Institutional Plan

FY 1996 – 2001

Lawrence Livermore
National Laboratory

University of California

October 1995

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Lawrence Livermore
National Laboratory
University of California

October 1995

UCAR-10076-14

Preface

The *Institutional Plan* is intended to be a comprehensive source of information on the technical and operational activities that Lawrence Livermore National Laboratory (LLNL) is doing and planning to do.

In this year's document, readers will find several changes:

- Increased emphasis on strategy.
- Compressed program descriptions.
- Additional references (Section 4) that give users access to in-depth information.
- A survey form that gives readers the opportunity to evaluate the document and suggest further improvements concerning its content and function.

How to find information in the *Institutional Plan*

Quick Find	Index, Appendix 4.4, lists key topics and where they are discussed. Contents, beginning on the next page, lists the major topics in their order of presentation.
Status and Future	The Director's Statement indicates the overall status and direction of our Laboratory. Section 1.1, Planning for the Future, contains institutional strategic planning information and major initiatives for future programs and facilities. Section 1.2, Strategic Plans, summarizes the strategies of major programs, supporting science and technology activities, and critical institutional operations. Section 1.3, Initiatives, are proposed as major additions to existing programs or as new directions within our missions.
Programs	Section 2, Scientific and Technical Programs, is organized by sponsoring agency and briefly describes major activities in terms of recent accomplishments and near-term objectives. Use the Index to locate specific topics.
Operations	Section 3, Institutional Infrastructure, describes activities in the areas of communications and information; human resources; environment, health, and safety; business practices; and site and facilities.
Budgets	Section 4.1, Program Resource Requirement Projections, contains five budget tables, including two top-level funding and personnel summaries, and three detailed program projections. Each table is organized by funding source.
For More Information	Appendix 4.2, References, lists sources of more in-depth information, including both scientific and institutional publications and internet addresses.
Acronyms	Appendix 4.3, Acronyms, contains real English explanations for deciphering our verbal efficiencies.
Laboratory Organization	Inside the back cover, the chart shows our organizational structure and the programmatic responsibilities of our directors.

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Institutional Plan Readers' Survey

For what purpose do you use the *Institutional Plan*?

- ❑ Strategic plans
- ❑ Descriptions of programs
- ❑ Financial information
- ❑ Facility information
- ❑ Other _____

Is the *Institutional Plan* interesting to you?

_____

_____

Does it meet your needs?

_____

_____

What sections/features are most useful?

_____

_____

What additional information would you like to see?

_____

_____

Were you able to find what you were looking for? Please check what you used:

- ❑ Table of contents
- ❑ Index
- ❑ Text headings
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- ❑ Financial tables
- ❑ Strategic Plans
- ❑ Program descriptions

_____

_____

Who else should receive this information? (Include name, organization, and address.)

_____

_____

_____

Any other comments?

_____

_____

Your Organization _____

Position _____

Responsibilities _____

Return to: Merry O'Brien
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Fax 510-422-4116

Director's Statement

As is obvious from the local and national newspapers almost every day, the Congress and the Administration have been rethinking the priorities of national science programs. While the process is not complete, very important decisions have been made. On September 25, President Clinton issued a directive, which stated, "To meet the challenge of ensuring confidence in the safety and reliability of our stockpile, I have concluded that the continued vitality of all three DOE nuclear weapons laboratories will be essential . . . . In accordance with this conclusion, I have directed the Department of Energy to maintain nuclear weapons responsibilities and capabilities adequate to support the science-based stockpile stewardship program . . . ."

I am extremely pleased with the President's confidence in the capability of the three Laboratories to provide for the national security through the stockpile stewardship program. The Laboratories and the Department of Energy have worked very hard to develop the program that made this decision possible. It will be an extraordinary challenge to all our employees to meet the program's objective in the coming years.

In addition, the President stated that ". . . these labs must be run as efficiently as possible. I have directed the Agencies to review and, as appropriate, to rescind internal management instructions and oversight that impede laboratory performance. I have directed the Agencies to clarify and focus the mission assignments of their laboratories. I also have directed the Agencies to achieve all possible budget savings through streamlining and management improvements before productive R&D programs are sacrificed."

C. Bruce Tarter
Director

As you all know, we are in the midst of organizational and operational actions aimed at streamlining and cost cutting in the Director's Office and throughout the Laboratory. I ask your help in identifying improvements and efficiencies and your patience with and support of the needed changes. We hope that the result will be more efficient execution of the Laboratory's programs.

Throughout this period of readjustment, the Laboratory has achieved many programmatic and technical successes. We have worked closely with DOE Defense Programs to define our role in the Stockpile Stewardship and Management Program. It includes new initiatives in high-performance computing, advanced diagnostics development, and improved experimental facilities. The upgrade of the existing Flash X-Ray Facility at Site 300 to a Contained Firing Facility is planned to move ahead this year. The prototype beam line for the National Ignition Facility (NIF) has been built and used to establish the technical performance and cost estimates for NIF. Secretary O'Leary and the Congress support this project as key to stockpile stewardship, with the expectation that fusion energy, plasma science, and advanced technology will also benefit. For their work in experimental and theoretical inertial confinement fusion, Mike Campbell and John Lindl received DOE Lawrence Awards this year; and six other Laboratory scientists and engineers received individual 1995 DOE Weapons Recognition of Excellence Awards.

We are pursuing advanced technologies for global surveillance and arms detection, weapon dismantlement, disposition of nuclear materials, and cleanup of the Cold War environmental legacy. These technologies are also being put to use in commercial applications.

Brad Allenby, one of the country's foremost experts on industrial ecology, has joined us for two years from AT&T to help develop an integrated strategic plan for our work on energy, environmental, transportation, and manufacturing technologies. In these areas, we have demonstrated on-site steam cleaning of soil contaminated by spilt fuel and microbial cleanup of ground water and soil. Our new aerogel water purification scheme promises to be much more cost- and energy-efficient than any other desalinization process. Our refuelable zinc–air battery was used in an on-site

demonstration to run a municipal bus. And, the U.S. Enrichment Corporation has now officially chosen atomic vapor laser isotope separation for future commercial uranium enrichment.

In bioscience, knowledge of the human genome and genetics is accelerating. Today we know the functions of about 250 genes on chromosome 19, the chromosome for which Livermore has now produced both a nearly complete map and a library of DNA fragments. We have identified about half of those genes this year. In addition, our work on the mutation effects of cooked food protein has been broadened to include many meat and some vegetable proteins. We have also created a Center for Healthcare Technologies that is focused on the potential applications to various healthcare needs ranging from improved mammography technologies to stroke prevention and repair.

In other science and technology areas, our wide-angle astronomical camera has now detected tens of MACHOs (massive compact halo objects) once thought to contain the mysteriously missing 90% of the universe's matter. Our observations prove that MACHOs do exist, but they do not account for all of the missing matter.

Our micropower impulse radar on-a-chip has proven to be one of the most popular inventions of the last year. The commercial license fees generated to date are beginning to support the further development of this technology for automobile control systems, security systems, and detectors of buried survivors in collapsed structures or avalanches, to mention a few applications. Both the MACHO camera and the impulse radar technologies were originally developed for defense applications.

In addition, we have been granted about 95 patents this year and received five R&D 100 Awards for outstanding technology innovations.

During this past year, both Plant Engineering and Safeguards and Security received Energy Quality Accomplishment Awards from DOE for superior practices. The Laboratory was named the DOE Contractor of the Year for our successes in awarding contracts to small and disadvantaged businesses.

We also completed an employee survey on diversity that benchmarks current practice in hiring, pay, and promotion. The survey indicated that there is room for improvement, but that the Laboratory is already in the top echelon of institutions on diversity issues.

Last year, we identified global security, global ecology, and bioscience as the principal future directions for our Laboratory. When the major DOE laboratories joined together to define their vision for the future, similar themes evolved as the summarizing national technical needs: security, sustainability, and science. The President and the Secretary of Energy have confirmed our role in meeting these needs. Our goal and our expectation remain continued service to the nation through excellence in science and technology.

Section 1

Planning for the Future

Framing the Laboratory's Future 1.1

Our Laboratory is developing roadmaps and long-term goals for each of our areas of technical emphasis. The formative bases for these resulting strategic plans are: *Framing the Laboratory's Future: A Vision for Lawrence Livermore National Laboratory* (June 1994), which is summarized in the remainder of this section; the Department of Energy's reengineering initiatives; and the Stockpile Stewardship and Management Program (May 1995).

These plans and the President's recent directive (September 1995) indicate that our primary mission remains the reduction of global nuclear danger. In addition, we have significant contributions to make in the areas of energy and environmental technologies that are needed to ensure sustainable growth of our economy. We are convinced that advances in bioscience will be key to future human well being. We see these areas—global security, energy, environment, and bioscience—as the principal elements of our future mission. Although this is a time of significant change in national technical priorities and in our own programs and methods of doing business, we remain committed to continued service to the nation in areas where science and engineering will produce an enduring benefit.

