosion and aging, and in the design of new materials. Table 4-7 shows resources required for the initiative.

Accomplishing these goals requires a multidisciplinary approach. Chemical modeling algorithms and software must be developed and validated, an effort primarily of computational chemists. Computer scientists with expertise in networking and software development must develop transparent interfaces between desktop computing resources and supercomputers. 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. Recent applications for this area of research include modeling selected food mutagens for their mutagenic potency, understanding DNA repair adduct formation, and using molecular dynamics and quantum chemistry to better understand the formation of double helices.

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.

To Disease Susceptibility Identification and Prevention, see Section 3.2.3.

4.4.6 Microbial Genomics Initiative (KP)

Although the importance of microbes in shaping human history has been well documented, recent advances in microbiology have led to an explosion of information about their role in human health and how they shape the environment. Microbes make up a majority of the Earth's biomass, they have been found in every conceivable environment, and they have been linked to a number of chronic diseases. The Laboratory has expanded the genomics program to address the impact that microbes have on our day-to-day life. Using technology developed for the human genome program, we are rapidly sequencing whole microbial genomes based on their relevance for energy, the global carbon cycle, bioremediation, and biological nonproliferation. We are leveraging this sequence information to rapidly, accurately, and cost-effectively sequence related species using newly developed subtractive hybridization methods. We are collaborating with industry partners to develop advanced methods to study microbial diversity and protein expression using both DNA- and protein-based microarray chips. Our continuing programs in microbial diagnostics and bioremediation have led to many advances, including the first diagnostic probes to be successfully used for the detection of the pathogen, *Salmonella enteritidis*. Table 4-8 gives the resource requirements for the effort in our expanded program.

To Biological Nonproliferation, see Section 3.2.2.

4.4.7 Materials Studies and Surface Characterization Initiative (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 the DOE Office of Science—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 enables 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. Unique instrumentation is located at 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 have developed a truly unique instrument—the positron microprobe—which will provide an unrivaled defect analysis capability to model three-

Table 4-8. Resources required for the Microbial Genomics Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	6.8	0.2	6.8	27
2001	8.0	0.2	8.2	30
2002	9.0	0.2	9.2	32
2003	10.0	0.2	10.2	34
2004	11.0	0.2	11.2	36
2005	12.0	0.2	12.2	38

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 able 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. Using 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, we are studying the potential of the technique to modify surfaces at the nanometer scale for a variety of industrial and national security applications.

To Application of Mission-Directed Science and Technology, see Section 3.3.2.

4.5 Assistant Secretary for Energy Efficiency

4.5.1 Hydrogen as an Alternative Fuel Initiative (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. 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. The model can be used to identify the most cost-effective integration of carbonless electric and transportation sectors for the long-term. 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 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 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-kilowatt, solid oxide electrolyzer, which would be adequate to provide fuel for a single vehicle. In addition, remote power applications offer immediate opportunities to demonstrate the technical feasibility of hydrogen technology systems because of the high cost of off-grid power. This same technology is applicable to the development of efficient, solid oxide fuel cells.

See Table 4-9 for resource requirements for this effort. In addition to this DOE support, we will continue to develop industrial partnerships.

To Energy, Carbon, and Climate, see Section 3.1.2.

Table 4-9. Resources required for Hydrogen as an Alternative Fuel ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
2000	2.0	0.4	2.4	7
2001	2.5	0.4	2.9	9
2002	4.0	0.3	4.3	13
2003	4.0	0.2	4.2	12
2004	4.0	0.2	4.2	12
2005	4.0	0.2	4.2	12

4.6 Multiple Program Offices

4.6.1 Nuclear Materials Initiative (Multiple Program Offices)

DOE is responsible for a wide variety of nuclear materials and operations that are used to fuel civilian power reactors and research reactors (in the U.S. and elsewhere), 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, from nuclear weapon materials to the nuclear fuel cycle, nuclear systems safety, and public health. We perform about $150 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.

These activities and our aggregate capabilities 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 reduction of nuclear arsenals in the U.S. and Russia. These materials require a disposition path that is both technically feasible and politically acceptable.
- The post–Cold War environmental legacy. Environmental cleanup and waste management needs of the defense complex continue to have a major impact on DOE budgets, credibility, operations, and missions.
- Management and disposal of civilian spent nuclear fuel both in the U.S. and internationally. DOE is facing significant deadlines 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 be felt in other parts of the defense complex. Interest is also growing in developing options for an international repository for spent nuclear fuel.
- Growing demands for nuclear power (particularly in Asia). The U.S. faces significant competition in the nuclear technology marketplace. Nuclear fuel reprocessing is continuing globally despite U.S. efforts to discourage this practice. There is a need to develop proliferation-resistant technologies for the design of new reactors—ones that consider the full fuel cycle.

Drawing upon our resources that are spread across several directorates and disciplines, we will support DOE's efforts to resolve these strategic issues and will focus on new mission-oriented work to improve proliferation resistance, especially in support of high-level waste, plutonium stabilization and disposition, mixed oxides (MOX), and greater-than-Class-C wastes. We will work with other laboratories and DOE Program Offices to respond to initiatives being developed by the Secretary's Office and the Albuquerque Operations Office. See Table 4-10 for resource requirements to continue this effort.

Table 4-10. Resources required for Nuclear Materials Initiative ($M; BA in FY 2001 dollars after FY 2000).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
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
2005	10.0	0.0	10.0	20

To Environmentally Sound Energy Technologies, see Section 3.1.2.

4.6.2 Accelerator Technologies Initiative (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 in engineering, precision manufacturing, and multidisciplinary project management. We are part of the three-laboratory effort building the B-Factory at Stanford University, and our accelerator expertise is being applied to important national security applications, including the development of advanced diagnostic capabilities for hydrodynamic testing. A candidate technology is the use of high-energy protons as the radiographic probe of hydrodynamic tests. We have been working with Los Alamos on the design of a machine and detectors for proton radiography. This design effort has been carried out in collaboration with DOE's High Energy Physics Program at several DOE national laboratories (Brookhaven National Laboratory, Fermi National Accelerator Laboratory, and Stanford Linear Accelerator Center).

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 Science, such as:

• **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-kilometer-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 Standard Model, including the study of the spectra of Higgs particles and determining whether supersymmetry is a valid description of nature. Following a strong endorsement by a High Energy Physics Advisory Panel (HEPAP) subcommittee report, DOE completed a Lehman Review of the NLC in May 1999, and a "Two-Site" Conceptual Design Report is expected to be completed in FY 2002. Title 1 Start would be in FY 2004.

The collider project is patterned after the very successful B-Factory collaboration, with SLAC and Lawrence Livermore and Lawrence Berkeley national laboratories providing much of the U.S. technical leadership for the NLC. We are making significant contributions in several areas of linear accelerator technology to improve system performance and obtain large reductions in project costs. Working with SLAC, we are developing an inductive solid-state modulator that is able to produce high-power, precisely shaped pulses of current (at 500 kilovolts, 2,000 amps, and 3 microseconds) with high efficiency and high reliability. The technology earned an R&D 100 Award in 1999. We are also providing expertise and technological capabilities in advanced manufacturing to significantly reduce the cost of precision pieces (copper cells) for the 20-kilometer-long accelerator structure. In addition, the Laboratory is applying its unique expertise in high-average-power, short-pulsed lasers to study the feasibility of designing a high-luminosity gamma–gamma collider as a second interaction region for the NLC. A gamma–gamma collider would open up entirely new physics complementary to the electron–positron collisions.

• **The Next Generation Light Source.** Advances in low-emittance electron linacs over the past several years have opened up the possibility of unprecedented brightness in a fundamentally new kind of synchrotron light source. A free-electron laser (FEL) consisting of such a linac driving a long precision-fabricated undulator can produce monochromatic 1-angstrom radiation that is 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, Los Alamos, and the University of California at Los Angeles 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 2003. Livermore is involved in several key aspects of the project, including undulator design, low-emittance electron sources, and novel x-ray optics.

To Application of Mission-Directed Science and Technology, see Section 3.3.1.

4.6.3 Computational Materials Science and Chemistry Initiative (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 in which 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, see Section 3.3.1.

4.6.4 National Wildfire Prediction Initiative (Multiple Program Offices)

Even before the tragic Cerro Grande fire in New Mexico this year, scientists from our Laboratory had been working with their counterparts at Los Alamos on an initiative to develop and implement a National Wildfire Prediction Program (NWPP). This new national resource will combine and leverage components of the ongoing wildfire modeling efforts at Los Alamos, the existing National Atmospheric Release Advisory Center (NARAC) at Livermore, and mesoscale atmospheric prediction capabilities at Livermore. The combination of a world-class emergency-response infrastructure and state-of-the-science atmospheric and fire modeling allows, for the first time, a scientifically based national wildfire prediction capability to be envisioned. By interactively coupling physics-based combustion models with advanced atmospheric prediction models, the NWPP will provide accurate fire behavior predictions for a wide range of locations and weather and fuel conditions.

With the cooperation of members of the wildfire management community (at the national, state, and county levels), we have defined four general support capabilities that potential customers would like to receive from a wildfire prediction service. We also have identified the key model components required to predict fire behavior, developed the concept for a highly cost-leveraged joint-lab effort to build on existing ARAC capabilities and infrastructure, and formed the basis for a strong partnership between Livermore and Los Alamos.

Once implemented, the NWPP will forecast the behavior of large wildfires and provide guidance to assist fire managers to most effectively use their limited firefighting resources. In addition to real-time responses (predicting fire behavior and the effects of various firefighting efforts), the NWPP would contribute to three other key areas of wildfire management: tactical planning (such as scheduling prescribed burns and assessing potential fire threats), strategic planning (such as long-term forest management and community planning), and simulation-based firefighter training. Because of its high degree of leveraging, the NWPP could have an initial capability within one to one-and-one-half years of project inception and be fully operational within five years. The project will move the NWPP concept a very important step closer to realization.

SECTION 5

Laboratory Operations

IN all Laboratory operations we strive to set a standard of excellence in safety, security, and business practices among high-technology applied research and development institutions. These factors are the underpinnings of success for all Livermore programs.

The Laboratory's operations serve many customers—the technical programs, sponsors, Congress, Laboratory employees, and the local community—to name just a few. To best meet the diverse, occasionally conflicting needs of these customers, the Laboratory takes an integrated approach to operations and balances attention to technical capabilities, services, and infrastructure in a way that best supports the Laboratory's overall objectives. Five overarching strategies reflect Laboratory priorities for operations.

Safety the Top Priority

Livermore has implemented DOE's Integrated Safety Management System (ISMS) throughout our workforce, both onsite and offsite. With DOE's seven guiding principles and five core functions as the foundation, ISMS establishes the basis for work authorization at the Laboratory. The introduction of ISMS at the Laboratory is affecting a cultural change through which operations will be carried out in the most efficient and productive manner possible under the existing umbrella of Work Smart Standards.

ISMS is integrated into all levels of work, including procured services. Operational support organizations receive training to assist the responsible individuals who are performing the work, and they in turn are trained to implement the ISMS principles.

Commitment to Improve Security

Recent events have reinforced the prime importance of security at the nuclear weapons laboratories. Working closely with Secretary Richardson and other senior DOE managers, Livermore, Los Alamos, and Sandia national laboratories have defined and are expeditiously executing a series of measures to tighten security and establish a baseline for an even more integrated approach to security. The future will see increased investments in security to ensure compliance and to adjust to new security threats and challenges, particularly those arising from rapid changes in information technologies.

In particular, we are providing even greater protection of critical assets at Livermore and implementing state-of-the-art cyber security, and we expanded the Laboratory's counterintelligence program.

An Emphasis on Teamwork

Since the founding of the Laboratory by E. O. Lawrence in 1952, team science—the ability to respond to challenges by forming multidisciplinary teams to get the job done—has been one of Livermore's key strengths. Teamwork is a broadly applied principle at the Laboratory—using a matrix management system to focus scientific and engineering talent where needed and integrating operational support with programs to achieve mission success. To seamlessly integrate Laboratory operational support with programs, staff and systems must be flexible, agile, and cost effective, adding value to Livermore's technical work. Many critical aspects of smooth and effective Laboratory operations, such as safety, security, and environmental protection, are every employee's responsibility.

Strategic Institutional Reinvestment

The Laboratory has been implementing a well-defined initiative to streamline business practices, improve information management, and outsource services when practical and cost effective. The result has been about a 30% reduction (inflation adjusted) in traditional General and Administrative (G&A) costs since FY 1993. These reductions are benefiting Laboratory programs and enabling the institution to meet strategic reinvestment needs. Reinvestment dollars are currently being allocated to specific objectives directed at strengthening the Laboratory's scientific and technical base, meeting critical infrastructure and facility needs, and realizing long-term cost savings through one-time investments anticipated to have high return-on-investment ratios. Specific areas pertaining to Laboratory Operations, such as facilities maintenance, have been identified as high-priority items for institutional reinvestment.

Use of Performance-Based Management to Improve Operations

In 1992, the University of California (UC) and DOE pioneered a contracting approach that integrated performance-based requirements into the contract for managing and operating the three UC laboratories. Performance-based management is contributing to improvements in Laboratory operations in several significant ways:

• Benchmarking to understand norms and improve performance measures. Across almost the entire spectrum of operational activities, we are benchmarking our performance with that of other research and development laboratories to find ways to better gauge performance and identify specific areas that warrant improvement.

• Use of performance measures to improve operations. Through iteration and continual improvement of the self and DOE assessment processes, Livermore has markedly improved

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 5 Laboratory Operations 5.1 Environment, Safety, and Health (ES&H) 5.2 Laboratory Security 5.3 Laboratory Personnel 5.4 Facilities and Plant Infrastructure 5.5 Support Services 5.6 Information Management 5.7 Internal and External Communications	• The Laboratory has made significant gains in improving safety and is now viewed as a leader in the DOE complex. Livermore's operational record in counterintelligence and physical security continues to be viewed as excellent, and the Laboratory has made state-of-the-art advances in cyber security. • The workforce and management reflect an ability to attract and retain a high-quality and diverse staff. • The National Ignition Facility building complex is complete in 2001, and laser support equipment is being installed. • The Laboratory is increasingly recognized as integral to the state of California….

operations, as measured by factors such as cost efficiency, service timeliness, and work quality.
• Performance-based management as a means of building teamwork. In addition to team building within the Laboratory, Livermore's performance-based management system is fostering a closer working relationship among the Laboratory, UC, and DOE. Through a variety of forums, we are achieving better communication of performance expectations, more efficient oversight, and ultimately, improved performance.