Mission

The mission of the Lawrence Livermore National Laboratory is to serve as a national resource in science and engineering, focused on national security, energy, the environment, and bioscience, with special responsibility for nuclear weapons.

The Laboratory's programmatic work in support of this mission is dynamic and has been changed over the years to meet new national needs.

Core Values

To provide the scientific and technological capability needed to meet critical national missions in the next 20 years, we must cultivate and inspire a quality-driven Laboratory staff guided by the highest principles. Adherence to core values is the criterion by which our contract with the nation is evaluated.

We will continuously earn and uphold the public trust. This requires **integrity** in

- Maintaining the highest ethical standards in science and technology.
- Supporting a culture of academic freedom.
- Demonstrating personal and institutional responsibility in our business operations.
- Assuring honest, open interactions with all customers and team members within the Laboratory, in the communities we serve, and with our partners.

To solve the nation's biggest technical problems, we will have the best science, engineering, management, and people. This requires **excellence** in

- Discovering and executing creative, innovative solutions to complex problems.
- Attracting and encouraging the best available talent.
- Enhancing the diversity and capabilities of our workforce.
- Motivating and rewarding employee excellence.
- Managing business, safety, and the environment to achieve a high level of accountability in an atmosphere of continuous improvement.
- Leading or participating in cost-effective team partnerships.

As a national laboratory, we will meet the nation's needs. This requires **commitment** to

- Meeting the goals and requirements of our customers.
- Focusing our science and technology on national objectives.
- Continuously improving our productivity and efficiency.
- Aggressively helping our Laboratory and our partners achieve maximum benefit for the nation.

1.1 Framing the Laboratory's Future

Vision and Goals

Today's world requires a fresh assessment of the role of the national laboratories in general and the role of the defense laboratories and Livermore in particular. The future of our Laboratory demands change.

The Department of Energy's (DOE's) national laboratories were born out of an urgent need to direct the best that science and technology could offer to the most pressing national issues. The three national defense laboratories were created because it was believed that they could accomplish their vital mission faster, better, and with greater certainty than any combination of private industry and universities. The remarkable success of that initiative remains the foundation of these laboratories and inspires our efforts today.

Today, the challenges facing the nation have changed, but the need for the national laboratories remains. Experience has shown that these laboratories are most valuable when

- The national interest is at stake.
- The best science and technology are required.
- Large and complex research facilities are needed.
- Expertise in a variety of disciplines must be integrated.
- The technical risk is high, with the potential of very high rewards.
- A sustained commitment is needed.
- The job will go undone without federal government investment.

At Livermore, we are changing to meet today's challenges. By matching our areas of expertise to pressing national and global challenges, we are focusing on three areas of long-term importance, where our contributions are unique and valuable. These areas are:

1. ***Global Security and Reducing the Nuclear Danger.***
2. ***Global Ecology and Harmonizing the Economy with the Environment.***
3. ***Bioscience and Revolutionizing Human Health.***

Our global security program has two major thrusts: to prevent and counter nuclear proliferation by applying our expertise in nuclear science and technology, and to ensure confidence in the safety, security, and performance of the U.S. nuclear deterrent forces. The safe and secure "build-down" of the world's stockpiled weapons will be a continuing responsibility. We will be carrying out these responsibilities in concert with the other two defense laboratories as part of the DOE's integrated plan. The application of our advanced defense technologies will significantly enhance our nation's ability to use non-nuclear means for containing regional conflicts.

Harmonizing the demands of the world's economy with the needs to preserve the environment is a crucial national and global issue. Achieving this balance will require energy sources that are safe and clean, as well as manufacturing processes and consumer goods that make wise use of resources and provide for the protection of the environment. We can contribute to all aspects of this challenge—developing energy sources, working with industry to devise advanced manufacturing processes, and developing innovative and cost-effective technologies for environmental management and cleanup.

Bioscience is the new frontier of research. For the first time in history, the tools exist to decipher the genetic blueprint (DNA) and reveal the basic science of human life. This knowledge will make it possible to ameliorate, cure, or even prevent genetic diseases, thus enhancing the quality of life and decreasing the health-care costs to society. The fruits of this human biology research will undoubtedly carry over into agriculture, environmental management, and industry.

Beyond our primary focuses, we will continue to support other innovative science and technology initiatives that have the potential for high impact in their field and that reinforce our scientific and technological strengths. In addition, we remain committed to fostering science and math education to help ensure the scientific literacy of the general population and to inspire future generations of scientists and engineers.

To realize this vision, we will rely on our excellent and diverse staff. Robust quality management systems are being put in place to ensure that Laboratory operations are accountable, cost-effective, and meet measurable performance standards.

Our vision for the future aligns with the business areas identified in the DOE's strategic plan—national security, energy resources, and environmental quality—all addressed through science and technology. We will build on and enhance partnerships with DOE staff to ensure excellence in the achievement of our common goals.

Attaining our goals will also require new forms of cooperation among the national laboratories, universities, and industry. Key national facilities will be built and used by multi-institutional teams of researchers. Laboratory sites will be readily accessible to outside partners. The commercialization of new technologies will be the planned end product of these collaborative projects.

Our vision for the future of the Livermore Laboratory is one of sustained, results-oriented excellence. We are committed to serving the country as a national resource of scientific and technological expertise, dedicated to global security, the environment, and the future scientific needs of the nation.

Competencies

The most distinguishing feature of the Livermore Laboratory is our ability to integrate many, often disparate, areas of science, engineering, and management to solve complex technical problems. We have delivered, for example, fully tested nuclear weapon designs, the Nova laser, the atomic vapor laser isotope separation system, several generations of magnetic fusion facilities, world-class precision machining capabilities, and the sensor systems for the Clementine space mission.

The scientific, technological, and management capabilities developed for specific projects intertwine synergistically across program boundaries. This multidisciplinary, multiprogram approach is the Livermore way of scientific problem-solving.

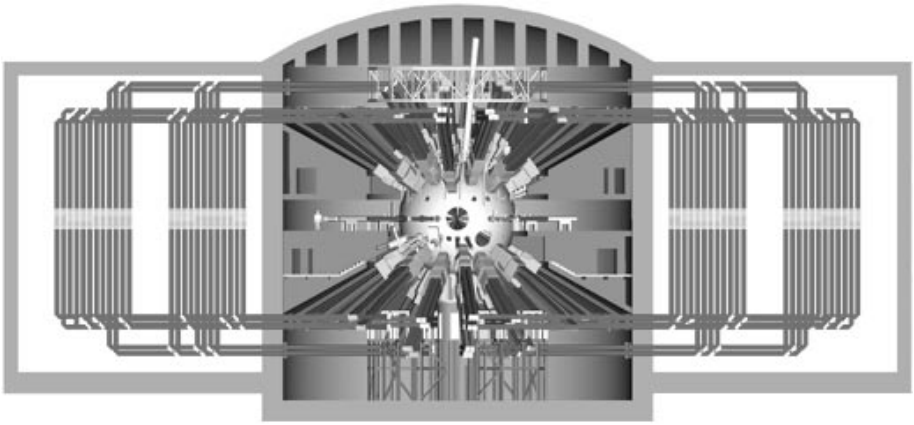
As a result of this approach to applied science, we have developed a suite of strengths that have application in a range of current and future technical endeavors. Table 1.1-1 maps the following competencies to our major program areas.

Nuclear Science and Technology

The Laboratory has demonstrated 40 years of excellence in nuclear science and technology directed at the development of nuclear weapons and the harnessing of thermonuclear and fission energy for civilian power. To fulfill our responsibilities for the enduring stockpile without nuclear testing, we must now depend on *a priori* physics knowledge, detailed computer simulations, and experiments at special national facilities that can create the extreme conditions of matter that exist in stars. Our nuclear science expertise also is being applied to stem nuclear proliferation and to develop innovative, lower-cost techniques for environmental cleanup.

Lasers and Electro-Optics

Livermore is the pre-eminent laser science and technology laboratory in the world. We have built six major laser systems, including Nova (currently the world's largest laser) and the industrially qualified atomic vapor laser isotope separation system. The laser for the proposed National Ignition Facility (NIF), being designed under Livermore's lead by the three national security laboratories and the University of Rochester, will provide more than ten times the power of Nova at a greatly decreased unit cost. We are also world leaders in applying laser and electro-optic technologies to a wide range of civilian and defense needs.



Cut-away view of the NIF target area showing the major subsystems. The laser beams will focus energy onto a target located at the center of the target chamber, which is housed in a reinforced-concrete building. Target diagnostics mounted on the chamber will collect the experimental data.

Table 1.1-1. Livermore core competencies. This matrix shows the relationship between our core competencies and the programs and missions to which they lend critical or significant support.