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

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

We expect to meet high standards of ES&H performance within our current operations budgets. 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, and ES&H must be fully integrated into all Laboratory activities, with appropriate balance between risk acceptance and costs.

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.

Situation and Issues

Integrated Safety Management. The Laboratory policy is that safety of both workers and the public has the highest priority. Although we work with hazardous materials and perform complex operations, our activities must be conducted safely, with full protection given to the public and the environment.

We want to be recognized as an institution capable of carrying out challenging projects and state-of-the-art research and development in a safe manner. To this end, we have implemented DOE's Integrated Safety Management System (ISMS) in all aspects of Laboratory operations. The central themes of this cultural change are that each individual is responsible for his or her own safety, that work must be authorized before it can proceed, and that anyone can—and should—stop unsafe work practices.

Laboratory-wide ISMS embodies all of DOE's seven Guiding Principles and five Core Functions:

Guiding Principles

1. Line management responsibility for safety.
2. Clear roles and responsibilities.
3. Competence commensurate with responsibilities.
4. Balanced priorities.
5. Identification of safety standards and requirements.
6. Hazard controls tailored to work being performed.
7. Operations authorization.

Core Functions

1. Define the scope of work.
2. Analyze the hazards
3. Develop and implement hazard controls.
4. Perform work within controls.
5. Provide feedback and continuous improvement.

In September 2000, a DOE Verification Team reported that ISMS is effectively implemented in Laboratory organizations—from the associate director level, to the facility level, and to activity levels. The team leader stated that "LLNL has demonstrated a commitment to excellence with respect to ISM." In their verification report, the team cited three areas of noteworthy practices in the Laboratory's ISMS program: a mature Integration Work Sheet (IWS) process, the use of peer reviews of explosives activities, and the effective use of the Laboratory's ES&H teams as an element in ISMS implementation.

Complying with Environmental Regulations. Livermore's Site Annual Environmental Report, prepared each year by our Environmental Protection Department, 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 fulfilling 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

Consistent Practices through ISMS. Through ISMS, we have established Laboratory ES&H policy guidelines and procedures that enhance accountability. Practices that are followed at high-performance, private-sector R&D organizations were studied as a guide. A major focus has been on better defining and articulating the flow of responsibility in Livermore's matrix management system. We have also reviewed our system of rewards and discipline for ES&H to assure consistency and to both promote safety and better deal with safety violations and poor safety performance.

As a part of the ISMS, work activities are formally reviewed and authorized before work begins, consistent with the work planning and authorization process. In addition, safety manuals throughout the Laboratory have been updated and reorganized in a structure consistent with ISMS. Activities to implement ISMS have led to more consistent, clear communication of expected safety practices, effective training, and interchangeability of skills within the Laboratory. Clearly defined roles and responsibilities have been 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, delineate communication protocols, maintenance responsibilities, and reporting requirements.

Now that ISMS is in place, consistency and accountability in ES&H practices across the Laboratory will help us to meet safety goals while achieving cost efficiency. ISMS implementation will be a steady-state effort at the Laboratory—not a one-time event. We will also work to strengthen the ISMS program by addressing opportunities for improvement and solidifying the ES&H enhancements that have been put into place as a result of implementing ISMS. Particular attention will be paid to three areas in which there are opportunities for improvement that were identified by the DOE Verification Team.

Cost Effectively Reducing Waste. 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, 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.

Remediation and Restoration. 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 Laboratory Security

Protection of sensitive information, nuclear materials, and other valuable assets at the Laboratory is a critically important aspect of responsible operations. Effective protection depends on the efforts of the Laboratory's safeguards and security professionals, computer security experts, and counterintelligence specialists as well as the proper training and vigilance of all employees.

We take security very seriously at Livermore. An extensive apparatus is in place at our Laboratory, and we continually make adjustments and upgrades to address new threats and concerns. Protection is provided by employing increasingly sophisticated measures in a cost-efficient manner through a triad of security—physical, cyber (computer), and counterintelligence.

Physical Security, based on a series of defensive layers and access control, is implemented by our Safeguards and Security Program. We take a graded approach to physical security in which physical barriers (e.g., fences, doors, repositories, and vaults) and permitted access are increasingly stringent, depending on the value or sensitivity of the asset.

Cyber Security provides protection of the Laboratory's electronic information, computers, data networks, and telecommunications systems in a world that is growing ever more interconnected and dependent on the transfer of digital information. Our computer security experts incorporate Laboratory requirements, best business practices, and DOE orders relating to computer security to create a balanced computer security program. The Computer Security Program also coordinates training on computer security issues and provides capabilities in threat analysis, incident response, and computer security forensics.

Counterintelligence at the Laboratory is the responsibility of the SAFE (Security Awareness for Employees) program. SAFE was formed in January 1986 in response to a Presidential Decision Directive dated November 1, 1985, that required all U.S. government agencies to establish their own counterintelligence programs. SAFE's purpose is to identify and counter foreign intelligence threats against Laboratory personnel, information, and technologies.

Situation and Issues

Security Challenges of Global Science and Technology. A major challenge facing the Laboratory is to protect sensitive information and technologies as we participate in an increasingly global scientific and technical community. As a national security laboratory, Livermore must provide a secure environment for sensitive

Table 5-1. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives, including capital funding ($M).

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005 and beyond
Waste Minimization and Pollution Prevention	1.1	0.7	0.5	0.5	0.5	0.5	0.5
Environmental Restoration	22.3	21.2	22.8	22.8	22.8	22.9	22.9
Waste Management	27.5	25.3	25.8	24.5	23.0	21.5	21.5

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.

Increased Awareness of Security Issues. Highly publicized incidents that occurred in 1999 and 2000 and the report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China (the Cox Committee) greatly raised public awareness of security issues and foreign intelligence-gathering efforts at the DOE national security laboratories. At the time of the release of the Cox Committee report (May 1999), many key reforms had already been taken in response to Presidential Decision Directive (PDD) 61, issued in February 1998, and the preliminary findings of the Cox committee helped to accelerate implementation.

PDD-61 ordered the DOE to establish a stronger counterintelligence program and called for more extensive security reviews, a beefed-up cyber security plan, an improved screening process for foreign visitors from sensitive countries, and an increase in the counterintelligence budget. For FY 2000, the program is budgeted at nearly $40 million, an increase from $2.6 million in 1996. At Livermore, the SAFE program, even as it undergoes improvements, is serving as an example for the development of DOE-wide counterintelligence programs and procedures. We are also taking steps to improve cyber security and increase physical security at the Laboratory.

Our success depends on the vigilance of everyone—from senior managers to individual employees. Increased vigilance is evidenced by a significant reduction in the number of security infractions that have occurred over the past year. All Livermore workers are aware of the severe consequences of security violations that place nuclear secrets at risk. We rely on a comprehensive Safeguards and Security Awareness Program at the Laboratory to understand the responsibilities, proper procedures, and best practices. In addition to a series of DOE mandatory briefings—many of which are annual requirements—the Laboratory offers nearly a dozen additional programs, some of which train people for specialized security responsibilities. Each year, all employees are required to complete security refresher training, and those that do not complete it or fail the follow-on test have their clearances suspended or revoked.

An Extensive Security Apparatus. An extensive security apparatus is in place at Livermore. In the area of physical security, our defense-in-depth approach includes a system of clearances, badging, and background checks; physical barriers and access control to protect sensitive and classified assets; and a fully trained and accredited security force. In addition, a vigorous Operations Security (OPSEC) program serves to identify potential "open" pathways to sensitive information in Laboratory operations and recommends cost-effective countermeasures to deny exploitation.

A defense in layers also characterizes cyber security at the Laboratory. Our classified computer and unclassified computer networks are totally separate. All systems connected to the classified system are secure, and access to information on the classified system is on a need-to-know basis. For unclassified computers connected to the outside world, we provide protection against intrusion, monitor traffic, and respond to incidents. Moreover, DOE's Computer Incident Advisory Capability provides on-call technical assistance to DOE sites and other government agencies facing computer security incidents, such as break-ins, attempted break-ins, viruses, and scans by outsiders.

Livermore's counterintelligence program, SAFE (Security Awareness for Employees), was established in 1986 and has grown in response to the Laboratory's increasing number of foreign interactions, particularly lab-to-lab programs. SAFE—largely staffed by former FBI special agents—works closely with the FBI and is well integrated into the U.S. counterintelligence community.

A Satisfactory (Green) Security Performance Rating. Throughout 1999, we worked expeditiously to address all issues that arose in self-evaluations or resulted from the May 1999 inspection by the DOE Office of Independent Oversight and Performance Assurance. In particular, we took steps this past year to upgrade each leg of our security triad—physical security, cyber security, and personnel security (including counterintelligence). Actions included steps to improve:

- Protection of special nuclear materials.
- Procedures for materials control and accountability.
- Physical security and protection of classified matter.
- Cyber security.
- Counterintelligence.
- Employee security awareness and training.

As an outgrowth of these efforts, we received an overall Satisfactory (Green) rating from the Office of Independent Oversight and Performance Assurance in their Follow-up Inspection in December 1999. We continue to make upgrades to strengthen all aspects of security, address identified issues—such as those that arose because of the Los Alamos incident—and deal with any perceived weaknesses. Since the Los Alamos incident in May 2000, we have been expeditiously implementing enhanced protection measures—those directed by DOE Secretary Richardson and those taken on our own initiative.

Strategic Thrusts

Emphasis on Physical Security. The Laboratory regularly prepares a comprehensive Site Safeguards and Security Plan, predicated on the DOE Design Basis Threat, that details the computer, physical, and procedural measures we are taking. In general, the physical security of the Livermore site (and Site 300) is maintained through a multilevel, graded approach to limit access and protect information. We have taken specific actions to ensure that the Laboratory is fully compliant with all DOE security requirements. In addition, in response to evolving security requirements, the Laboratory continues to make physical security improvements.

As an example, we have made important physical and technical upgrades to the security of our Superblock, which contains our Plutonium Facility, to provide early detection of terrorist or other adversary attacks. The Laboratory has hired and trained additional officers to protect the Superblock and taken other measures to assure the security of our special nuclear material assets. In particular, we have recruited and put in place an offensively trained Special Response Team with the training to implement a recapture or recovery action. Over 400 computer simulations as well as numerous field evaluations of adversary attacks have been completed, and we are continuing to refine our simulation methodology, attack scenarios, and defensive strategies. An external advisory group of senior military experts has been engaged to advise us in this work.

Following the Los Alamos incident in May–June 2000, we conducted our own parallel review at Livermore to assure that our emergency-response assets had not been compromised. All Nuclear Emergency Search Team (NEST) data stored at the Laboratory was and is accounted for. The incident raised broader issues about access to vaults and portable, highly concentrated collections of sensitive data at Livermore. A working group was immediately chartered to review the Laboratory's classified data holdings, identify the locations of especially sensitive and portable collections of high concentrations of data, and recommend appropriate procedures to provide additional protection.

This review, completed in June, found that we were compliant with DOE requirements. Nonetheless, enhanced chain-of-custody controls and access procedures have been implemented at the identified locations. In addition, we have upgraded our vault-access verification procedures in accordance with the Enhanced Protection Measures directed by DOE Secretary Richardson on June, 19, 2000. The Laboratory has also instituted a working group to address the effectiveness of our vault and VTR operations and management. They are identifying additional protection measures beyond those required by DOE that can further enhance security.

We 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.

Site-specific Security Operating Procedures (SOPs) will be audited to ensure validity and compliance with required DOE directives. In the past, the physical and technical security staff did not have sufficient resources to engage in continuing oversight of SOPs that were written to accommodate various programs and departments. Additional staffing will allow this oversight to become more effective in the future.

Attention to Security Procedures for Foreign Interactions. Physical security measures are augmented by a system of security controls that apply to day-to-day operations. Specific issues that are raised by foreign nationals' visits and assignments to the Laboratory, as well as sensitive foreign travel by our staff, are addressed on a case-by-case basis. A foreign visit or assignment involving a sensitive country, a sensitive facility, or sensitive information undergoes careful individualized scrutiny, and it requires completed indices checks, a review for sensitive unclassified information, and an individual security plan. Other visits and assignments are conducted through a standard security plan.

Livermore's two-step sensitive unclassified information review was recently praised by the Government Accounting Office as a "best practice." The review applies to foreign visits, assignments, and travel. Our process uses DOE's official Sensitive Subjects List as a flag for the careful individualized review of technical material proposed to be exchanged in foreign interactions to ensure that no proliferative or otherwise sensitive information is included. The review is carried out by a departmental network of trained scientists who sit down with the traveler or the host of the foreign national on a one-on-one basis to discuss the exchange. The process allows us to screen all sensitive visits and assignments while still permitting the many foreign collaborations that enhance U.S. national security.

Highest Standards of Computer Security. Recent concerns about espionage involving computer-based information and codes spurred a thorough reassessment of computer security at the Laboratory. We stood down all classified computers (and colocated unclassified machines) as all employees and contractors went through intensive retraining in cyber security. Every classified computer work area and environment was evaluated, and changes were made as necessary to ensure that the Laboratory's classified and sensitive computing meets the highest standards of information security.

In April 1999, Secretary of Energy Richardson approved the Tri Lab INFOSEC Action Plan. The plan responded to nine action items, developed by Secretary Richardson and the directors of the three weapons laboratories, that identified specific areas of improvement for all three laboratories. As of March 1, 2000, all 32 of Livermore's milestones were completed on time. Some of the more significant improvements made to our computer security posture include: a significantly improved institutional firewall capability, improved computer security training, elimination of the possibility of transferring classified information with compatible media within an office, intrusion detection on classified systems, and implementation of a three-level network architecture.

More generally, we are supporting the Secretary's cyber security initiative and are contributing to DOE-wide information security planning. Leading-edge cyber security is vital to our programmatic missions and is an area where we can leverage our expertise to enhance national security in the broadest sense. We are using our computer security upgrade as an opportunity to apply our multidisciplinary approach to science and technology to become a model for computer security.

A Vigorous Counterintelligence Program. Our counterintelligence program (SAFE) develops threat assessments for the Laboratory, reviews visits and assignments by foreign nationals, and runs a vigorous Laboratory-wide counterespionage awareness program. SAFE was reviewed by DOE's head of counterintelligence in April 1998 and identified as a model for similar programs throughout the DOE.

We proactively continue to expand SAFE and improve its capabilities so that the Laboratory's security measures stay ahead of increasingly challenging espionage threats. For example, we have developed, tested, and installed the Visitor Tracking System for use at Livermore. Information on each foreign visit and assignment is entered into the system as part of the review and approval process. The database automatically captures numerous pieces of information about each visit and assignment and can provide statistics as needed. The Laboratory also is developing a similar system for employees who go on official travel to foreign countries.

We continue to upgrade our extensive employee espionage awareness programs. The SAFE staff provides briefings and debriefings for personnel who host foreign visitors or travel abroad and sponsors Laboratory-wide presentations on espionage-related topics by guest speakers from the U.S. intelligence community.

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 Tables 5-2 and 5-3.

Recruitment, reward, and advancement policy decisions are based on contribution to Livermore's success. The Laboratory greatly values outstanding scientific, technical, and administrative 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

Strong Bond with University of California. 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 the 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.

Recruiting and Retaining High-Quality Employees. In spite of these competitive advantages, we must be more aggressive in policies and practices

Table 5-2. Laboratory staff composition as of March 31, 2000 (excludes summer hires and temporary program participants; may include indefinite employees).

		Management		Scientific		Administrative		Technical		Others		Totals	
			(%)		(%)		(%)		(%)		(%)		(%)
White	M	845	(66.1)	1,359	(70.6)	138	(22.9)	1,002	(65.9)	424	(33.0)	3,768	(57.0)
	F	252	(19.7)	248	(12.9)	330	(54.8)	235	(15.5)	504	(39.3)	1569	(23.7)
Black	M	28	(2.2)	23	(1.2)	11	(1.8)	41	(2.7)	47	(3.7)	151	(2.3)
	F	9	(0.7)	12	(0.6)	24	(4.0)	12	(0.8)	39	(3.0)	96	(1.5)
Hispanic	M	42	(3.3)	26	(2.2)	9	(1.5)	93	(6.1)	87	(6.8)	273	(4.1)
	F	27	(2.1)	9	(0.5)	28	(4.7)	16	(1.1)	94	(7.3)	174	(2.6)
Indian	M	15	(1.2)	6	(0.3)	4	(0.8)	19	(1.3)	15	(1.2)	59	(0.9)
	F	4	(0.3)	0	(0.0)	11	(1.8)	11	(0.7)	12	(0.9)	38	(0.6)
Asian	M	31	(2.4)	162	(8.4)	13	(2.2)	60	(3.9)	31	(2.4)	297	(4.5)
	F	23	(1.8)	45	(2.3)	34	(5.6)	22	(1.4)	30	(2.3)	154	(2.3)
Total minority	M	116	(9.1)	234	(12.3)	37	(6.1)	213	(14.0)	180	(14.0)	780	(11.8)
	F	63	(4.9)	66	(3.4)	97	(16.1)	61	(4.0)	175	(13.6)	462	(7.0)
Unidentified	M	3	(0.2)	15	(0.8)	0	(0.0)	7	(0.5)	1	(0.1)	26	(0.4)
	F	0	(0.0)	2	(0.1)	0	(0.0)	2	(0.1)	0	(0.0)	4	(0.1)
Totals	M	964	(75.8)	1608	(83.6)	189	(30.7)	1,222	(80.4)	605	(47.1)	4,574	(69.2)
	F	315	(24.2)	316	(16.4)	427	(69.3)	298	(19.6)	679	(52.9)	2,035	(30.8)
Lab totals		1,279		1,924		602		1,520		1,284		6,609	

Table 5-3. Laboratory staff composition as of March 31, 2000 (excludes summer hires and temporary program participants; may include indefinite employees).

	None	AA	BA/BS	MA/MS	PhD	Total Pop.
Management	304	112	227	265	371	1,279
Scientific Professional	20	6	493	556	849	1,924
Administrative Professional	246	45	202	96	13	602
Technical Jobs	742	500	254	23	1	1,520
Other Jobs	1,044	157	80	3	0	1.284
Totals	2,356	820	1,256	943	1,234	6,609

designed for recruitment and career development in 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.

A Skilled and Flexible Workforce. Our goal is an employee population with the motivation, innovation, and diversity needed for Livermore to excel in its mission. We must also 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 helps employees adapt to changing needs and encourages skills development while it keeps employee dislocations to a minimum. The Laboratory therefore should continue to balance efforts between being a storehouse of skills and a purchaser of skills. Our Flexible Term employment category, improved workforce planning processes and tools, and employee development and placement programs are important components of our effort to achieve greater agility. In addition, we have increased 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

A Re-examination of Workforce Issues. During the DOE Equal Employment Opportunity (EEO) Diversity Stand-Down in April 2000, Laboratory Director Bruce Tarter announced that as a follow-on action, the Laboratory would undertake a thorough re-examination of workforce issues in Autumn 2000. A careful review of the effectiveness of steps taken to increase diversity at the Laboratory, together with assessments of broader challenges in workforce recruitment and retention, will serve as the basis for this re-examination. We need to understand what it will take to better achieve diversity goals and make the Laboratory an attractive place for scientists and technologists, and then take appropriate actions.

Implementing Contemporary Personnel Practices. Like other employers, we are finding that recruitment and retention are major issues for the Laboratory. We are reviewing a number of policies and practices across a broad range of human resource functions to ensure that our ability to attract and retain employees remains competitive for the type of skills we need. A contemporary work environment requires both appropriate policies and attention to implementation, including equity in compensation and other personnel practices, effective and fair complaint resolution processes, recognition of the importance of balancing work and family needs, and means for assuring that employees feel well informed and have a shared sense of excitement about the success of the Laboratory.

Particular Attention to Compensation. We continue to work with—and benefit from exceptional support from—the DOE to ameliorate difficulties in the "hot" skills areas by adjusting the compensation system, where possible, to address the most critical problems. For example, as part of the merit increase package in FY 1998, we supplemented by 10% the salaries for computer scientists, whose skills are in great demand in the San Francisco Bay Area. Further increases were provided in FY 1999, and the Director set aside part of the approved salary package to be used by the directorates for their internal hot skills and/or internal alignment problems. More generally, we continue to monitor and analyze compensation practices of other institutions for potential augmentation to the Laboratory's all-base compensation system.

Attention to Workforce Diversity. In April 2000, the Laboratory participated in the DOE Equal Employment Opportunity (EEO) Diversity Stand-Down, developed by DOE to highlight the importance of respecting and valuing diversity in the work place and negative consequences of racial profiling. The standdown was one of the actions taken by DOE Secretary Richardson based on the results of the Task Force Against Racial Profiling, which was established to investigate the climate at the laboratories following allegations of Chinese espionage reported last year.

During the day-long standdown program, Laboratory Director Bruce Tarter recommitted the Laboratory to achieving the goals and outcomes identified in the 1995 diversity survey. Most of the recommendations from that survey have been implemented, but not all of the goals have been achieved. As a follow-on action to the workforce standdown, all of the Laboratory senior managers were tasked to perform an assessment of the effectiveness of steps taken in their own area since the diversity survey and to target areas for improvement.

More generally, the annual workforce plans that are developed and implemented at the Laboratory consider both programmatic needs and institutional goals, such as achieving a workforce that is reflective of the rich diversity of California and the nation. Hence, Livermore's Affirmative Action Plan is an integral part of our workforce. It is essential that the Laboratory develops and maintains a diverse workforce and provides employees and applicants for employment with a discrimination-free workplace.

A focal point for our efforts to ensure equal employment opportunity and workforce diversity is the Laboratory's Affirmative Action and Diversity Program (AADP). In addition to monitoring compliance with relevant executive orders and legislation, AADP develops the Laboratory's action plans to increase diversity, sponsors a variety of outreach programs, and interacts with employee network groups to foster strong working relationships among these diverse associations. AADP provides funds to these groups to promote cultural awareness and matching scholarship funds to eligible, federally protected groups. For a summary of AADP's broad range of activities, see their Web page, www.llnl.gov/aadp/zindex.html.

Employee Development. The Laboratory's workforce 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. Our recently opened 8,000-square-foot Laboratory Training Center is designed with facilities, equipment, and staffing to enhance learning and information exchange. Three standard classrooms and one computer classroom support online media input and video broadcasts from the Laboratory TV network. Many career development and training resources are now made more easily available to employees through the Laboratory's internal Web page, including links to:

- Training programs and organizations: information on the Laboratory's training programs and organizations and links to DOE training.
- Training resources: course catalogs, mentoring and self-directed learning resources, and online training courses.
- U-Learn: an online training alternative and supplement for employees who prefer the convenience of taking computer-related courses at their office desktop. Students can log-in at any time and use course information as desktop support.
- Career development resources: information on the Career Center, career management, and employment opportunities.
- Academic programs: information on degree programs, coursework, undergraduate scholarships, academic assistance, onsite university programs, and Laboratory TV courses.
- Training documents: online resources and contact information.

Leadership and Management Development. A particular area of emphasis for the last three years has been training for supervisors and managers. We have a set of core courses for supervisors and managers: Supervision I for new supervisors, Supervision II for all supervisors, and the Management Institute for division leaders and above. These programs are designed to assure that all supervisors and managers understand their full responsibilities, including Laboratory policies and procedures, and develop solid leadership and people skills. Senior managers are actively involved in the design and implementation of these programs and serve as the faculty for Supervision I and the Management Institute.

In addition to the core programs, the Laboratory sponsors a Leadership Lecture Series featuring key-note speakers on leadership topics. Open to all employees, the lecture series reflects our commitment to building leaders at all levels of the organization. Other programs include recommended internal and external courses for various management levels that enhance the development of leadership and management skills.

Under development for over a year, the Management Institute was piloted in spring 2000. The institute, designed to help prepare the next generation of Laboratory leaders, received highly positive responses from 31 participants, who especially valued interaction with top managers during the two-day-long program. A second session is being planned for later this year.

5.4 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 184 permanent buildings and 253 temporary structures and houses over 9,000 people. At Site 300, there are 97 permanent buildings and 37 temporary structures. The replacement plant value is estimated to be $3.1 billion, which does not include some $1.8 billion in personal property and land value (see Tables 5-4 and 5-5).

In a generally stable future projected for the Laboratory population, the facility square-footage inventory given in these tables is considered adequate to meet future needs. However, replacement and rehabilitation of substandard and technically obsolete space, as well as modernization of technical capabilities, shall be continuing requirements in maintaining the inventory.

Stewardship of DOE lands and facilities at Livermore is an important responsibility. We have 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—and our 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.

The challenges we face stem from our expectation of minimal new office construction in the near term and the need for sufficient resources to achieve our goal through site revitalization. As described in the Laboratory's *Comprehensive Site Plan* (www.llnl.gov/comp_plan/csp.html), our strategy includes a balanced set of efforts to rehabilitate older facilities, consolidate activities as mission priorities change, maintain mission-critical aging facilities, and efficiently manage legacy facilities.

Table 5-4. Laboratory space distribution.

Type of space	Area in 1000s of Square feet	Area in 1000s of Square meters
Main site	5,788	538
Leased-university	0	0
Leased-off-site	8	8
Site 300	381	35
Total	6,256	581

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

	Buildings	Trailers	Other structures	Utility/infrastructure	Total
Livermore Site	1,841	83	4	951	2,879
Site 300	119	1	13	104	237
Total	1,960	84	17	1,055	3,116

Situation and Issues

Upgrades and New Construction. Unique, state-of-the-art, experimental research facilities are a core strength of the Laboratory. The major national security directorates all have some modern core facilities in use or under construction. Construction is in progress on the 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 investments such as electrical and infrastructure modernization have also helped to upgrade the Livermore site. In addition, the communication 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.

Rehabilitation and Replacement. Strategic management of Laboratory facilities must balance the needs and resources for maintenance, facility rehabilitation, and new facilities development. Many structures are 30 to 50 years old (see Figure 5-1). They are particularly demanding for maintenance to keep them adequate, and over time, all need rehabilitation or replacement. Only 60% of our employees currently reside in permanent space, and the majority of temporary office space (70%) is nearing or already beyond the end of service life. As more facilities age beyond their intended life, our need for modern office space will continue to grow. Figure 5-2 shows the current condition of Laboratory space.

The health and safety of employees are of primary importance to the Laboratory. Any facility that poses a risk in this regard is vacated, rehabilitated, or removed, and the occupants are relocated. In addition, from long-discontinued programs, we have outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and/or demolished. Livermore's legacy facilities and other excess marginal space requires considerable up-front investment to rectify.

To efficiently manage our older facilities, site planners employ a scoring system of 0–4 for 12 criteria to identify facility candidates for rehabilitation or removal. The system, referred to as the Facility Assessment and Ranking System (FAaRS), helps us to prioritize institutional maintenance requirements and to keep our Mission Essential aging facilities operational and in adequate condition. Prompted by FAaRS, the Laboratory has made significant reductions in substandard space in recent years, either by removal or mothballing (see Table 5-6).

Strategy Thrusts

An Institutional Focal Point. Appointed in 1997, the Institutional Facility Manager (IFM) serves as the focal point for developing and implementing a long-term strategy for managing facility investments at Livermore. The IFM office works with senior managers from each Laboratory organization to establish priorities for new facilities, maintenance and backlog reduction, and space reduction. By having a Director's-Office-level focal point for working facility management issues, the Laboratory has become more effective in focusing investments to mission priorities and in meeting essential institutional demands.