● Critical to program
• Significant to program

Mission / Major Program	Multidisciplinary Integration	Nuclear Science and Technology	Lasers and Electro-optics	Computer Simulation	Sensors/ Instrumentation	Biotechnology	Process/ Manufacturing
Global Security							
Stewardship of U.S. Nuclear Weapons	●	●	●	●	●		●
Nonproliferation and Arms Control	●	●	●	●	●	●	•
Disposition	●	●		●	●		●
Technology Infrastructure	●	●	●	●	●		●
Restructuring DOE National Security Enterprise	●	●		•	•		●
Advanced Conventional Weapons	●	•	●	●	●		•
Global Ecology							
Environmental Science	●	•	•	●	●	●	•
Environmental Technology	●	•	•	●	●	●	•
Magnetic Fusion Energy	●	●	•	●	●		•
Inertial Fusion Energy	●	●	●	●	●		•
Fission Energy	●	●		●	•		
Atomic Vapor Laser Isotope Separation	●	•	●	●	•		●
Conventional/Alternative Energy	●			●	•		•
Transportation	●			•	•		•
Manufacturing	●		●	●	●	•	●
Bioscience							
Genomics	●		•	●	●	●	•
Structural Biology	●		•	●	•	●	•
Biomedicine and Health Care	●	•	•	●	●	●	•
Industrial Partnerships							
Industrial Technology Base	●	●	●	●	●	●	●
Science and Technology							
Laboratory Directed Research and Development	●	●	●	●	●	●	●
Basic Energy Services	•	•	•	●	•		●
National Energy Research Supercomputer Center	●			●			
Education							
Science, Engineering, and Math Education	•	•	•	•	•	•	•

Computer Simulation of Complex Systems

Livermore's strength in computation originates with the scientists and engineers who simulate complex phenomena—for example, the behavior of fluids under extreme conditions, the structure of biomolecules, properties of "designer" materials, and changes in global climate. This work requires world-class computational facilities. We currently operate a large national-security computer center as well as DOE's National Energy Research Supercomputer Center. Livermore also operates the National Energy Sciences Network and the National Storage Laboratory. Computer modeling is our method of first resort for examining and evaluating new concepts and systems. The Center for Computational Science and Engineering modeling projects span a broad range of topics including combustion dynamics, atmospheric flows, subsurface contaminant flow, and nuclear well logging.

Advanced Sensors and Instrumentation

Our need to understand complex phenomena, ranging from nuclear explosions to the behavior of materials on a microscopic level, has driven the development of state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. Concurrent development of fiber optics, microelectronics, and technical data-processing systems has given us the capability to design and build sophisticated measurement systems. These systems are finding widespread use in such applications as nonproliferation, environmental monitoring, and space-based scientific measurement.

Biotechnology

Established more than 30 years ago to understand the effects of ionizing radiation on humans, our biomedical sciences program has transformed itself to focus on understanding health issues at the molecular level. This focus is possible because we can draw on a base of multidisciplinary expertise that integrates the physical and life sciences, computations, and engineering. We have assembled the technical infrastructure required for comprehensive studies of genetic susceptibility to disease and the mapping and sequencing of an organism's genome. We have developed many of the instruments and techniques now used worldwide in biological research, including high-speed flow cell sorters, whole chromosome paints, monoclonal antibodies, gene-mapping and DNA-sequencing technologies, and "libraries" of mapped DNA segments.

Advanced Process and Manufacturing Technology

Through our focus on applied science, we have developed a broad-based, in-depth understanding of processing and manufacturing technologies. Livermore is specifically known for innovation in chemical, biological, and photon processes; advanced materials; precision engineering; microfabrication; nondestructive evaluation; and complex-system control and automation.

Our multiprogram, multidisciplinary approach is most successful when our capabilities are complemented and enhanced by those of our partners in academia and industry.

Global Needs

By comparing the distinguishing strengths of this Laboratory with the pressing technological issues facing the nation and the world, we have identified three areas in which we can make unique and valuable contributions.

Global Security: Reducing the Nuclear Danger

The dramatic reduction of the international nuclear threat is one of the greatest accomplishments of the past decade. Nonetheless, nuclear dangers remain today and for the foreseeable future.

We are committed to providing the technical support this nation needs to help resolve political conflicts peacefully and eliminate anarchy and terrorism. At the same time, we have a continuing responsibility to help maintain a strong and flexible national defense.

To these ends, we are tackling the problems of preventing nuclear proliferation; ensuring the safety, security, and reliability of the enduring U.S. nuclear stockpile; and helping to dismantle and dispose of the materials from thousands of nuclear weapons. We are also applying our capabilities to meet the needs of the Department of Defense for conventional, high-technology weapons.

Stockpile Stewardship

As a result of the cessation of nuclear testing, new ways of ensuring confidence in the safety, security, and

performance of the U.S. stockpile are needed. Instead of an empirical approach to stockpile stewardship (based in large part on data from nuclear tests), we must develop a science-based approach. We will

• Exploit the performance and speed of massively parallel computers to expand the scope and quality of our numerical simulations.
• Devise ways of obtaining more detailed data from non-nuclear experiments.
• Use the proposed National Ignition Facility to provide critical data to help resolve stockpile issues and to attract and train the high-quality staff necessary for the stewardship program.
• Develop multiaxis, multitime radiographic capabilities for improved hydrodynamic testing.

Nonproliferation

Preventing, reversing, and responding to nuclear proliferation are top priorities for national and global security. To support these goals, we will focus our efforts as follows:

• Develop remote sensors and analysis techniques, integrated into space, air, and ground-based platforms, to detect signatures of clandestine nuclear weapons programs and to help verify international arms-control and inspection agreements.
• Provide assessments of worldwide nuclear weapons activities.
• Provide expertise and technology to establish dismantlement, tracking, and transparent accountability regimes for the control of nuclear weapons and fissile materials worldwide.
• Support cooperative activities with the nuclear inheritor states of the former Soviet Union to speed the dismantlement of their nuclear weapons and the conversion of their weapons laboratories to civilian projects.
• Develop more effective technical capabilities to find and neutralize battlefield and terrorist nuclear threats.
• Assess counterproliferation strategies using computer-based conflict simulation and comprehensive systems analysis.
• Develop advanced non-nuclear weapon and sensor systems that can be used for counterproliferation.
• Use our core competencies to support U.S. efforts to reduce the danger from other weapons of mass destruction and to support other national and international security interests.

Dr. Edward Teller and Russian Professor Vadim Seminyinko at dinner during an international conference on protecting Earth from astoroid collisions.

Dismantlement

We have enduring responsibilities for ensuring the safe and environmentally sound dismantlement of the retired weapons and for the safe storage and long-term disposition of the nuclear materials. Of particular concern is the long-term storage and disposition of special nuclear materials. We will

• Develop technologies and procedures for verifying the dismantlement of nuclear weapons, for processing the materials for disposition, and for allowing the nuclear materials to be placed under international safeguards without releasing information that would aid proliferant nations.
• Develop technologies for disposition of excess fissile materials for the U.S. and in conjunction with the Russian Federation.
• Develop technologies for the environmentally sound disposal of high explosives and other weapon materials.

Advanced Conventional Weapons

Technologies developed for the nuclear weapons program will be pursued for Department of Defense applications, including highly intelligent weapons, high-performance

explosives, and high-technology countermeasures. These activities will provide the dual benefits of maintaining and enhancing our nuclear-weapon core competency while addressing defense problems.

Global Ecology: Harmonizing the Economy with the Environment

A sustainable economy requires that the demands of production and consumption be in harmony with the global environment and with resource constraints. This balance requires energy that is abundant, safe, and clean; transportation systems that do not pollute; and production and consumption processes that use resources wisely, recycle materials efficiently, and dispose of wastes safely. For these advances to be truly effective, they must derive from a globally held view and provide for widespread economic development without causing adverse ecological changes.

This vision is a challenge, one that will require the best efforts of the world's scientific and political institutions. Re-engineering the industrial-economic system to one that supports the environment is a global priority. The Laboratory has begun developing technologies that will support U.S. leadership in this worldwide endeavor.

Environment

To ensure that new activities do not cause ecological harm, we need a fundamental understanding of the global environment, and the benefits, risks, and costs of alternative options. Livermore is a world leader in environmental modeling, with decades of experience in the assessment of hazards. We will broaden the scope of these efforts in order to develop the elements of a comprehensive Earth-system model that integrates the impact of human and natural activities on Earth's environment.

Of near-term importance are issues related to environmental remediation and treatment of toxic wastes. The proposed Mixed Waste Management Facility will provide a testbed for evaluating technologies for treating previously untreatable mixed waste (waste that is both radioactive and chemically toxic). In addition, we are providing the technical bases for major elements of the Yucca Mountain Site Characterization Project to provide safe disposal of high-level radioactive waste.