A Balanced Portfolio for Site Revitalization. Our objective is to follow a balanced approach in providing facility management to meet programmatic needs, with the goal of assuring the future vitality of the Laboratory and its primary missions. In particular, a coherent Laboratory-wide office requirements plan is continually refined to address the needs of the nearly 4,000 employees who work in less-than-adequate space—trailers, modular units, and World War II-era buildings—that we keep operational by using the FAaRS process to prioritize maintenance investments. Four principal elements of the plan are:

- Construction of new facilities through line items and general plant projects.
- Rehabilitation of older facilities, where cost effective.
- Prioritization and reduction of deferred maintenance backlog.
- Efficient management of legacy facilities.

Our ability to carry out a balanced portfolio of plans for site revitalization depends on the availability of adequate funding to do so. With Readiness in Technical Base and Facilities as one of the three organizing thrusts of the Stockpile Stewardship Program (see Section 2.1.4), it is clear that the Laboratory's principal sponsor, DOE Office of Defense Programs (DP), recognizes the importance of modernizing its national laboratories. On the other hand, DP is under considerable stress with many competing demands for investments—stockpile life-extension programs, stewardship campaigns, new research facilities, and revitalization of both laboratories and production facilities. Funding projections show lower-than-historic levels of funding for infrastructure line items and General Plant Projects, and there are many competing demands within the Laboratory for internal investments.

We continue to improve our processes for managing site revitalization. In consultation with DOE/OAK, we recently updated the way we think about our space usage.

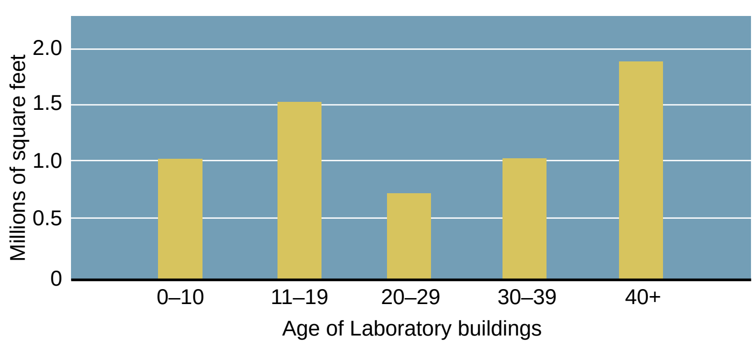


Figure 5-1. Age of Laboratory buildings.

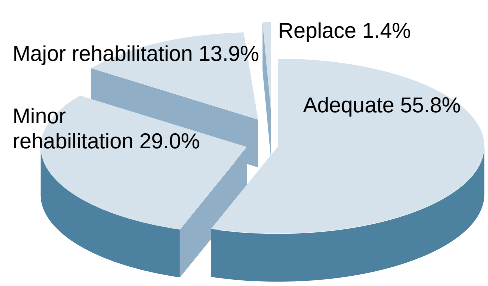


Figure 5-2. Condition of Laboratory space.

Technology has changed the types and amounts of space in which we work, and so we have changed some definitions and requirements for planning and managing our sites. The changes help to address the space issues we face today—distributing and rehabilitating existing space for new purposes and equipment rather than building new offices. With our new priority rating system, we will more quickly fix current problems and be able to plan for the kinds of facilities that the Laboratory needs for future programs.

New Technical Facilities. New technical facilities at Livermore are being constructed through DOE program investments. Two major new technical facilities—the National Ignition Facility and the Terascale Simulation Facility mentioned above—are the Laboratory's highest priorities. Scheduling the many nontechnical facility line-item construction projects is a product of (1) the priorities that the Laboratory has set on each project and (2) discussions among the three DOE national security laboratories and DP to make the most effective use of overall funding.

Rehabilitating Older Facilities. To meet the greater portion of the Laboratory's office space needs, we are rehabilitating our older facilities identified through the FAaRS to provide adequate quality office space where cost effective. See Figures 5-3 and 5-4.

Depending on the return on investment, older but fundamentally sound facilities are being returned to "good" condition by maintenance rehabilitation projects. In this connection, we are pursuing workable options for innovative, cost-effective, facility revitalization and new construction/renovation.

For example, a recent pilot project brought one of the World War II-era building complexes (B314/315), which has over 100 offices, up to good condition (an additional 15 years of life) at a very affordable cost. Space in a large open-bay building (T-1879) was rehabilitated and modified into four large, well-designed and -equipped classrooms that meet the specific needs of the Laboratory's teaching and training organizations. Additional projects include the rehabilitation of trailers in the 1400 block to affordably revitalize an additional 200 office spaces from poor to good/adequate condition.

Reducing the Maintenance Backlog. A Laboratory Facility Charge (LFC) based on square footage is levied on building "owners" to support the costs of routine maintenance for their facilities and of Laboratory infrastructure. We are using

Table 5-6. Reduction in substandard space (in 1000s of square feet).

Fiscal year	Substandard space removed	Substandard space mothballed
FY 1996	116.8	141.2
FY 1997	28.1	23.6
FY 1998	22.0	0.0
FY 1999	24.9	137.7
FY 2000	7.3	53.4

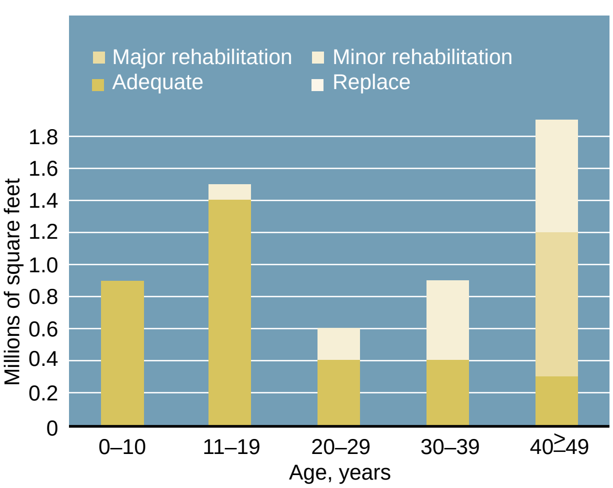


Figure 5-3. Use and condition of Laboratory space.

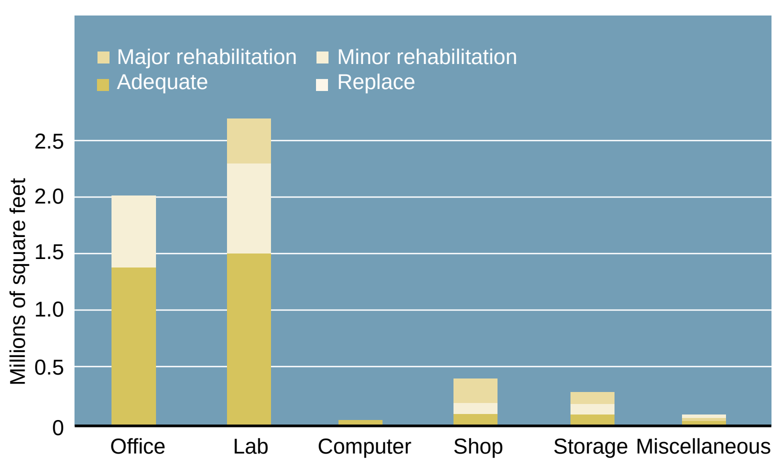


Figure 5-4. Age and condition of Laboratory buildings.

and continuing to refine a planning process for work prioritization to reduce the Laboratory's maintenance backlog using G&A funds. Priorities are set by the programs, considering both the level of risk to the Laboratory's mission if there is a failure and the probability of failure (in the absence of replacement). The process assures that the prioritized backlog is addressed with planned expenditures using LFC funds.

Projects that rank highest in both criteria are "A list" items that require immediate attention. Other maintenance projects fall into less critical categories: "B" items to address within one year and "C" items to address in less than three years. These three categories constitute the Laboratory's Essential Backlog, representing approximately 20% of the total backlog. Immediate attention to long-range, lower-priority categories ("D" through "F") would bring all facilities up to "as built" condition but would result in prohibitive expenditures. Items in these less essential categories are addressed only when they move into the essential regime. Through this process, we have developed and are executing a multiyear institution-wide maintenance backlog reduction plan. Funding sources have been allocated in FY 2000 through FY 2001 to correct all the "A" and "B" and the most important "C" deficiencies.

Facility Plans and Resource Requirements

Table 5-7 provides a summary of the Laboratory's funded and proposed construction projects with total estimated cost (TEC) in excess of $5 million. Construction projects that started funding in FY 2000 or are proposed to begin in FY 2001 or 2002 include:

Sensitive Compartmented Information Facility (SCIF) (FY 2001 start, TEC: $24.0 M). The new 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 the Nonproliferation, Arms Control, and International Security Directorate (NAI) to continue to carry out its mission by providing major enhancements in information management, optical-fiber networking, storage and retrieval, and real-time communications with DOE and the intelligence community.

Terascale Simulation Facility (TSF) (FY 2000 start, TEC: $89.0 M). The project provides for the design, engineering, and construction of the Terascale Simulation Facility (TSF - Building 453), which will be capable of housing future computers required to meet the Accelerated Strategic Computing Initiative (ASCI). The building will contain a multistory office tower with an adjacent computer center. The Terascale Simulation Facility (TSF) proposed here is designed from inception to enable the very large-scale weapons simulations essential to ensuring the safety and reliability of America's nuclear stockpile. The timeline for construction is driven by requirements coming from ASCI within the Stockpile Stewardship Program. The TSF will manage the computers, the networks, and the data and visualization capabilities necessary to store and understand the data generated by the most powerful computing systems in the world.

5.5 Support Services

Programmatic work at the Laboratory is supported by business, procurement, financial, and other types of services. Livermore is making considerable improvements in its operational support for programs, striving to size and manage support activities to optimize overall cost effectiveness and performance. As gauged by performance measures in the UC/DOE contract, Laboratory support functions are increasing in quality, delivered in a timely manner, and priced competitively.

We strive to provide operational services in a professional manner and to institute equitable, self-consistent procedures and systems that support Laboratory values. 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. Our support and service organizations provide assurance that compliance is managed responsibly and efficiently and in a way that is clearly defensible to the public, regulators, and Laboratory programs.

Situation and Issues

Reducing Support Costs. Many improvements have been made since FY 1993 to reduce support and overhead costs, making more resources available for direct program work. The actions were 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.

Functional elements that are responsible for providing many support 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 major changes at DOE—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. Rapid changes in technology also offer many opportunities for improvements in information systems (see Section 5.6 Information Management for Business Systems).

Procurement and Materiel Requirements. It is the policy of DOE to fully integrate small businesses, small disadvantaged businesses, women-owned businesses, and Historically Underutilized Business Zone (HUBZone) business concerns in DOE's core mission and programs. Accordingly, the Laboratory is required to provide opportunities to increase to the maximum extent practicable the participation of these firms in our acquisition process.

In support of this requirement and on behalf of the Laboratory, the Procurement and Materiel (P&M) Department negotiates annual goals in prescribed socioeconomic categories. Using a sophisticated forecasting model and working in concert with resource analysts from around the Laboratory, P&M develops annual socioeconomic goals that are both reasonable and attainable. The goals, carefully monitored and compared to actual procurements throughout the fiscal year, may be adjusted at mid-year, depending on changes to individual program spending plans or the Laboratory budget at large.

Strategy Thrusts

The Laboratory will continuously improve systems and processes for providing support services and effectively communicate with and involve both employees and customers in the changed process.

Supplier Management Program. To promote the establishment of strategic supplier partnerships, P&M has developed a supplier management program. The goals for this program were: to establish a manageable and viable supplier database, enhance our

Table 5-7. Funded and proposed major construction (in millions of dollars).[a]

Project Title	TEC	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006 & beyond
Defense Program - Funded Projects:									
National Ignition Facility[b]	2094.9	243.3	247.2	209.1	245.0	187.2	150.0	130.0	275.1
Protection of Real Property - II	19.9	2.5	2.4	2.8	2.8	9.4			
Isotope Sciences Facility	17.4	2.0	2.0	5.0	4.4	4.0			
Site 300 Contained Firing Facility	49.7	6.7							
Site 300 Fire Station and Medical Facility	5.4	4.5							
DP Total Funded Construction		259.0	251.6	216.9	252.2	200.6	150.0	130.0	
Defense Program - Proposed and Newly Started Projects:									
Terascale Simulation Facility	89.0		2.0	5.0	32.0	25.0	23.0	2.0	
DP New Funding Requirements			2.0	5.0	32.0	25.0	23.0	2.0	
Total Defense Programs		259.0	253.6	221.9	284.2	225.6	173.0	132.0	
Nonproliferation and National Security - Proposed Projects:									
SCIF Area for NAI	24.0			5.0	16.0	3.0			
EW Projects - Funded Projects:									
Decontamination/Waste Treatment Facility	62.4	11.0	1.4	7.1	1.5				
Total Laboratory		270.0	255.0	234.0	301.7	228.6	173.0	132.0	

[a] Totals for facilities with TEC greater than $5 million.
[b] FY 2001 NIF construction amount is now $199.1M after the passage of the FY 2001 Energy and Water Appropriations Bill. NIF construction amounts for FY 2002 and beyond reflect the funding profile for the new NIF baseline approved by DOE and submitted to Congress on September 15, 2000.

ability to develop long-term relationships with key suppliers, enhance the quality of all vendors doing business with the Laboratory, simultaneously achieve Livermore's socioeconomic goals, and serve as the primary source of suppliers to Laboratory customers. The program has four major components: prequalification, supplier performance review, supplier feedback development, and follow-up and monitoring.

Travel Management. Dynamic changes in the travel industry and the advent of Web-based electronic commerce present the Laboratory with unique opportunities to explore new methods of processing travel reservations and reimbursement. We are developing a long-term strategy for an integrated, cradle-to-grave, Web-based travel-management process. Laboratory travelers will be able to make travel reservations via a Web booking tool linked to both the designated travel agency and the expense reporting system. Links with the travel card vendor and other travel suppliers will allow the Laboratory direct access to their data and electronic payment of official travel expenses.

The Web-based travel expense reimbursement system was initiated in late FY 1999. In partnership with the Laboratory's designated travel agency, the booking tool will be implemented in late FY 2000. The last piece in this strategy, scheduled for late FY 2001, will be improved system integration.

Anticipating Customer Needs. Successful reengineering includes anticipating customer expectations; soliciting continuous customer feedback to assess satisfaction, needs, and 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. (See also Section 5.6 Information Management for Business Systems.) In some cases, for example, we will rely on institutional reinvestment to absorb short-term expenses that will lead to long-term cost savings. When outsourcing is a viable option, organizations should be staffed to take advantage of it.

Balancing Priorities. 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 at which local optimization undercuts compliance or other institutional objectives.

5.6 Information Management for Business Systems

The Laboratory's business systems and information planning process explores, compares, and learns about new business approaches and technologies that can be used to improve our business practices. Our studies address crosscutting business issues—from the organization of Deputy Director for Operations to the entire Laboratory—to design our future business systems architecture.

The themes for these planning processes include:

- Determining the crucial needs and directions for future Laboratory business systems.
- Identifying cross-organizational requirements for supporting external business partners.
- Determining best future practices that will achieve cost reductions, cycle-time reductions, quality improvements, and end-user self-service applications.
- Ensuring that explicit business systems align with Laboratory programs and projects.
- Understanding and influencing the strategic directions as determined by Livermore's information architecture activities sponsored by the Chief Information Officer (CIO).
- Identifying and recommending for implementation the best-of-class strategies, business systems, applications, and technologies from industry and sister laboratories.

Situation and Issues

Adopting Best Business Practices. Our business systems architecture is heavily influenced and validated by benchmarking and best-practice activities. In our benchmarking process, twice a year we study a large technically sophisticated organization that is familiar with technologies that are part of our current infrastructure and future directions. The organization can be a key technology vendor or other DOE national laboratory. During this process, we review information technology (IT) infrastructure, drivers of change, and future directions and compare our methods with those of the selected organization.

In the best-practices arena, the scope of the interactions is much more specific. First, we identify critical technology directions in which the solutions are unproven and relatively high-risk. We then find organizations that have experience and knowledge in the technical area and compare approaches and results. We also review our critical current technologies and processes to assess how we are doing.

In both cases, the objectives include:

- Identifying innovative approaches and technologies relevant to our future.
- Validating our major tactical and strategic directions, including feasibility, risks, costs, and benefits.

• Evaluating our strategic and tactical alignment with our vendors and the IT industry.
• Assessing our progress relative to similar organizations and industry as a whole.

During FY 2001 and beyond, we will initiate major architectural changes, particularly in authentication, access control, intranet portals, workflow, integrated help-desk knowledge base, desktop computing management, computer security, and object-based application development and deployment.

Strategy Thrusts

Information Technology Professionals Recruitment and Retention. The Laboratory faces a tremendous imbalance in the demand vs. supply of IT skills, a situation that we believe will continue through 2006. The shortage of IT professionals, particularly given our proximity to Silicon Valley, has made it imperative to create a strategic thrust in building and maintaining tomorrow's workforce. To shape our future directions, we are forging a major initiative to study the possibilities and implications of new management styles required for the next wave of new employees, sophisticated reward systems, alternative workforce sourcing arrangements, and various recruitment models, practices, and policies for selective retention. These multifaceted studies will help us redefine and deploy robust, rational, and strategic IT skills-management programs.

Enterprise Self-Service Applications Strategic Direction. The fundamental driver for our strategic planning is enabling cost and cycle-time reductions or quality improvements for key business processes. For example, a number of leading-edge organizations have realized significant cost and cycle-time reductions by moving processes out to end-point participants via the Web and automating everything in between. These applications are sometimes referred to as enterprise self-service applications, which we have adopted as our primary strategic direction.

We are replacing manual processes with enterprise-scale self-service applications (timecard, training, budgeting, purchasing) delivered to the browsers at the desktop. The Web technologies also enable us to extend business processes to external vendors and partners. Over the last two years, our user population has gone from about 1,500 users to approximately 7,000 with little increase in infrastructure staffing.

Intranet Portals and Web-Based Systems. Providing customized Web portals for specific customer segments is a major trend in industry. Many organizations have internal home pages that provide access to Websites and Web-based applications. In the first phase of a similar effort, we are exploring ways to provide a user-customizable intranet Web portal that integrates internal and external Website access, Web-based application access, workflow in-basket, messaging, and utilities integrated with single sign-on and integrated access control. A second phase for this effort will be creating portals for specific customer segments, including workbenches for resource managers, enterprise users, project managers, and human resource managers.

Electronic Commerce Initiatives. The Internet is driving an emerging revolutionary business paradigm at Livermore. Virtual relationships and collaborations between Laboratory business units and external partners are emerging at an ever-increasing rate. We currently provide electronic data interchange based on just-in-time purchasing capabilities with a virtual catalog of over 1.5 million items. In the near term, we are expanding our use of collaborative technologies that support engineering designs and job orders, and we are investigating the application of commercial business-to-business purchasing networks.

Business Systems Architecture. Managing and deploying an evolving business system and technical infrastructure have unique problems. In this type of environment, the complexity increases as the number of interrelated applications and users increases and as the time to technical maturity decreases. Our challenge is to provide an agile, responsive infrastructure with reliable, secure, and scalable production services. Meeting this challenge requires fusion between the Livermore business and technology strategies, continual prudent evolution of technical capability, and a future infrastructure designed for serviceability to our business units.

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, the Public Affairs Office (PAO), and others, Livermore continues to develop its internal and external communications program by bringing the Laboratory's messages to important audiences and seeking the concerns and comments of those audiences. Internally, the Laboratory needs effective communication to support dialogue on key issues, institutional 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 to the state of California and a helpful neighbor in the Bay Area and California's Central Valley, and we want the communities around us to be proud we are here.

Situation and Issues

Listening to Our Customers. The Laboratory must continue to ensure that customers and stakeholders are identified and that their concerns are considered in planning and decision-making as well as in the formulation of operational policies. The range of customers and stakeholders is extremely wide, from the general public to senior managers in Washington. With the regional public in mind, PAO contracted for a community and employee survey (its fourth in a decade) to understand broad trends and specific issues and concerns. Like preceding surveys, this one was a means to evaluate needs and performance and to guide communications practices inside and outside the Laboratory. Input had also been broadly sought in preparing *Creating the Laboratory's Future*, a document that put forth Livermore's vision, goals, priorities, values, and strategy and was widely distributed to both external and internal audiences.

Improving Community Relations. The Laboratory continues to reach out to stakeholders and customers, to participate in community events, and to seek feedback directly as well as by formal survey (see above). From past surveys, we are aware that relations with the community are fundamentally sound, but most members of the community would like more information about our activities. PAO strengthened its community relations staff in 1999–2000, began a monthly electronic community newsletter, and began a public lecture series. It conducted regular community tours as well as special tours for select groups, such as a community leader tour of the National Ignition Facility (NIF) under construction. Community comment was solicited in all of these activities. PAO also arranged meetings between senior Laboratory management and community leaders. The Laboratory participated in various public forums on environmental topics, NIF, and security modifications.

Strategic Thrusts

Information Outlets. The Laboratory is using 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 extensively for all of these audiences. For example, the Laboratory newspaper, *Newsline*, now has an online version (*NewsOnLine*) that is issued twice weekly. Selected *Newsline* articles are posted on the publicly accessible PAO Web page. Similarly, Public Affairs news releases are issued electronically and posted with news photos on the Web. *Newsline* and *Grapevine* (our internal Internet home page) carry a "From the Director" column, which provides employees with information about key institutional efforts and Laboratory issues. This year, PAO joined with Sandia Livermore and local cable TV for a biweekly talk show, "Technology Today," which reaches the local public with nontechnical discussions of projects at both Livermore laboratories.

Online Communications. Institutional publications, such as *Creating the Laboratory's Future*, *Science & Technology Review*, the *Laboratory Annual Report*, the *Institutional Plan*, news releases, and major stories from *Newsline* are available on the Laboratory's external Internet home page. These publications have all 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 publications are available online, and information is provided about our organization, operations, and programs, as well as opportunities for employment and research partnerships. Web pages for general public use, such as PAO's, recently have been redesigned for greater clarity and improved public access and usefulness.

Involvement in Various Community Programs. In the local community, the Director and other senior managers have increased their visibility through more frequent meetings with local officials and civic groups. For various local chambers of commerce, service clubs, and science fairs, Livermore managers and employees serve as board members representing the Laboratory or as volunteers. They also participate in ongoing activities of Tri-Valley (Livermore, Dublin, Pleasanton, San Ramon) business councils and economic development leadership committees, serve as the spearhead for memoranda of understanding between the Laboratory and nearby community colleges in the field of workforce development, and participate in a youth summit, Livermore's Promise: Alliance for Youth, which is an offshoot of General Colin Powell's national effort.

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. We publish a newsletter and offer a Web site on these topics, and we frequently respond to questions from students, members of the general public, homebuyers, and realtors.

SECTION 6

Institutional Plan FY 2001–2005

Appendices

6.1 Program Resource Requirement Projections

Data for FY 1999 is taken from the FY 1999 LLNL Budget Office Annual Report. Data for FY 2000 through FY 2002 represent a combination of the FY 2002 Field Budget Submission and the FY 2002–2003 Defense Programs Field Budget Estimates (April 2000). NIF construction reflects the funding profile for the new NIF baseline approved by DOE and submitted to Congress on September 15, 2000. The guidance case is used for all programs. The resource data for FY 1999 through 2005 are based on the following:

- FY 1999 through 2000: actual budget obligations and authority.
- FY 2001 through 2005: program managers' estimates of resource requirements.
- Inflation factor: for FY 2001 and FY 2002, inflation is 2.0%; for years beyond FY 2002, resources requirements are expressed in constant FY 2002 dollars.
- Personnel figures do not always add correctly because the numbers have been rounded to whole numbers.
- For FY 2001 and beyond, Safeguards and Security costs, previously indirectly funded, are expected to be direct-funded by the DOE Office of Security and Emergency Operations. This change may result in a reduction in funding to other DOE areas, which is not reflected in this report. Accordingly, some funding estimates for FY 2001 and later may be overstated.

The program resource projections are shown as follows:

- Tables 6.1-1 and 6.1-2. Laboratory funding and personnel summaries.
- Tables 6.1-3 and 6.1-4. Resources and personnel by major DOE program.
- Tables 6.1-5 through 6.1-19. Detailed resource breakouts by DOE sponsors.
- Table 6.1-20. Small and disadvantaged business procurement.

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

	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
DOE Effort[c]	775.1	837.5	944.6	994.6	996.3	997.2	1004.6
Work for Others	73.7	99.8	128.6	125.6	125.6	125.6	125.6
Work for Non-DOE	204.9	179.1	184.6	195.3	195.3	203.3	218.3
Total Operating	1053.7	1116.4	1257.8	1315.5	1317.2	1326.1	1348.5
Program Capital Equipment	13.5	1.6	1.6	3.1	3.1	3.1	3.1
Program Construction[d]	283.3	265.0	233.4	303.7	229.6	175.0	130.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	8.6	7.5	3.3	1.4	1.4	1.4	1.4
General Purpose Equipment[e]	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Total Laboratory Funding[d]	1359.0	1390.5	1496.1	1623.7	1551.3	1505.6	1483.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Projected Funding[c]	1359.0	1390.5	1496.1	1623.7	1551.3	1505.6	1483.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]Excludes DOE Field Offices.
[d]FY 2001 NIF construction amount is now $199.1M after the passage of the FY 2001 Energy and Water Appropriations Bill. NIF construction amounts for FY 2002 and beyond reflect the funding profile for the new NIF baseline approved by DOE and submitted to Congress on September 15, 2000.
[e]GPE is not included in Total Laboratory Funding figures because funding is collected as a distributed budget.

Table 6.1-2. Laboratory personnel summary (in full-time employee equivalent, or FTE).

	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Direct							
DOE Effort	2579.0	2740.4	3251.0	3209.3	3169.3	3099.3	2979.3
Work for Others	246.3	281.4	262.6	262.6	262.6	262.6	262.6
Work for Non-DOE	636.2	421.7	399.0	439.0	439.0	469.0	519.0
Total Direct	3461.5	3443.5	3912.6	3910.9	3870.9	3830.9	3760.9
Total Indirect	3800.9	3806.5	3187.4	3189.1	3229.1	3269.1	3339.1
Total Personnel	7262.4	7250.0	7100.0	7100.0	7100.0	7100.0	7100.0

[a]For FY 2001 and 2002,escalation of 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-3. Funding by Secretarial Officer; resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Defense Programs							
Operating Costs	529.8	578.3	551.6	585.0	586.7	587.6	595.0
Capital Equipment	5.2	1.1	0.0	0.0	0.0	0.0	0.0
Construction	283.3	263.6	224.3	284.2	225.6	175.0	130.0
Total Cost/Funding	818.3	843.0	775.9	869.2	812.3	762.6	725.0
Direct Personnel	1828.3	1878.0	1737.8	1653.4	1613.4	1543.4	1423.4
Security & Emergency Operations							
Operating Costs	8.2	21.8	134.9	141.9	141.9	141.9	141.9
Capital Equipment	0.1	0.0	0.5	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.3	21.8	135.4	143.9	143.9	143.9	143.9
Direct Personnel	25.7	80.0	658.1	686.2	686.2	686.2	686.2
Defense Nuclear Nonproliferation							
Operating Costs	100.3	103.8	108.4	105.7	105.7	105.7	105.7
Capital Equipment	0.7	0.1	0.4	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	101.0	103.9	108.8	106.1	106.1	106.1	106.1
Direct Personnel	241.5	269.0	230.5	224.7	224.7	224.7	224.7
Office of Intelligence							
Operating Costs	4.5	4.9	4.9	5.5	5.5	5.5	5.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	2.0	18.0	4.0	0.0	0.0
Total Cost/Funding	4.5	4.9	6.9	23.5	9.5	5.5	5.5
Direct Personnel	15.5	16.0	14.5	15.6	15.6	15.6	15.6
Office of Counterintelligence							
Operating Costs	2.2	3.6	4.8	5.0	5.0	5.0	5.0
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	2.2	3.6	4.8	5.0	5.0	5.0	5.0
Direct Personnel	9.5	12.0	20.5	20.5	20.5	20.5	20.5
Office of Science							
Operating Costs	60.6	61.7	67.6	73.1	73.1	73.1	73.1
Capital Equipment	6.5	0.4	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	67.1	62.1	68.2	73.7	73.7	73.7	73.7
Direct Personnel	197.3	217.2	307.8	307.3	307.3	307.3	307.3
Environmental Restoration & Waste Management							
Operating Costs	49.7	48.4	49.6	52.2	52.2	52.2	52.2
Capital Equipment	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.4	7.1	1.5	0.0	0.0	0.0
Total Cost/Funding	50.7	49.8	56.7	53.7	52.2	52.2	52.2
Direct Personnel	201.8	211.2	202.0	213.9	213.9	213.9	213.9