Energy

An evolving mix of fossil, fission, and renewable energy—each producing progressively less environmental impact—can meet this nation's energy needs for the next half-century with the development of appropriate policies and technologies. To this end, we have developed the atomic vapor laser isotope separation (AVLIS) process to reduce the cost and environmental impact of processing fuel for fission reactors. We are also improving the safety of reactor control systems, fuel transport, and high-level waste disposal.

Fusion is being developed internationally as the energy source for the long term. Our magnetic fusion work is carried out in collaboration with international partners to develop the tokamak concept as well as alternative concepts that should lead to smaller, cheaper reactors for the next century.

We are world leaders in inertial fusion research. Building on the accomplishments of the Nova laser, we expect to demonstrate energy gain for the first time ever with the proposed National Ignition Facility.

Transportation and Advanced Manufacturing

Transportation and manufacturing play key roles in the economy, in the environment, and in defense. These industries must strive to achieve essentially zero emissions, energy efficiency, safety, and cost effectiveness.

Our contributions to transportation technology will come from work on energy storage systems for electric vehicles, on lightweight ultrahigh-mileage gasoline-powered vehicles, and on hydrogen as an alternative transportation fuel.

We will also apply our expertise in precision manufacturing (materials, fabrication, assembly) and nondestructive evaluation to improve the quality, efficiency, and environmental soundness of commercial processes for both civilian and defense missions. This expertise will contribute to the Advanced Design and Production Technologies initiative of Defense Programs.

Bioscience: Revolutionizing Human Health

We are part of an accelerating revolution in biology and biotechnology. Advances in these

areas will have a profound impact on human health, on environmental management and remediation, on agriculture, and on industrial processes and products.

This program is a natural for Livermore. The research is inherently multidisciplinary, drawing not only on the life sciences but also on all the physical sciences, engineering, and computing sciences. In addition, a variety of technologies not normally associated with biological research is proving central to this work, including accelerator mass spectrometry, lasers, and microfabrication. The opportunity to make truly significant discoveries that will dramatically improve the well-being of mankind, now and in the future, demands our most innovative efforts.

Our goal is nothing less than an understanding of the basic physics and chemistry of life as recorded in DNA—the genome, or master template, for an organism's genetic heritage. The knowledge gained will be applied to ameliorate, cure, or prevent disease and to improve the quality and decrease the cost of health care. The results of our human-biology efforts will also have important applications and extensions into agriculture, environmental management, and industry.

Genomics

We are engaged in an international effort to decipher the genetic code of the human genome. We have developed many of the technologies that make this endeavor possible. We have almost completed the mapping of human chromosome 19 and will soon begin work on other sections of DNA relevant to human health problems. The infrastructure developed for decoding human DNA will be applied to study the genomes of plants, animals, and micro-organisms on a priority basis.

Structural Biology

We are unraveling the three-dimensional structure of proteins and other biomolecules to learn how these molecules interact with DNA. With this knowledge, it may be possible to design or engineer specific biomolecules. This undertaking requires an extensive array of diagnostic and analytic instruments together with advanced research facilities, many of which we have already at Livermore. Our goal is to engineer biomolecules to improve human health and the environment and contribute to a better quality of life.

Disease Susceptibility

We will undertake a comprehensive assessment of the effect on human health of exposures to chemicals and radiation. Methods and data developed in this assessment will lead to a science-based analysis of risk, which will facilitate important decisions regarding cost/benefit trade-offs. With our pioneering work in genomics, coupled with state-of-the-art capabilities for detecting ultratrace levels of DNA damage, we will develop a better understanding of human genetic variation and the consequences of DNA damage. We will concentrate our efforts on the genes responsible for DNA repair, metabolism, and gene expression.

Bioinstrumentation and Health Care Technology

An integral part of our biotechnology research is the development of advanced tools and instrumentation. To focus this effort on opportunities for improving the quality and decreasing the costs of health care, we have formed the Center for Health Care Technologies. This center will coordinate the Laboratory's multidisciplinary efforts in biotechnology, with particular focus on minimally invasive medicine, diagnostics and imaging, microsurgical instruments, and medical information management.

We are adapting unique technologies originally developed for defense and other Livermore programs to high-priority problems in health care. In the long run, the success of this program will be measured by health problems avoided or cured, health-care cost savings, and extended benefits for other human needs.

PARTNERING

Partnering with the DOE, other laboratories, government agencies, industry, and academia has become a primary mechanism for accomplishing our programmatic objectives.

The recent reduction in classified research and development presents an historic opportunity to open up the Laboratory to an increasing variety of collaborations. It is our goal to make this Laboratory user-friendly and more easily accessible to the public and to

the technical community. We want partnering with the Livermore Laboratory to be a compelling business decision.

The knowledge and tools developed at Livermore will be applied in both the public and private sectors. Our partnering efforts will be successful if the intended benefits are measurable by our partners and sponsors at national levels—that is, if the parties involved find that these endeavors lead to technically improved, cost-effective products; provide for more effective use of capabilities and facilities; and make significant contributions to the U.S. economy and other national missions.

Partnering with the DOE

Our partnership with the DOE is both contractual and based on the common vision of service to the nation. Our mission, goals, strategies, and plans are all developed in concert with the DOE. We share a commitment to excellence, diversity, and total quality.

Partnering with the University of California

We are, of course, an integral part of and managed by the University of California. In 1992, the University and the DOE signed a performance-based management contract that enables a new era of management effectiveness and efficiency. This contract redefined our relationship with the University, a relationship that we believe is critical to our success. University management fosters and facilitates high standards of intellectual quality, openness, and objectivity, under which the Laboratory has been able to contribute to the solutions of critical national problems in defense, energy, basic science, and technology. University management also makes it possible for us to recruit and maintain a staff of the highest quality, one that is energized by intellectual freedom and challenge. Laboratory staff who have had experience in academia and private industry have found that the UC-operated laboratories are truly remarkable in providing an opportunity to mesh the University's orientation to quality, excellence, and objectivity with the applications orientation found in the private sector. In combination, the University and the Laboratory represent a unique capability to address the issues of today and tomorrow, whether they be in international security, environment, energy, or bioscience.

Collaborations with Other Laboratories

In the future, the national laboratories must become interdependent to provide the best capability for the fewest dollars. Cooperation will be driven by a sharing of specialized research

Our interactions with states of the former Soviet Union expanded considerably this year. Natalia Zaitseva from Moscow State University and LLNL's Jim De Yoreo examine KDP crystals grown at Livermore as part of a Laboratory-to-Institute collaboration. Their rapid-growth technique won an R&D 100 award this year.

facilities to ensure their maximum utilization. Recent planning with other national laboratories and academia for the proposed National Ignition Facility is one example. The national laboratories will also collaborate through commercialization alliances, such as the emerging manufacturing and environmental technology centers. These alliances will facilitate the rapid development and transfer of technologies to private industry.

Partnerships with Industry

Our partnerships with industry will focus on mission-supporting industrial partnerships and technology licensing to bring our innovations to the U.S. commercial market. We currently have partnerships with more than 200 companies through a variety of cooperative research and development arrangements. Many companies will work with us through consortia, and the results should spread broadly through an industrial sector. We will also continue to work with individual companies and help stimulate entrepreneurial start-ups.

Collaborations with Academia

We continue to increase our many formal and informal research collaborations with the University of California campuses and other universities. By making our facilities and staff more accessible to the academic community, we have access to a larger pool of talent, which helps us to effectively accomplish our programmatic goals.

The University of California at Davis Department of Applied Sciences is located on our site. In addition, we have a dozen formally established institutes and centers that support hundreds of ongoing projects with academia. We will seek expanded participation of universities in collaborative projects and will increase the number of students and faculty engaged in research at Livermore. We want to be seen as an academic center for science and technology with nationwide access to our experimental facilities and staff.

Partnerships in California

California must deal with many issues involving science and technology, such as water conservation, natural resource management, earthquakes, transportation, environmental protection, and science education. We have expertise in many of these areas and can provide the technical basis to support effective decisions. In this way, we can serve as a cost-effective mechanism for addressing complex technical issues facing California, many of which are also challenging the nation.

Partnerships with Other Federal Agencies

Complex national issues, such as health care, the environment, and crime, increasingly require collaboration among the DOE laboratories and other federal agencies. We have unique facilities (e.g., genetics, environment, forensics laboratories) and have developed effective working relationships with the National Institutes of Health, the Environmental Protection Agency, the National Aeronautics and Space Administration, the Department of Defense, and other federal agencies. We will build upon these existing relationships and will seek new collaborations to tackle important national problems where our technical expertise can assist.

International Partnerships

Increasingly, many of our scientific and technological programs have an international dimension. Evidence of our increasing participation includes the International Thermonuclear Experimental Reactor program with Russia, Japan, and the European Community; several hundred cooperative projects with countries of the former Soviet Union; and laser projects with France and England.

Managing Effectively

Our goal is to be recognized by our industrial and academic customers as a well-managed, forward-looking organization that performs world-class research and development. The challenge we face is to increase the quality of our business practices and to reduce costs.

A strong partnership with the University of California, the DOE, our suppliers, and others who have key

roles in Laboratory operations is critical to our success. We will strengthen team efforts by developing and implementing the adaptable management systems needed in today's complex business environment.

Assuring a Talented and Diverse Workforce

The Laboratory's principal asset is a quality workforce. Our goal is to create a work environment second to none, one that attracts and encourages talent and diversity. Our recruitment, reward, and advancement decisions will be based on merit, with successful employees being those whose performance contributes to the Laboratory's objectives. We will recognize the importance of partnering by rewarding excellence for team—as well as for individual—accomplishment. We will ensure our vitality by taking pride in our work, taking responsbility for our work, improving our skills, and continuing our professional growth.

Managing for Quality

The Laboratory will operate through a system of quality management in an atmosphere of openness and trust. We expect to meet contractual and ethical standards and to be evaluated on how well we meet or exceed our programmatic and institutional goals. New methods of performance measurement and continuous improvement, which are now used in our operations, are being adapted to our research programs.

Structuring for the Future

We are structuring the Laboratory to meet our new programmatic and business goals. Matching the skills and talents of our staff to these goals is an important component of this process. We will undertake a Laboratory-wide evaluation to define and reduce all costs of doing business. In addition, we will examine ways to increase efficiency and effectiveness, including contracting out work, simplifying procedures, decentralizing, and redeploying major functions.

Achieving Excellence in Environment, Safety, and Health (ES&H)

Livermore will set the standard among major research laboratories for environmental stewardship and employee safety and health. The challenge is to achieve ES&H excellence within the cost benchmarks of the best industrial practices. Experience shows that ES&H excellence saves money through improved employee morale and worker productivity. Meeting this goal requires that we and the DOE take a new look at system requirements, compliance, and regulation. We will apply science-based cost/benefit assessment in our management of ES&H.

Opening Up the Laboratory for Effective Partnering

We will reconfigure the Laboratory site to make as much of the area as possible accessible to our partners and customers. We will make our people, data, and facilities more accessible through open information networks and through high-performance networks that allow remote access to key experiments, such as the networks that are being developed among fusion energy research partners. Our goal is to make Livermore the first-choice meeting ground for blending new ideas from all our partner communities.

Strategic Plans 1.2

We have formulated specific strategic plans for each of our major program areas and institutional activities. The six groups of plans presented here stem from the DOE's strategic plan, Defense Programs' (DP's) stockpile stewardship and management plan, and our own understanding of the Laboratory's future responsibilities.

Global Security includes all of our defense work. Global Ecology covers our energy, environment, transportation, manufacturing, and basic energy sciences programs. Bioscience is treated separately. Science and Technology includes Laboratory Directed Research and Development Program as well as our basic capabilities in physics and space technology, chemistry and materials science, engineering, and computation. Collaborations include industrial partnering and science education.

The Institutional Infrastructure section is modeled on the DOE's critical success factors. It includes communications and information; human resources; environment, health, and safety; management practices; and our site and facilities.

Global Security

Stewardship of U.S. Nuclear Weapons

The nation's posture in regard to nuclear weapons is undergoing historic changes. The nuclear forces of the U.S. and the former Soviet Union are being dramatically reduced, and nuclear testing has stopped. Still, nuclear deterrence remains central to our national defense structure. We face the extraordinary challenge, mandated by the President, of keeping critical expertise intact and certifying the safety and reliability of our nuclear stockpile without the ultimate validation provided by underground tests. Furthermore, the danger of nuclear proliferation and the possibility of incidents of nuclear terrorism are of increasing concern.

Specifically, the challenges are to fulfill our responsibility for stockpile stewardship and our commitment to arms control; to transform the laboratory and production capabilities to support the smaller stockpile as cost effectively as possible; and to preserve our core intellectual and technical competencies by implementing a program directed at a comprehensive, fundamental understanding of the science and engineering of nuclear weapons. Our plans have been developed as we worked closely with DOE Defense Programs, and they reflect our contributions and commitment to *The Stockpile Stewardship and Management Program* (May 1995).

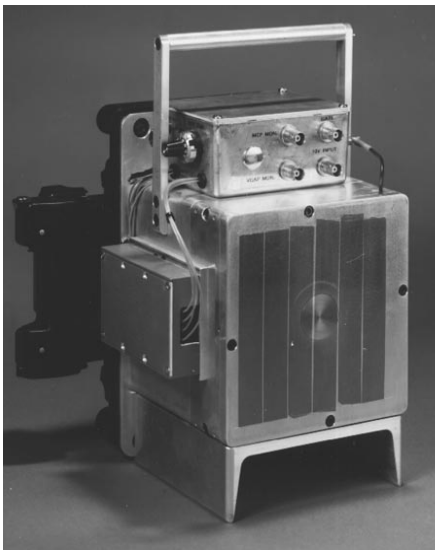
Vision

An effective deterrence is based on

- Confidence in our nuclear stockpile, which will require confidence in our judgment on nuclear issues based on fundamental scientific understanding and enhanced experimental facilities.
- The capacity to sustain into the future a reliable and safe reduced stockpile.
- The capability to reconstitute, if necessary, testing and production capacity.

Goals

- High confidence in the safety, security, and reliability of the enduring stockpile.
- Effective arms control and prevention of nuclear proliferation.
- A substantially smaller, safer, and more cost-effective production capability.



With this new gamma-ray camera, we can obtain more accurate and more informative images of imploding primaries in flash x-ray experiments. In particular, this camera produces images of much higher resolution (at least double that possible with previous instruments) and therefore much greater detail; it can also obtain images at much later stages in the implosion process.

• The ability to reconstitute nuclear test capability and larger production capacity.

Issues

• Achieving a balanced distribution of assets and responsibilities within Defense Programs such that costs are minimized, production requirements are met when needed, and critical competencies are carefully arrayed to provide innovative problem solving, peer review, and valid certification of weapon systems.
• Completing the local and program-wide environmental impact statements (PEIS) and other enabling assessments.
• Achieving operation of the new facilities and capabilities needed to support stockpile stewardship and management on the time scale needed to avoid gaps in capability.
• Making efficient use of capabilities to cost-effectively meet the requirements of deterrence and arms control and nonproliferation.

Strategies

• Use a mix of enhanced facilities and capabilities to maintain confidence in the stockpile, including
  – Advanced hydrodynamic facilities to test primary implosion physics and to confirm the initial conditions for secondaries.
  – The proposed National Ignition Facility to test aspects of high-energy-density physics and secondary performance effects.
  – Enhanced computational capabilities for better modeling of the physics of nuclear weapons and their performance (ASCI, Accelerated Strategic Computing Initiative).
  – Treaty-compliant experiments with fissile materials.
• Analyze stockpile lifetimes, surety upgrades for existing weapons, and weapon replacement options.
• Archive and update current weapons data and experience.
• Carry out a vigorous program of "first principles" weapon-physics understanding.
• Improve testing and evaluation methods for the surveillance program.
• Demonstrate integrated design, engineering, and manufacturing capabilities (ADaPT).
• Encourage industrial partnership and the development of supportive industrial technology integral to ADaPT.

We developed a portable chemical-analysis instrument to accurately analyze samples at an inspection site, a key issue related to the Chemical Weapons Convention. The latest generation of this instrument is contained in a small suitcase and weighs only 23 kg (~50 lb).

Success Indicators

• Development of advanced engineering and manufacturing capabilities to improve surveillance and to help maintain the stockpile.
• Improved understanding of the physics for each warhead component and weapon system adequate to resolve ongoing and foreseeable weapon system problems.
• Ability to integrate physics understanding and stockpile surveillance activities with other elements of the stockpile stewardship and management complex, thereby achieving confidence and flexibility at reduced cost.
• Ability to maintain the nuclear competence of our scientists and engineers and to attract and train new people.

Nonproliferation, Arms Control, and International Security

The Nonproliferation, Arms Control, and International Security (NAI) directorate leads the Laboratory's response to the nation's top security concern in the post-Cold War era—the proliferation of nuclear weapons. Today, NAI supports the federal government's efforts to reduce the danger from foreign nuclear weapon threats by contributing to the ability of government agencies to prevent, reverse, and respond to nuclear proliferation. NAI provides nuclear weapon and multidisciplinary expertise, field and advisory personnel, and cost-effective technology.

Vision

NAI will provide the U.S. Government with technology, analysis, and expertise that will substantially contribute to reducing all threats from nuclear weapons.

Issues

The dominant issues are related to funding and coordination of nonproliferation and arms control programs. To address these issues, the following actions are needed:

• A coordinated multi-agency effort, with the major responsibility assigned to a lead agency, in the area of preventing and responding to nuclear smuggling and potential covert delivery of nuclear weapons.
• A DOE plan consistent with the recommendations of the Galvin Report to make nonproliferation a high-priority program.
• A strong program that helps ensure interagency–laboratory communications and planning, including temporary exchange assignments of experts between agencies.