Table 6.1-3, continued. Funding by Secretarial Officer; resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Environmental Safety & Health							
Operating Costs	3.5	3.1	2.8	2.9	2.9	2.9	2.9
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	3.5	3.1	2.8	2.9	2.9	2.9	2.9
Direct Personnel	11.2	11.0	8.3	8.3	8.3	8.3	8.3
Nuclear Energy							
Operating Costs	6.9	0.6	0.8	0.9	0.9	0.9	0.9
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	6.9	0.6	0.8	0.9	0.9	0.9	0.9
Direct Personnel	18.9	5.0	2.2	2.6	2.6	2.6	2.6
Fossil Energy							
Operating Costs	1.6	3.2	7.4	10.0	10.0	10.0	10.0
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	3.2	7.4	10.0	10.0	10.0	10.0
Direct Personnel	5.6	16.8	31.4	38.4	38.4	38.4	38.4
Energy Efficiency & Renewable Energy							
Operating Costs	6.7	7.7	11.8	12.4	12.4	12.4	12.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	6.7	7.7	11.8	12.4	12.4	12.4	12.4
Direct Personnel	20.8	23.1	37.6	38.1	38.1	38.1	38.1
Management & Administration							
Operating Costs	0.7	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	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.4	0.0	0.0	0.0	0.0	0.0	0.0
Policy, Planning, & Program Evaluation							
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	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Office of Civilian Radioactive Waste Management - DF							
Operating Costs	0.3	0.4	0.1	0.1	0.1	0.1	0.1
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	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.5	1.1	0.2	0.2	0.2	0.2	0.2

Table 6.1-3, continued. Funding by Secretarial Officer; resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Other DOE Facilities/Field Offices							
Operating Costs	73.7	99.8	128.6	125.6	125.6	125.6	125.6
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	73.7	99.8	128.6	125.6	125.6	125.6	125.6
Direct Personnel	246.3	281.4	262.6	262.6	262.6	262.6	262.6
Total DOE Programs							
Operating Costs	848.8	937.3	1073.2	1120.2	1121.9	1122.8	1130.2
Capital Equipment	13.5	1.6	1.6	3.1	3.1	3.1	3.1
Construction	283.3	265.0	233.4	303.7	229.6	175.0	130.0
Total Cost/Funding	1145.5	1203.9	1308.2	1427.0	1354.6	1300.9	1263.3
Direct Personnel	2825.3	3021.9	3513.6	3471.9	3431.9	3361.9	3241.9
Work for Others/Non-DOE							
Operating Costs	204.9	179.1	184.6	195.3	195.3	203.3	218.3
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	204.9	179.1	184.6	195.3	195.3	203.3	218.3
Direct Personnel	636.2	421.7	399.0	439.0	439.0	469.0	519.0
Total Program Funding							
Operating Costs	1053.7	1116.4	1257.8	1315.5	1317.2	1326.1	1348.5
Capital Equipment	13.5	1.6	1.6	3.1	3.1	3.1	3.1
Construction	283.3	265.0	233.4	303.7	229.6	175.0	130.0
Total Cost/Funding	1359.0	1390.5	1496.1	1623.7	1551.3	1505.6	1483.0
Direct Personnel	3461.5	3443.6	3912.6	3910.9	3870.9	3830.9	3760.9
General Purpose Equipment	8.3	8.3	8.3	8.3	8.3	8.3	8.3
General Plant Projects	8.6	7.5	3.3	1.4	1.4	1.4	1.4
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-4. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Defense Programs							
Operating Costs	1386.9	1386.0	1339.7	1326.2	1194.1	1220.3	1273.4
Capital Equipment	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Construction	439.8	492.0	398.1	327.2	419.3	323.1	150.0
Total Defense Programs	1828.3	1878.0	1737.8	1653.4	1613.4	1543.4	1423.4
Security & Emergency Operations[c]							
Operating Costs	25.7	80.0	658.1	686.2	686.2	686.2	686.2
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 Security & Emergency Ops.	25.7	80.0	658.1	686.2	686.2	686.2	686.2
Defense Nuclear Nonproliferation							
Operating Costs	241.5	269.0	230.5	224.7	224.7	224.7	224.7
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 Defense Nuclear Nonprolif.	241.5	269.0	230.5	224.7	224.7	224.7	224.7
Office of Intelligence							
Operating Costs	15.5	16.0	14.5	15.6	15.6	15.6	15.6
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 Office of Intelligence	15.5	16.0	14.5	15.6	15.6	15.6	15.6
Office of Counterintelligence							
Operating Costs	9.5	12.0	20.5	20.5	20.5	20.5	20.5
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 Office of Counterintelligence	9.5	12.0	20.5	20.5	20.5	20.5	20.5
Office of Science							
Operating Costs	197.3	217.2	307.8	307.3	307.3	307.3	307.3
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 Office of Science	197.3	217.2	307.8	307.3	307.3	307.3	307.3
Environmental Restoration & Waste Management							
Operating Costs	201.8	205.7	176.8	207.9	207.9	207.9	207.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	5.5	25.3	6.0	6.0	6.0	6.0
Total Env. Rest./W. Mgmt.	201.8	211.2	202.0	213.9	213.9	213.9	213.9
Environmental Safety & Health							
Operating Costs	11.2	11.0	8.3	8.3	8.3	8.3	8.3
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 Env. Safety & Health	11.2	11.0	8.3	8.3	8.3	8.3	8.3

Table 6.1-4, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Nuclear Energy							
Operating Costs	18.9	5.0	2.2	2.6	2.6	2.6	2.6
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 Nuclear Energy	18.9	5.0	2.2	2.6	2.6	2.6	2.6
Fossil Energy							
Operating Costs	5.6	16.8	31.4	38.4	38.4	38.4	38.4
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 Fossil Energy	5.6	16.8	31.4	38.4	38.4	38.4	38.4
Energy Efficiency & Renewable Energy							
Operating Costs	20.8	23.1	37.6	38.1	38.1	38.1	38.1
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 Energy Efficiency & Renew	20.8	23.1	37.6	38.1	38.1	38.1	38.1
Management & Administration							
Operating Costs	2.4	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 Management & Administration	2.4	0.0	0.0	0.0	0.0	0.0	0.0
Policy, Planning, & Program Evaluation							
Operating Costs	0.1	0.1	0.1	0.1	0.1	0.1	0.1
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 Policy, Planning, & Prog. Eval.	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Office of Civilian Radioactive Waste Management–DF							
Operating Costs	0.5	1.1	0.2	0.2	0.2	0.2	0.20
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 Civilian Radioactive Waste Mgmt.	0.5	1.1	0.2	0.2	0.2	0.2	0.2
Other DOE Facilities/Field Offices							
Operating Costs	246.3	281.4	262.6	262.6	262.6	262.6	262.6
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 Other DOE Facilities/Field Off.	246.3	281.4	262.6	262.6	262.6	262.6	262.6

Table 6.1-4, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Total DOE Programs							
Operating Costs	2383.9	2524.4	3090.3	3138.7	3006.6	3032.8	3085.9
Capital Equipment	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Construction	439.8	497.5	423.4	333.2	425.3	329.1	156.0
Total DOE Programs - FTEs	2825.3	3021.8	3513.6	3471.9	3431.9	3361.9	3241.9
Work for Others (Non-DOE)							
Operating Costs	636.2	421.7	399.0	439.0	439.0	469.0	519.0
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 Work for Others (Non-DOE)	636.2	421.7	399.0	439.0	439.0	469.0	519.0
Total Program Effort							
Operating Costs	3020.1	2946.1	3489.3	3577.7	3445.6	3501.8	3604.9
Capital Equipment	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Construction[c]	439.8	497.5	423.4	333.2	425.3	329.1	156.0
Total FTEs	3461.5	3443.5	3912.6	3910.9	3870.9	3830.9	3760.9
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects[d]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Direct Personnel	3461.5	3443.5	3912.6	3910.9	3870.9	3830.9	3760.9
Total Indirect Personnel	3800.9	3806.5	3187.4	3189.1	3229.1	3269.1	3339.1
Total Laboratory Personnel	7262.4	7250.0	7100.0	7100.0	7100.0	7100.0	7100.0

[a]For FY 2001 and 2002, escalation of 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]Security Operations projected to be direct funded beginning in FY 2001. FY 1999 data were included in indirect personnel.
[d]FTE levels for General Plant Projects were included in construction estimates.

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

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Core Stockpile & Stewardship-DP0101							
Operating Costs	376.1	426.4	397.5	432.6	432.6	432.6	432.6
Capital Equipment	2.1	1.0	0.0	0.0	0.0	0.0	0.0
Construction	34.0	8.7	12.8	39.2	38.4	25.0	0.0
Total Cost/Funding	412.2	436.1	410.3	471.8	471.0	457.6	432.6
Direct Personnel	985.1	1008.3	972.3	972.3	972.3	972.3	972.3
Inertial Confinement Fusion-DP02							
Operating Costs	92.0	102.7	100.9	102.3	104.5	106.3	113.7
Capital Equipment	1.9	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	93.9	102.7	100.9	102.3	104.5	106.3	113.7
Direct Personnel	259.8	269.0	233.2	233.2	233.2	233.2	233.2
National Ignition Facility-DP0213							
Operating Costs	14.7	5.8	5.9	1.4	0.9	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction[c]	243.3	247.2	209.1	245.0	187.2	150.0	130.0
Total Cost/Funding[c]	258.0	253.0	215.0	246.4	188.1	150.0	130.0
Direct Personnel	396.5	450.0	450.0	380.0	340.0	270.0	150.0
Technology Transfer & Education-DP03							
Operating Costs	4.1	0.9	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	4.1	0.9	1.5	1.5	1.5	1.5	1.5
Direct Personnel	17.1	7.0	5.0	5.0	5.0	5.0	5.0
Weapons Stockpile Management-DP0401[d]							
Operating Costs	39.9	41.8	45.9	47.2	47.2	47.2	47.2
Capital Equipment	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	41.5	41.8	45.9	47.2	47.2	47.2	47.2
Direct Personnel	122.6	99.0	62.9	62.9	62.9	62.9	62.9
Program Direction-DP05							
Operating Costs	3.0	0.9	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	0.9	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6.2	2.0	0.0	0.0	0.0	0.0	0.0
DARHT Construction							
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	5.6	7.7	2.4	0.0	0.0	0.0	0.0
Total Cost/Funding	5.6	7.7	2.4	0.0	0.0	0.0	0.0
Direct Personnel	41.0	42.7	14.4	0.0	0.0	0.0	0.0

Table 6.1.5, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Total Defense Programs							
Operating Costs	529.8	578.3	551.6	585.0	586.7	587.6	595.0
Capital Equipment	5.2	1.1	0.0	0.0	0.0	0.0	0.0
Construction[c]	283.3	263.6	224.3	284.2	225.6	175.0	130.0
Total Cost/Funding [c,d]	818.3	843.0	775.9	869.2	812.3	762.6	725.0
Direct Personnel	1828.3	1878.0	1737.8	1653.4	1613.4	1543.4	1423.4
General Purpose Equipment (GPE)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
General Plant Projects (GPP)	8.0	4.7	1.0	0.5	0.5	0.5	0.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]FY 2001 NIF construction amount is now $199.1M after the passage of the FY 2001 Energy and Water Appropriations Bill. NIF construction amounts for FY 2002 and beyond reflect the funding profile for the new NIF baseline approved by DOE and submitted to Congress on September 15, 2000.
[d]Part of DP04 (NEST/ARAC programs) recast to B&R SO – Office of Security & Emergency Management.

Table 6.1-6. Security and Emergency Operations detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Office of Security & Emergency Management-SO[c]							
Operating Costs	0.0	10.1	119.8	123.1	123.1	123.1	123.1
Capital Equipment	0.0	0.0	0.5	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	10.1	120.3	125.1	125.1	125.1	125.1
Direct Personnel	0.0	47.0	613.6	622.0	622.0	622.0	622.0
Emergency Management-ND							
Operating Costs	1.1	0.9	0.9	0.9	0.9	0.9	0.9
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	1.1	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	0.6	2.0	1.7	1.7	1.7	1.7	1.7
Nuclear Safeguards & Security-GD							
Operating Costs	7.1	10.8	14.2	17.9	17.9	17.9	17.9
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	7.2	10.8	14.2	17.9	17.9	17.9	17.9
Direct Personnel	24.0	31.0	42.8	62.5	62.5	62.5	62.5
Related Security Investigations Activity-GH03							
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	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Security and Emergency Operations							
Operating Costs	8.2	21.8	134.9	141.9	141.9	141.9	141.9
Capital Equipment	0.1	0.0	0.5	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.3	21.8	135.4	143.9	143.9	143.9	143.9
Direct Personnel	25.7	80.0	658.1	686.2	686.2	686.2	686.2
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	2.4	1.5	0.5	0.5	0.5	0.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]SO projected to be direct funded beginning in FY 2001.