Goals

Our program goals are consistent with the DOE strategic plan objectives for nonproliferation and arms control:

• Maintain a pre-eminent technical base.
• Provide quality intelligence assessments.
• Provide a pre-eminent analytical base.
• Provide an emergency management capability.
• Develop international arms control processes.

Our project goals are also in line with the new DOE nuclear nonproliferation focus:

• Secure nuclear materials in the former Soviet Union.
• Assure safe, secure long-term storage and disposition of excess fissile materials.
• Establish transparent and irreversible nuclear reductions.
• Strengthen the nuclear nonproliferation regime.
• Control exports of nuclear technology and materials.

Strategies

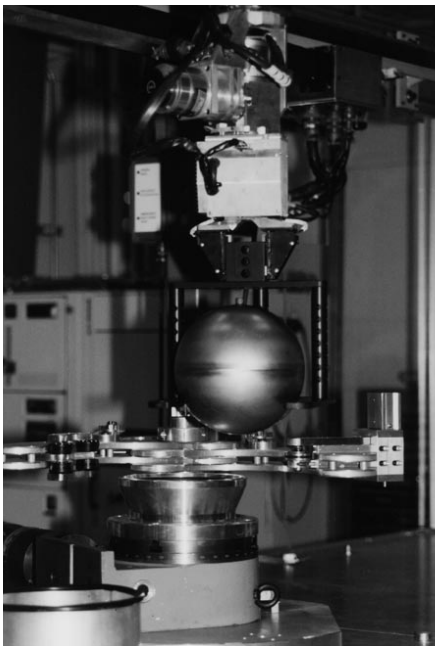
• Develop sensors, platforms, and analysis techniques that extend the capabilities to detect signatures of nuclear weapon programs and help verify international weapons and arms control agreements.
• Provide the U.S. with assessments of worldwide nuclear weapons activities.
• Provide the U.S. with expertise and technology for cooperative activities with the nuclear inheritor states of the former Soviet Union in areas that will speed weapon dismantlement, defense conversion, and control of fissile materials.
• Provide support for arms control policy makers on treaties and agreements and in response to nuclear-related crises.
• Develop technology that can find and neutralize battlefield and terrorist nuclear weapons.
• Develop concepts and technologies to support the government's goals in safely disposing of and controlling surplus fissile material.
• Assess the effect of possible counterproliferation strategies by using computer simulation and comprehensive system analyses.
• Use our core competencies to support U.S. efforts to reduce the danger from other weapons of mass destruction and to support other national and international security interests.

In all these activities, we work closely with Los Alamos, Sandia, and other national laboratories to ensure a strong and coordinated DOE program. The Laboratory works closely with government agencies that have nonproliferation and arms control responsibilities, including the Department of Defense (DoD), the State Department, the Arms Control and Disarmament Agency, the Department of Justice, and intelligence agencies.

Success Indicators

• Tasks awarded by DOE continuing or increasing at the same rate relative to other national laboratories.
• Requests by DOE for participation in the formulation, negotiation, and implementation of treaties and other bilateral and international activities.
• Requests by DOE and other government agencies for NAI personnel to serve in temporary assignments.
• Continued creation of U.S.–Russian activities that contribute to the goals of nonproliferation and arms control.
• Development of sensors and equipment that proves capable of detecting proliferation signatures and monitoring treaties.
• Development of equipment and technology that can respond to nuclear-related emergencies.
• Successful exercises showing emergency response capability.

• Production of intelligence analyses that are used in the formulation of national estimates and policies related to foreign threats.
• Development of concepts that can safely and irreversibly dispose of fissile material.
• Development of simulation codes and system analyses that can help the U.S. military reduce costs and be better trained.
• Transfer of national security technologies to U.S. industry for development.
• Spin-off of national security technologies to civilian benefits.



Disassembly of nuclear weapons and the disposition of their materials continue to be important national issues. The Laboratory has developed an innovative, automated technique to disassemble weapons and remove material by a hydride/dehydride process. The spherical unclassified mock object above was used to develop this technique.

Dismantlement

The DOE plays a central role in the safe, secure, and timely dismantlement of nuclear weapons and in the storage and eventual disposition of components and materials. These activities support the reductions being made in the U.S. stockpile as a result of arms-control treaties as well as reductions being made in the Russian stockpiles.

Over the next ten years, major reductions will occur in the stockpiles of both countries, particularly with the ratification of the START I treaty and attempted ratification of START II. Thousands of warheads will ultimately be dismantled. Due to the backlog of weapons and the full pipeline of returns, the DOE's Pantex Plant in Amarillo, Texas, will continue to dismantle well over a thousand weapons per year until the 1997–1998 time frame.

Warhead dismantlement and disposition require care and attention to details. We are committed to providing the people and expertise needed to fulfill our responsibilities for these activities. To expedite the safe and secure dismantlement of nuclear weapons, multidisciplinary teams from the Laboratory will work with those who actually dismantle weapons.

Vision

As the size and composition of the U.S. stockpile changes, the Laboratory is being called upon with increasing frequency to provide the scientific and technical expertise needed to dismantle the nation's nuclear weapons safely and efficiently.

Goal

Our present goal is to assist in dismantling LLNL-designed warheads, specifically the W48, W55, W56, W70, W71, W79, and W68. Our primary emphasis is on
• Helping ensure the safety of the dismantlement process.
• Providing scientific and technical review.

Strategies

• Provide close monitoring of equipment and procedures for the dismantlement of LLNL-designed warheads.
• Ensure that dismantlement process is consistent with environmental, safety, and health standards.
• Address the problems of long-term storage and disposition of weapon components and materials.
• Support U.S. efforts to assist weapon dismantlement in the former Soviet Union.

Success Indicators

• Timely and safe dismantlement of LLNL-designed weapons.
• Development of advanced technologies for rapid and safe dismantlement and disposition of components and materials.
• Solution of long-term storage issues.
• Timely assistance to the Russian republics to conduct similar activities.

Advanced Conventional Defense

As part of our global security mission, we are developing technologies to maintain the superiority of U.S. conventional forces. Technological superiority is a principal characteristic of our U.S. military advantage that enables affordable, decisive military capability.

Dramatic changes in the world situation have affected our national

security posture. With the end of the Cold War, there have been heightened threats of regional conflicts, proliferation of weapons of mass destruction, and increased demand for peacekeeping and humanitarian missions. At the same time, the force structure has been reduced, and development and production of new weapon systems have been sharply curtailed.

Almost from its very beginning, Livermore has engaged in work for federal agencies other than the DOE. The Atomic Energy Act of 1954 authorized the DOE laboratories to perform R&D for other entities if private facilities or laboratories were inadequate.

Application of LLNL-developed nuclear weapons technology is synergistic with enhancement of the U.S. conventional defense in many critical technologies, such as energetic materials, warhead design, advanced materials, assessments of lethality, vulnerability, and survivability.

Vision

Our objective is to enhance the U.S. military technological edge and develop options for decisive military capabilities. Solving challenging defense problems is a significant factor in maintaining and enhancing Laboratory core competencies, which yield significant benefits in both nuclear and conventional defense technologies as well as national economic security.

Goal

• Establish a more substantial, sustained, and successful working relationship with DoD.

Issues

• Department of Defense budget constraints will limit these programs and decrease their synergistic benefit to DOE Defense Programs.
• These same constraints can decrease the Laboratory's ability to respond to new challenges and to contribute to the nation's defense technology base.
• Finally, the new defense challenges cut across traditional organizational lines within the DoD and DOE.

Strategies

• Establish a new Livermore DoD Program Office to:
– Serve as the vehicle to maintain, broaden, and strengthen LLNL's DoD programs through sound business planning.
– Encourage the diversification of the LLNL technical portfolio as new DoD strategic thrust areas are developed.
• Effectively use LLNL resources to focus on DoD challenges.
• Encourage joint efforts with U.S. industry that can apply and enhance core mission.
• Focus on DoD customer orientation.

Success Indicators

• DoD customers' satisfaction and the extent to which there are future mutual benefits.
• Demonstrated ability to meet schedules and milestones.
• Demonstrated ability to create innovative concepts and solutions.
• The number and total dollar value of newly funded DoD initiatives and the growth of overall DoD funding.
• The extent to which DoD programs contribute to LLNL's other main missions—especially in the stewardship of nuclear weapons technology and nonproliferation.
• The extent to which DoD programs aid in maintaining key core competencies at critical masses and allow us to spin off nuclear weapons technology to advance conventional defense.

Global Ecology

In order to develop an integrated strategic plan for our energy and environmental programs, Dr. Braden Allenby, Research Vice President for Technology and Environment at AT&T and author of a book and many papers on industrial ecology, has recently accepted a two-year assignment at Livermore as Director of Energy and Environmental Systems. He will head a council of the directors and program leaders of the affected programs. The results of this planning effort will begin to appear in next year's *Institutional Plan*.