Table 6.1-7. Defense Nuclear Nonproliferation detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Fissile Materials Disposition-GA							
Operating Costs	26.8	21.8	21.0	15.0	15.0	15.0	15.0
Capital Equipment	0.0	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	26.8	21.9	21.0	15.0	15.0	15.0	15.0
Direct Personnel	56.7	55.0	42.0	30.0	30.0	30.0	30.0
Transparency Measures-MV30							
Operating Costs	0.0	6.5	7.2	7.5	7.5	7.5	7.5
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	6.5	7.2	7.5	7.5	7.5	7.5
Direct Personnel	0.0	17.0	20.0	20.0	20.0	20.0	20.0
Nonproliferation & Verification R&D-GC00							
Operating Costs	39.7	42.0	44.9	46.6	46.6	46.6	46.6
Capital Equipment	0.7	0.0	0.4	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	40.4	42.0	45.3	47.0	47.0	47.0	47.0
Direct Personnel	119.9	138.0	108.5	113.7	113.7	113.7	113.7
Arms Export Control & Nonproliferation-GJ							
Operating Costs	33.7	33.5	35.3	36.6	36.6	36.6	36.6
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	33.7	33.5	35.3	36.6	36.6	36.6	36.6
Direct Personnel	64.9	59.0	60.0	61.0	61.0	61.0	61.0
Program Direction–KK							
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	0.0	0.0	0.0	0.0
Total Office of Defense Nuclear Nonproliferation							
Operating Costs	100.3	103.8	108.4	105.7	105.7	105.7	105.7
Capital Equipment	0.7	0.1	0.4	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	101.0	103.9	108.8	106.1	106.1	106.1	106.1
Direct Personnel	241.5	269.0	230.5	224.7	224.7	224.7	224.7
General Purpose Equipment (GPE)[c]	1.1	1.1	1.1	1.1	1.1	1.1	1.1
General Plant Projects (GPP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]GPE is not included in Total Lab Funding figures because funding is collected as a distributed budget.

Table 6.1.8. Intelligence detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Intelligence–IN							
Operating Costs	4.5	4.9	4.9	5.5	5.5	5.5	5.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	18.0	0.0	0.0	0.0
Total Cost/Funding	4.5	4.9	4.9	23.5	5.5	5.5	5.5
Direct Personnel	15.5	16.0	14.5	15.6	15.6	15.6	15.6

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-9. Counterintelligence detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Counterintelligence-CN							
Operating Costs	2.2	3.6	4.8	5.0	5.0	5.0	5.0
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	2.2	3.6	4.8	5.0	5.0	5.0	5.0
Direct Personnel	9.5	12.0	20.5	20.5	20.5	20.5	20.5

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-10. Science detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Field Operations-FA[c]							
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	0.0	0.0	0.0
Life Sciences-KP11							
Operating Costs	28.7	28.6	27.9	27.9	27.9	27.9	27.9
Capital Equipment	5.7	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	34.4	28.6	27.9	27.9	27.9	27.9	27.9
Direct Personnel	103.7	112.8	136.2	130.2	130.2	130.2	130.2
Environmental Processes-KP12							
Operating Costs	6.2	6.6	11.6	11.9	11.9	11.9	11.9
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	6.2	6.6	11.6	11.9	11.9	11.9	11.9
Direct Personnel	22.2	25.1	61.5	55.7	55.7	55.7	55.7
Medical Applications & Measurement Science-KP14							
Operating Costs	0.3	0.8	0.7	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	0.8	0.7	0.3	0.3	0.3	0.3
Direct Personnel	3.0	5.5	3.6	1.5	1.5	1.5	1.5
	5.7	0.0	0.0	0.0	0.0	0.0	0.0
Fusion Energy Sciences-AT							
Operating Costs	12.0	14.1	13.3	15.4	15.4	15.4	15.4
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	12.3	14.1	13.3	15.4	15.4	15.4	15.4
Direct Personnel	42.5	46.0	48.6	53.0	53.0	53.0	53.0
Basic Energy Sciences-KC02							
Operating Costs	3.6	3.5	3.6	3.6	3.6	3.6	3.6
Capital Equipment	0.4	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	4.0	3.8	3.9	3.9	3.9	3.9	3.9
Direct Personnel	11.0	11.0	15.0	14.5	14.5	14.5	14.5
Chemical Sciences-KC03							
Operating Costs	1.1	0.8	1.3	1.4	1.4	1.4	1.4
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	1.1	0.8	1.4	1.5	1.5	1.5	1.5
Direct Personnel	1.4	1.0	6.6	6.2	6.2	6.2	6.2

Table 6.1-10, continued. Science detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Engineering & Geosciences-KC04							
Operating Costs	1.7	1.7	2.3	2.5	2.5	2.5	2.5
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	1.7	1.7	2.4	2.6	2.6	2.6	2.6
Direct Personnel	2.5	3.2	10.0	10.2	10.2	10.2	10.2
Math, Information, & Computation Science-KJ01							
Operating Costs	3.3	3.4	3.5	6.2	6.2	6.2	6.2
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	3.3	3.4	3.5	6.2	6.2	6.2	6.2
Direct Personnel	8.0	9.5	10.8	17.9	17.9	17.9	17.9
Advanced Energy Projects-KJ02[c]							
Operating Costs	0.8	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	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Advanced Energy Projects-KJ03							
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	0.0	0.0	0.0
Facility Operations-KA02							
Operating Costs	0.8	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	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.6	0.0	0.0	0.0	0.0	0.0	0.0
High-Energy Technology-KA04							
Operating Costs	1.2	1.3	2.3	2.8	2.8	2.8	2.8
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	1.2	1.3	2.3	2.8	2.8	2.8	2.8
Direct Personnel	1.5	1.3	10.0	12.6	12.6	12.6	12.6
Heavy Ion Physics-KB01							
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	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 6.1-10, continued. Science detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Heavy Ion Physics-KB02							
Operating Costs	0.1	0.4	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	0.1	0.4	0.5	0.5	0.5	0.5	0.5
Direct Personnel	0.1	0.9	2.5	2.5	2.5	2.5	2.5
Low-Energy Physics-KB04							
Operating Costs	0.6	0.6	0.6	0.6	0.6	0.6	0.6
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	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Direct Personnel	0.3	0.9	3.0	3.0	3.0	3.0	3.0
Total Science							
Operating Costs	60.6	61.7	67.6	73.1	73.1	73.1	73.1
Capital Equipment	6.5	0.4	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	67.1	62.1	68.2	73.7	73.7	73.7	73.7
Direct Personnel	197.3	217.2	307.8	307.3	307.3	307.3	307.3
General Purpose Equipment	3.2	3.2	3.2	3.2	3.2	3.2	3.2
General Plant Projects	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.
[c]Uncosted obligations less than $50,000.

Table 6.1-11. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Post-2006 Completion-EW02							
Operating Costs	1.0	0.2	0.7	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	1.0	0.2	0.7	0.6	0.6	0.6	0.6
Direct Personnel	0.2	1.0	2.2	2.3	2.3	2.3	2.3
Site/Project Completion-EW04							
Operating Costs	43.0	43.3	45.3	47.6	47.6	47.6	47.6
Capital Equipment	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.4	7.1	1.5	0.0	0.0	0.0
Total Cost/Funding	44.0	44.7	52.4	49.1	47.6	47.6	47.6
Direct Personnel	177.9	189.4	186.9	196.1	196.1	196.1	196.1
Program Direction (Defense)-EW10							
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	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Technology Development-EW40							
Operating Costs	4.1	3.3	2.1	2.3	2.3	2.3	2.3
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	4.1	3.3	2.1	2.3	2.3	2.3	2.3
Direct Personnel	17.3	14.0	7.3	8.9	8.9	8.9	8.9
Energy Supply Research - Post-2006 Completion Waste Management (non-D)-EX02							
Operating Costs	1.5	1.6	1.6	1.7	1.7	1.7	1.7
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	1.5	1.6	1.6	1.7	1.7	1.7	1.7
Direct Personnel	6.0	6.8	5.5	6.6	6.6	6.6	6.6
Total Environmental Restoration & Waste Management							
Operating Costs	49.7	48.4	49.6	52.2	52.2	52.2	52.2
Capital Equipment	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.4	7.1	1.5	0.0	0.0	0.0
Total Cost/Funding	50.7	49.8	56.7	53.7	52.2	52.2	52.2
Direct Personnel	201.8	211.2	202.0	213.9	213.9	213.9	213.9
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.3	0.4	0.8	0.4	0.4	0.4	0.4
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-12. Environmental Safety and Health detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Line Management Support-HC11							
Operating Costs	0.5	0.2	0.1	0.1	0.1	0.1	0.1
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	0.5	0.2	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1.6	1.0	0.4	0.4	0.4	0.4	0.4
Health Studies-HD20							
Operating Costs	3.0	2.9	2.7	2.8	2.8	2.8	2.8
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	3.0	2.9	2.7	2.8	2.8	2.8	2.8
Direct Personnel	9.6	10.0	7.9	7.9	7.9	7.9	7.9
Total Environmental Safety & Health							
Operating Costs	3.5	3.1	2.8	2.9	2.9	2.9	2.9
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	3.5	3.1	2.8	2.9	2.9	2.9	2.9
Direct Personnel	11.2	11.0	8.3	8.3	8.3	8.3	8.3
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-13. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Nuclear Research & Development-AF							
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	1.0	0.0	0.0	0.0	0.0	0.0
Naval Reactors Development-AJ							
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atomic Vapor Laser Isotope Separation-CD1008							
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	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Program Management Services-CD1012							
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	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Depleted Uran Hexaflour Cyl & Maint.-CD1015							
Operating Costs	0.1	-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	0.1	-0.7	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Transparency Measures-CD30							
Operating Costs	6.1	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	6.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	17.4	0.0	0.0	0.0	0.0	0.0	0.0

Table 6.1-13, continued. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Program Direction - Nuclear Energy-KK05							
Operating Costs	0.1	0.9	0.5	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	0.9	0.5	0.6	0.6	0.6	0.6
Direct Personnel	0.0	4.0	2.2	2.6	2.6	2.6	2.6
Total Nuclear Energy							
Operating Costs	6.9	0.6	0.8	0.9	0.9	0.9	0.9
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	6.9	0.6	0.8	0.9	0.9	0.9	0.9
Direct Personnel	18.9	5.0	2.2	2.6	2.6	2.6	2.6
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-14. Fossil Energy detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Coal Research-AA							
Operating Costs	0.0	0.3	3.0	4.7	4.7	4.7	4.7
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	0.0	0.3	3.0	4.7	4.7	4.7	4.7
Direct Personnel	0.1	1.8	10.9	16.9	16.9	16.9	16.9
Natural Gas Research-AB05							
Operating Costs	0.4	0.7	1.2	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	0.4	0.7	1.2	1.2	1.2	1.2	1.2
Direct Personnel	0.9	2.7	6.9	6.8	6.8	6.8	6.8
Petroleum Research-AC1000							
Operating Costs	0.0	0.0	0.0	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	0.0	0.0	0.5	0.5	0.5	0.5
Direct Personnel	0.0	0.0	0.0	1.0	1.0	1.0	1.0
Exploration & Production Supporting Research-AC1005							
Operating Costs	1.1	2.0	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	1.1	2.0	3.0	3.5	3.5	3.5	3.5
Direct Personnel	4.3	11.7	12.8	12.9	12.9	12.9	12.9
Exploration & Production Supporting Research-AC1015							
Operating Costs	0.1	0.2	0.2	0.2	0.2	0.2	0.2
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	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.3	0.6	0.8	0.8	0.8	0.8	0.8
Total Fossil Energy							
Operating Costs	1.6	3.2	7.4	10.0	10.0	10.0	10.0
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	3.2	7.4	10.0	10.0	10.0	10.0
Direct Personnel	5.6	16.8	31.4	38.4	38.4	38.4	38.4
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-15. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Energy Conservation-Industries of the Future-ED18							
Operating Costs	0.3	0.5	0.8	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	0.5	0.8	0.3	0.3	0.3	0.3
Direct Personnel	0.9	1.0	2.4	0.8	0.8	0.8	0.8
Energy Conservation-EE							
Operating Costs	4.2	4.1	7.0	6.8	6.8	6.8	6.8
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	4.2	4.1	7.0	6.8	6.8	6.8	6.8
Direct Personnel	10.6	11.1	21.6	21.1	21.1	21.1	21.1
Solar & Renewable Resource Technologies-EB							
Operating Costs	1.7	3.1	3.8	5.1	5.1	5.1	5.1
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	1.7	3.1	3.8	5.1	5.1	5.1	5.1
Direct Personnel	5.1	11.0	13.4	16.0	16.0	16.0	16.0
In-House Energy Management-WB00							
Operating Costs	0.5	0.0	0.2	0.2	0.2	0.2	0.2
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	0.0	0.2	0.2	0.2	0.2	0.2
Direct Personnel	4.2	0.0	0.2	0.2	0.2	0.2	0.2
Total Energy Efficiency & Renewable Energy							
Operating Costs	6.7	7.7	11.8	12.4	12.4	12.4	12.40
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	6.7	7.7	11.8	12.4	12.4	12.4	12.4
Direct Personnel	20.8	23.1	37.6	38.1	38.1	38.1	38.1
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-16. Management and Administration detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Human Resource & Admin-WM10							
Operating Costs	0.7	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	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.4	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-17. Policy, Planning, and Program detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Policy, Planning, & Program Analysis-PE							
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	0.1	0.1	0.1	0.1	0.1	0.1	0.1

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-18. Office of Civilian Radioactive Waste Management detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Civilian Radioactive Waste Management - DF01							
Operating Costs	0.3	0.4	0.1	0.1	0.1	0.1	0.1
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	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.5	1.1	0.2	0.2	0.2	0.2	0.2

[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-19. Other DOE detailed resource breakout by program element (in millions of dollars; personnel in FTEs).

Major Program	FY 1999 BO	FY 2000 BA	FY 2001[a] BA	FY 2002[a] BA	FY 2003[b] BA	FY 2004[b] BA	FY 2005[b] BA
Work for Other DOE Integrated Contractors							
Operating Costs	31.1	31.5	29.1	30.0	30.0	30.0	30.0
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	31.1	31.5	29.1	30.0	30.0	30.0	30.0
Direct Personnel	103.9	103.9	103.9	103.9	103.9	103.9	103.9
Work for Other DOE Installations							
Operating Costs	42.6	68.3	99.5	95.6	95.6	95.6	95.6
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	42.6	68.3	99.5	95.6	95.6	95.6	95.6
Direct Personnel	142.4	177.5	158.7	158.7	158.7	158.7	158.7
Total Other DOE							
Operating Costs	73.7	99.8	128.6	125.6	125.6	125.6	125.6
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	73.7	99.8	128.6	125.6	125.6	125.6	125.6
Direct Personnel	246.3	281.4	262.6	262.6	262.6	262.6	262.6

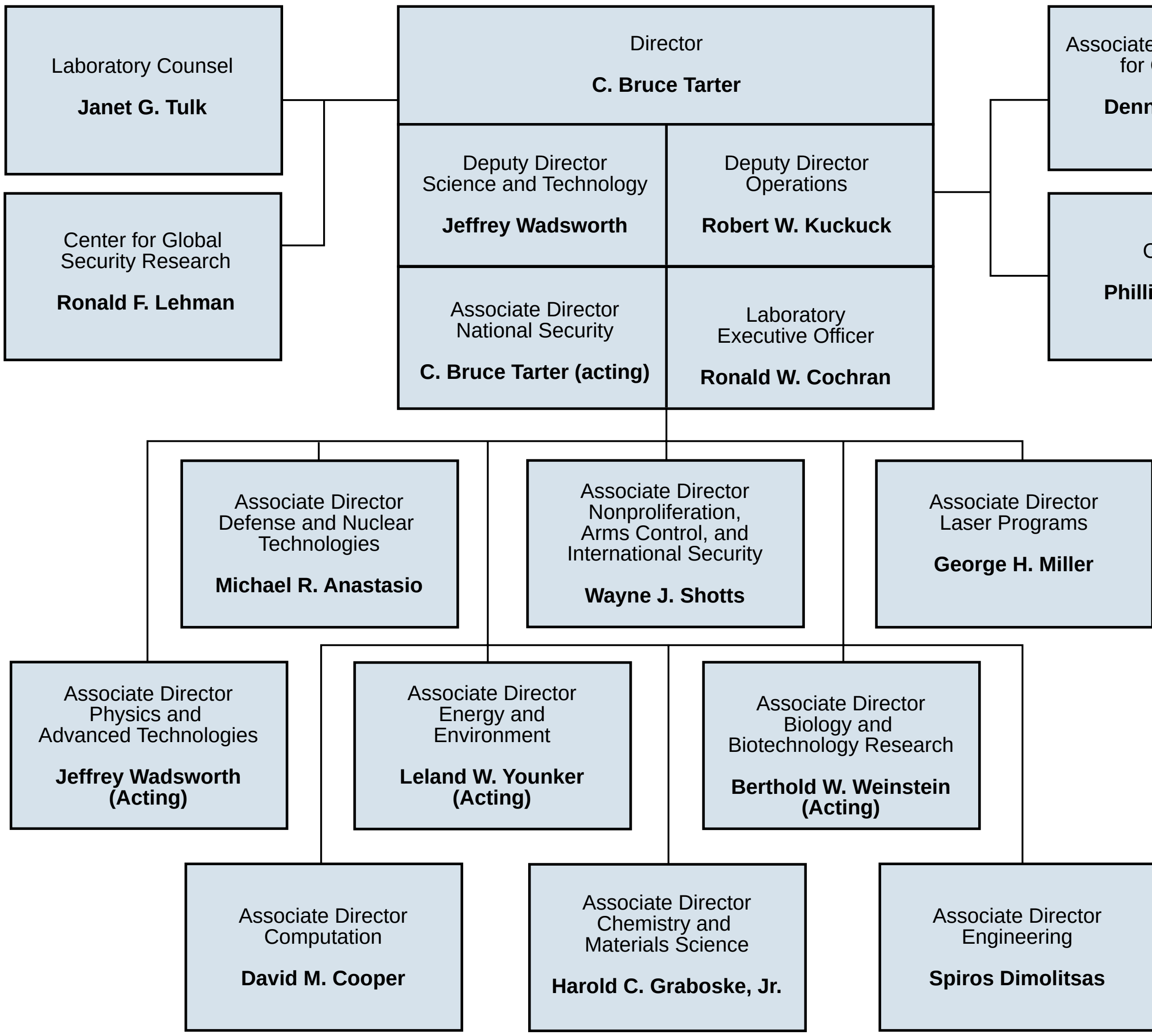
[a]For FY 2001 and 2002, escalation of 2.0% for operating expenses and 3.7% for pay and personnel-related items.
[b]FY 2003 and beyond in constant FY 2002 dollars.

Table 6.1-20. Small and Disadvantaged Business Procurement FY 2000[a] (BA in millions of dollars).

Procurement category	FY 1998	FY 1999	FY 2000
Procurement from small and disadvantaged businesses	43.9	45.0	184.1
Percent of annual procurement	12.1%	15.9%	39.1%

[a]Prior to FY 2000, the calculation was made for businesses that were both small and disadvantaged.

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

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

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

Department of Energy Strategic Plan: Strength through Science Powering the 21st Century, U.S. Department of Energy, September 2000, www.cfo.doe.gov/stratmgt/plan/doespla n.htm.

Integrated Safety Management System Plan Description, LLNL, Livermore, CA, UCRL-AR-132791, February 2000.

Laboratory Directed Research and Development FY 1998, LLNL, Livermore, CA, UCRL-LR-113717-98, 1999.

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

LLNL 1999 Executive Summary—Affirmative Action Plan for Women, Individuals with Disabilities, and Covered Veterans, LLNL, Livermore, CA, UCRL-AR-111638-99-#XE-SUM.

LLNL Comprehensive Site Plan, LLNL, Livermore, CA, UCRL-MI-110253-99, March 1999.

LLNL Site 300 Comprehensive Site Plan, LLNL, Livermore, CA, UCRL-MI-130630-00, August 2000.

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

Site Annual Environmental Report, LLNL, Livermore, CA, UCRL-50027-99, September 1999.

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

The National Ignition Facility and the Stockpile Stewadship Program, U.S. Department of Energy, Office of Defense Programs, DOE/DP-0143, April 2000.

2020 Foresight: Forging the Future of LLNL (The Report of the Long-Range Strategy Project), LLNL, Livermore, CA, UCRL-LR-137882, January 2000.

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. Article topics and their Internet addresses are listed below. Additional topics can be found using *S&TR*'s search engine. Hard copies are available through the Off-Site Requests Coordinator (address above).

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

2.1.2
- High Explosives for Surveillance: www.llnl.gov/str/Lundberg.html
- Enhanced Surveillance of Weapons: www.llnl.gov/str/Kolb.html
- High Explosives: www.llnl.gov/str/Grissom.html
- Materials Aging: www.llnl.gov/str/Lemay.html

2.1.3
- Subcritical Experiments: www.llnl.gov/str/Conrad.html

2.1.4
- ASCI White Supercomputing: www.llnl.gov/str/Seager.html
- Computer Simulations for ASCI: www.llnl.gov/str/Christensen.html
- Modeling High Explosives: www.llnl.gov/str/Simpson99.html
- Lasers for NIF: www.llnl.gov/str/Payne.html
- Laser Targets: www.llnl.gov/str/Lowns.html
- NIF Laser Developments: www.llnl.gov/str/Powell.html
- NIF Controls: www.llnl.gov/str/Vanarsdall
- NIF Ignition Experiments: www.llnl.gov/str/Haan.html
- TATB: www.llnl.gov/str/Pagoria.html

2.2.1
- Proliferation Prevention Technologies: www.llnl.gov/str/Dunlop.html

• Surplus Weapons from the Cold War: www.llnl.gov/str/Gray.html
• Working with Russia: www.llnl.gov/str/Dunlop2.html

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

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

2.3.1
• Combat Simulation: www.llnl.gov/str/Shimamoto.html
• Leveraging Science and Technology: www.llnl.gov/str/Coll.html
• High Explosives in Stockpile Surveillance: www.llnl.gov/str/Lundberg.html
• Explosives: www.llnl.gov/str/Kury.html
• Detonation Modeling with CHEETAH: www.llnl.gov/str/Fried.html
• Actinides: www.llnl.gov/str/Terminello.html

2.3.2
• Argus Protection System: www.llnl.gov/str/Davis.html
• Forensic Science Center: www.llnl.gov/str/Andresenhi.html

Section 3
• Energy Overview at LLNL: http://www.llnl.gov/str/Energy.html

3.1.1
• Argus Security Protection System: www.llnl.gov/str/Davis.html
• Simulations of Geologic Changes at Yucca Mountain: www.llnl.gov/str/Glassley.html

3.1.2
• Corsica: Simulations for Magnetic Energy: www.llnl.gov/str/Cohen.html
• Hydrogen Fuel: www.llnl.gov/str/pdfs/03_96.3.pdf
• Electromechanical Battery: www.llnl.gov/str/pdfs/04_96.2.pdf
• Unitized Regenerative Fuel Cell: www.llnl.gov/str/Mitlit.html
• Carbon Dioxide in Global Warming: www.llnl.gov/str/Duffy.html

3.1.3
• Dangers of MBTE: www.llnl.gov/str/Happel.html
• ARAC Forewarns of Hazards: www.llnl.gov/str/Baskett.html
• Environmental Cleanup Basics: www.llnl.gov/str/Jackson.html
• Groundwater Cleanup—Hydrous Pyrolysis Oxidation: www.llnl.gov/str/Newmark.html

3.2.1
• Joint Genome Institute: www.llnl.gov/str/Brandscomb.html
• Structural Biology: www.llnl.gov/str/Balhorn.html
• DNA Sequencing: www.llnl.gov/str/Ashworth.html
• High-Speed DNA Sequencing: www.llnl.gov/str/Balch.html

3.2.3
• Structural Biology: www.llnl.gov/str/Balhorn.html
• Kidney Gene with Human Genome Program: www.llnl.gov/str/Hamza.html

3.2.4
• Osteoporosis: www.llnl.gov/str/pdfs/06_96.3.pdf
• Ergonomics Research: www.llnl.gov/str/Burastero.html
• Peregrine: www.llnl.gov/str/Moses.html
• Technology for Stroke Attack: www.llnl.gov/str/

3.3.1
• Laser Experiments with Hydrogen: www.llnl.gov/str/Cauble.html
• Plasmas of Distant Stars: www.llnl.gov/str/Springer.html
• Acoustic Models and Algorithms: www.llnl.gov/str/Clark.html
• Material Behavior at the Atomic Level: www.llnl.gov/str/Moriarty.html
• Antimatter to Protect the Stockpile: www.llnl.gov/str/Howell.html
• Laser Guide Star and Adaptive Optics: www.llnl.gov/str/Olivier.html
• Metallic Hydrogen: www.llnl.gov/str/pdfs/Nellis.html
• Petawatt Laser: www.llnl.gov/str/Petawatt.html
• MACHO: www.llnl.gov/str/pdfs/04_96.1.pdf
• B-Factory: www.llnl.gov/str/VanBib.html
• Microtechnology Center: www.llnl.gov/str/Mariella.html
• Atomic Engineering: www.llnl.gov/str/Barbee.html
• Petawatt Laser: www.llnl.gov/str/MPerry.html

3.3.2
• 1997 R&D 100 Awards: www.llnl.gov/str/10.97.html
• 1998 R&D 100 Awards: www.llnl.gov/str/10.98.html
• 1999 R&D 100 Awards: www.llnl.gov/str/10.99.html

3.4.1
• 1998 R&D 100 Awards:
www.llnl.gov/str/10.98.html
• 1999 R&D 100 Awards:
www.llnl.gov/str/10.99.html
• 2000 R&D 100 Award:
www.llnl.gov/str/Roberson.html

3.4.2
• Methane Hydrate Surprises:
www.llnl.gov/str/Durham.html
• B-Factory:
www.llnl.gov/str/VanBib.html
• Visalia Cleanup:
www.llnl.gov/str/Newmark.html

3.4.3
• Laser Collaboration with University of Rochester: www.llnl.gov/str/Olivier.html
• Center for Accelerator Mass Spectrometry:
www.llnl.gov/str/Holloway.html
• Diamond Anvil Cell:
www.llnl.gov/str/pdfs/03_96.2.pdf
• Positron Technology:
www.llnl.gov/str/Howell.html
• Bridge Seismology and Modeling:
www.llnl.gov/str/McCallen.html

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

4.1.2
• ASCI White and Terascale Supercomputing:
www.llnl.gov/str/Seager.html
• Computer Simulations for ASCI:
www.llnl.gov/str/Christensen.html
• Data Visualization Tools:
www.llnl.gov/str/Quinn.html

4.1.3
• ASCI White and Terascale Supercomputing:
www.llnl.gov/str/Seager.html

4.3.1
• Carbon Dioxide in Global Warming:
www.llnl.gov/str/Duffy.html
• Energy Overview at LLNL:
www.llnl.gov/str/Energy.html

4.3.3
• DNA Sequencing:
www.llnl.gov/str/Balch.html
• Kidney Gene with Human Genome Program: www.llnl.gov/str/Hamza.html

4.3.5
• Computational Biochemistry:
www.llnl.gov/str/Balhorn.html

4.3.7
• Positron Technology:
www.llnl.gov/str/Howell.html

4.4.1
• Hydrogen Fuel:
www.llnl.gov/str/pdfs/03_96.3.pdf
• Unitized Regenerative Fuel Cell:
www.llnl.gov/str/Mitlit.html

4.5.1
• Nuclear Waste:
www.llnl.gov/str/pdfs/03_96.1.pdf
• Fusion Plan Cleanup:
www.llnl.gov/str/pdfs/06_96.2.pdf
• Surplus Weapons from the Cold War:
www.llnl.gov/str/Gray.html
• Energy Overview at LLNL:
www.llnl.gov/str/Energy.html

4.5.2
• B-Factory:
www.llnl.gov/str/VanBib.html
• Positron Technology:
www.llnl.gov/str/Howell.html
• Next Linear Collider:
www.llnl.gov/str/VanBibber.html

4.5.3
• Computational Mechanics:
www.llnl.gov/str/Raboin.html

4.5.4
• Atmospheric Release Advisory Capability:
www.llnl.gov/str/Baskett.html

Printed on recycled paper.

University of California
Science & Technology Review
Lawrence Livermore National Laboratory
P.O. Box 808, L-664
Livermore, California 94551