Magnetic Fusion Energy

Magnetic fusion has shown steady scientific progress worldwide during the past 20 years, with the key confinement parameter approximately doubling annually; recent experiments have demonstrated the beginnings of fusion burning of the plasma. The national goal is to demonstrate a magnetic fusion power reactor that would begin operating about 2025. In 1991, the DOE Secretary's Fusion Policy Advisory Committee advanced a program plan and budget consistent with this goal.

International cooperation has been identified as the means of sharing the cost and technical risks of large-scale fusion devices, such as the International Thermonuclear Experimental Reactor (ITER), which is being designed to demonstrate long-pulse ignition and nuclear testing.

We are participating in the research, development, and engineering design of ITER. We are also heavily involved in both the DIII-D tokamak at General Atomics and the Tokamak Physics Experiment (TPX) at Princeton University. We are developing comprehensive computational tools for modeling tokamaks in a large-scale, integrated manner. Our overall focus is on improving the tokamak concept and on exploring innovative magnetic fusion energy concepts, with a view to making a fusion reactor that is smaller and less expensive.

Vision

We envision working in partnership with others as part of the national and international magnetic fusion programs to develop a baseline fusion energy electric power source that is affordable, safe, and environmentally responsible.

Goals

• Advance the physics and technologies required for a magnetic fusion reactor.
• Improve the tokamak concept for magnetic fusion to make a smaller, less-expensive reactor.
• Develop comprehensive computational models to evaluate fusion concepts.
• Explore innovative magnetic fusion concepts seeking qualitative improvements in projected reactor costs, safety, and environmental impacts.
• Advance international cooperation in magnetic fusion energy to share the cost and technical risks of large-scale fusion devices.

Strategies

• Participate in experiments on the DIII-D tokamak to strengthen the physics and technology of magnetic fusion reactors.
• Participate in the design and construction of and experiments on the TPX to improve the tokamak concept.
• Develop comprehensive computational tools for modeling fusion plasmas in a large-scale, integrated manner.
• Explore innovative magnetic fusion energy concepts using theory and numerical modeling, experiments, and exploratory reactor designs.
• Participate in the engineering design and research and development of ITER to advance international cooperation.

Success Indicators

• An experimental demonstration on DIII-D of advances in tokamak science involving tokamak divertors, increases in stored plasma energy, and other key issues.
• Responsibility for and participation in significant science and technology on the TPX, including physics analysis, construction of major subsystems, and important diagnostics.
• Positive effect of computational modeling on fusion understanding and experimental advances.
• A thorough and convincing evaluation of exploratory concepts.
• Responsibility for engineering design and research and development of ITER.

Inertial Fusion Energy

In the long term, inertial fusion energy has the potential for producing commercial electric power. We are planning and conceptually designing systems that define the technological requirements of this application.

Vision

The development of inertial fusion energy will provide a clean, abundant source of electric power, promote U.S. leadership in new energy technologies, reduce the adverse environmental impacts associated with energy production from fossil fuels, and reduce our nation's dependence on imported oil.

Goals

• Understand the science and develop the technology of inertial confinement fusion (ICF) to achieve ignition and high energy gain.
• Finalize target and driver requirements for achieving high gain.
• Develop inertial confinement fusion reactors.

Strategies

• Continue the development of advanced solid-state laser technology.
• Work with Lawrence Berkeley National Laboratory on their Induction Linac Systems Experiment to evaluate heavy-ion-driver options for an inertial fusion Engineering Test Facility.
• Work with Los Alamos and the University of Rochester to advance the science of inertial fusion.
• Use the proposed National Ignition Facility to achieve thermonuclear ignition and moderate energy gain.

Success Indicators

• Achievement of energy gain.
• Demonstration of inertial fusion energy for civilian applications.

• Definition of engineering requirements for inertial fusion as an electrical energy source.
• Successful collaborative efforts with private industry.
• Successful collaborative efforts with private industry in the form of a transfer of AVLIS technology to U.S. Enrichment Corporation (USEC) and its suppliers, and activation of an atomic vapor laser isotope separation (AVLIS) -based enrichment plant at a production site.

Fission Energy and Systems Safety

Anticipated growth in the worldwide energy demands in industrialized and developing countries will stimulate demand for additional baseload generation. The harsh environmental impact of fossil fuel production and consumption should favor the use of technologies with low environmental impact such as nuclear power.

The Laboratory has more than 60 programs related to fission energy and a broad range of nuclear-system-design and safety-analysis projects. With nearly 20 years of experience in systems technology, safety engineering, and licensing, the Laboratory is an objective and technically respected intermediary for the reactor industry, the nuclear regulatory agencies, and the public.

Vision

We will apply the multi-disciplinary engineering and scientific capabilities of the Laboratory to all aspects of fission energy utilization. These activities will maintain and enhance our ability to respond to important national interests in reactor safety as well as in all elements of the nuclear fuel cycle—from fuel production to the final disposition of radioactive waste.

Goals

• Maintain a key role in all aspects of the nuclear fuel cycle, including fission energy.
• Provide guidance and support to future national and international nuclear fuel cycle and fission energy programs.

Issues

• Safety.
• Waste management.
• Proliferation of nuclear weapons.

Strategies

• Identify the root causes of engineering and safety issues that concern various U.S. Government agencies involved with nuclear and non-nuclear facilities.
• Propose the development of methodologies and strategies for studying and resolving these issues.
• Transfer and implement advanced engineering and safety technologies to those agencies.
• Work with the DOE to establish a mechanism to collaborate with other federal agencies, private industry, and foreign countries.
• Streamline the process of formalizing agreements with industry so that we can be more attractive to industrial partners.
• Identify areas where DOE interoffice coordination is needed to foster the development of new capabilities.

Success Indicators

• Implementation of a suitable nuclear waste repository for the country.
• The successful disposition of nuclear material from warheads of the U.S. and the countries of the former Soviet Union.
• The safe utilization of fission energy and issues associated with next-generation advanced fission reactors.
• The use of risk-assessment techniques in the promulgation of environmental, safety, and health policies and regulations.
• The deployment of the LLNL Argus security system across the DOE national security complex.

Atomic Vapor Laser Isotope Separation

The AVLIS technology has been successfully demonstrated at plant scale and is ready for deployment. As a consequence of the Energy Policy Act passed by Congress on October 24, 1992, sponsorship of the Laboratory's research and development in AVLIS has become the responsibility of the USEC, a government corporation. The USEC board has decided to proceed with the implementation of AVLIS technology.

Vision

AVLIS will provide an economical, environmentally improved method to enrich natural uranium or uranium tailings for light water reactor fuel. AVLIS has also been developed for gadolinium enrichment to provide improved reactor fuel control materials.

Goals
• Establish long-term business arrangements with USEC.
• Transfer the AVLIS technology to the USEC organization.
• Continue risk reduction in key technical areas of plant-scale equipment in support of AVLIS deployment.
• Support USEC in key activities including plant licensing, deployment, and strategic planning.
• Begin design and engineering that lead to licensing, construction, and production for the uranium plant.

Issues
There are several risk factors that could impact achievement of overall goals, including:
• Continuing need in the enrichment market for a low-cost production capacity when blended-down recycled from weapons enters the civilian fuel cycle.
• Regulatory schedule delays associated with Nuclear Regulatory Commission licensing.
• Establishment of metal-base fuel cycle interfaces.
• Integration of USEC and Laboratory organizations and coordination of facility use.

Strategy
• Support USEC in their deployment of a uranium-enrichment plant.

Success Indicators
• Completion of AVLIS technology development and demonstration for USEC.
• Participation of LLNL technologists in USEC's plant deployment project organization.
• Transfer of AVLIS technology to USEC and its suppliers, and activation of an AVLIS-based enrichment plant at a production site.

Alternative and Advanced Energy Programs

Achieving energy security is essential to the health of the U.S. economy and the maintenance of national security. We are challenged to develop energy technologies that can provide a reliable energy supply, stimulate economic growth, and improve the competitiveness of U.S. industry while not adversely affecting the environment. These goals must be addressed within the context of increased U.S. reliance on imported crude oil, the accompanying strains on U.S. security and a balance-of-payments deficit, and increased concern about the long-term environmental effects of the use of fossil fuels.

Vision
We will develop technologies to better use near-term energy resources that improve energy security, flexibility, and our environment.

Goals
• Reduce U.S. reliance on imported fossil fuels by simultaneously
  – Enhancing the domestic production capability of fossil and alternative fuels.
  – Improving the efficiency of using those fuels, particularly in transportation.
• Develop new fuel-efficient technologies, such as advanced batteries or a hydrogen-fuel capability, that drastically reduce emissions from vehicles in the transportation sector.

Issues
• Can LLNL define programs for working effectively in partnership with industry?
• Will industry adopt components designed and tested by the Laboratory for use in advanced vehicles and energy systems?
• Will there be public support for government investment in R&D?
• Will U.S. energy technology be globally competitive?

Strategies
• Develop partnerships between the DOE and U.S. industry that can enhance our ability to create relevant technologies and accelerate their introduction into the marketplace.
• Develop alternatives to gasoline internal-combustion engines, such as hydrogen-powered vehicles and hybrid vehicles that use small electromechanical batteries or carbon-aerogel-based supercapacitors for peak power.
• Use an integrated systems approach to solve issues related to the production, storage, transportation, and use of hydrogen as a transportation fuel.
• Seek to improve the technology for producing geothermal energy.
• Maintain shale oil as a viable future fuel option through near-term, high-value markets, such as improved road asphalt.

Success Indicators
• Development of several new industrial partnerships each year.
• The commercialization of one major innovation of energy technology each year.

Environmental Technology

The Laboratory conducts research to assess and mitigate environmental and human risk from natural and anthropogenic hazards and to develop and demonstrate new tools for environmental restoration. We carry out this mission in several ways: developing new cleanup technologies, developing and validating predictive models in emergency response, providing economic guidance in resource availability and climate issues over generational times, creating new diagnostic techniques and methodologies to predict human risk and ecosystem response, and developing and demonstrating technologies and protocols to remediate anthropogenic hazards or mitigate natural ones.

We have a broad range of core disciplinary strengths with strong supporting technologies:

• Atmospheric radiative transfer, chemistry, dynamics, and climate processes.
• Physics of the atmospheric boundary layer and cloud processes.
• Seismic processes.
• Geochemistry and geophysics.
• Pathway, dosimetry, and risk analysis of radioactive and toxic substances.
• Isotopic and ion beam sciences.

Our supporting technologies depend in part on the human and technical resources of other directorates. We create internal collaborations to access capabilities not available to many potential competitors. These technologies include

• Creation, testing, and operation of coupled models of climate, chemistry, and ecosystems on massively parallel computers.
• Mesoscale modeling of atmospheric processes.
• Modeling of subsurface flow and transport.
• Subsurface imaging and characterization.
• In-situ remediation with natural and engineered processes.
• Design, analysis, and testing of advanced waste treatment technologies.
• Sensor and diagnostic system development.
• Design, construction, and operation of complex instruments and analytical facilities.

Vision

We will be an internationally known and competitive multi-disciplinary environmental research and technology program. The program will address societal needs for minimizing the environmental and health impacts of developing new and mitigating old technologies and energy resources.

Goals

• Conduct science-based development and testing of environmental cleanup and restoration technologies.
• Assess environmental consequences of new and old technologies and energy usage to help policy makers properly balance risk and cost in legislation and other actions they take.
• Provide the technical framework and coordination for multidisciplinary environmental programs with collaborators outside the Laboratory, including the university community.

Strategies

• Develop and implement a focused business plan in conjunction with a workforce plan to identify skill requirements.
• Work with agencies outside DOE that have an interest in the global ecology, environmental assessment and mitigation, e.g., National Aeronautical and Space Administration (NASA), Environmental Protection Agency (EPA), and National Oceanographic Atmospheric Administration (NOAA).
• Foster and maintain a set of initiatives that maximize the use of the science and technologies within the program and among programs when appropriate.

Success Indicators

• Decreased cost, decreased time, and improved effectiveness of remediation technology.
• Improved specificity and sensitivity of diagnostics for environmental effects on living systems.
• Credible models for assessing the risks of environmental hazards.
• Ability to attract a range of sponsors within the federal and state governments.
• Continued ability to attract world class staff and collaborations.
• Ability to selectively attract and engage in new initiatives.

Energy, Manufacturing, and Transportation Technologies

Energy, manufacturing, and transportation problems and their impact on U.S. security and economic competitiveness are major concerns at state and national levels. We formed the Energy, Manufacturing, and Transportation Technologies (EMATT) Program to explore areas where a broad range of Livermore-developed technologies can contribute

to Accelerated Strategic Computing Initiative (ASCI) and ADaPT, and generally to national transportation and manufacturing needs. Our intent is to work with industry in addressing national needs that are beyond the scope of industry alone.

Vision

We are challenged to develop energy, manufacturing, and transportation technologies that can improve national security, stimulate economic growth, and improve the competitiveness of U.S. industry in the global market while not adversely affecting the environment.

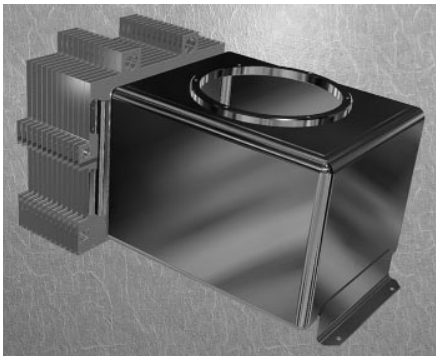
Goals

• In manufacturing, we intend to focus LLNL resources and expertise and to provide manufacturing engineering support to the DOE production complex with the collateral benefit to U.S. industrial competitiveness. Manufacturing-related projects can be grouped into the following technology areas: design, analysis, and characterization of machine tools; advanced materials and manufacturing processes; computer modeling of manufacturing processes; testing, inspection, and nondestructive evaluation; and education and training.

• In materials, our goal is to develop novel materials and processing tools to a maturity suitable for deployment in manufacturing. Our work spans materials from metal composites and lightweight metals to fiber composites and organic adhesives. Many projects include a strong three-dimensional process modeling component, with experiments to benchmark simulation predictions. Materials also cut across other work in energy and transportation. Improved materials processing, materials performance assessment and life-cycle analysis, and process numerical simulation are necessary tools to enable the materials to be manufactured on a large scale and to provide cornerstones for portions of the DOE/Defense Programs' (DP's) ADaPT and ASCI programs.

• In energy production, our goal is to reduce U.S. reliance on imported fossil fuels by simultaneously enhancing our domestic production capability for fossil and alternative fuels and by improving the efficiency of using those fuels, particularly in the transportation sector.

• To drastically reduce emissions from the transportation sector, we will develop new technologies, such as advanced batteries and hydrogen-fuel capability for vehicles.



We successfully tested the LLNL-developed refuelable zinc/air battery on site in an electric bus loaned by the Santa Barbara Municipal Transit District.

Strategies

Our strategy is to develop partnerships with DOE, other government agencies, and industry to enhance our ability to pursue mutually beneficial technologies and to accelerate their usage in the marketplace. A particularly useful approach is to find high-benefit entry-level products and to refine the technology for use in the mass market.

• In energy production and materials, we seek better ways to find, produce, and refine domestic petroleum through industrial partnerships cofunded by the Natural Gas and Oil Technology Partnership. We use computational modeling to maximize the efficiency of fossil fuels and to minimize emissions. Other objectives are to expand our oil-and-gas-production work into deepwater technologies. We will also work to enhance the production of geothermal energy and to develop new stationary energy storage devices such as flywheels, zinc/air batteries, and aerocapacitors.

• In transportation, we seek new aerogel catalysts to further reduce emissions. We also emphasize alternatives to gasoline internal-combustion engines, such as hydrogen-powered vehicles, refuelable zinc/air batteries, and hybrid vehicles containing small electromechanical batteries or carbon-aerogel-based supercapacitors for peak power. These alternatives will benefit DOE and DoD by continuing to reduce our reliance on imported fossil fuels and to improve efficiency; they also will be well suited to rugged high-voltage applications.

• In manufacturing, we intend to work with DP to integrate the past Technology Transfer Initiatives (TTI) manufacturing thrust of capabilities into the current ADaPT initiative to enhance DP manufacturing. We will identify, develop, and leverage advanced technologies to meet DP

needs and, in the process, stimulate and deploy leap-frog advances in manufacturing technologies to enhance near-term U.S. competitiveness.

• We will continue to develop materials with improved performance through control of microstructure and nanostructure. The cost-effective manufacture of such materials will be guided by increasingly sophisticated process simulation tools, which are necessary to characterize performance relative to structure and process-induced variations and to assess long-term durability under realistic service environments. This strategy will contribute directly to ADaPT, ASCI, and stockpile-surveillance requirements and will also provide superior, manufacturable materials necessary for implementing many of the objectives of the other EMATT programs.

Success Indicators

We will consider our efforts to be highly successful if we can develop several new mutually beneficial industrial partnerships each year.

• In energy resources, we intend to improve the technologies for producing economically competitive and environmentally acceptable transportation fuels. We hope to expand our role in the Industries of the Future Program in DOE/EE and the heavy oil upgrading and deepwater production activities in DOE/FE, maintain our strong participation in the ASCI and ADaPT, and expand our program in energy storage and distributed utility systems.

• In transportation, we are developing and applying defense technologies from many scientific areas to create a new generation of hybrid vehicles. The ultimate intent is that these vehicles be completely recyclable and operate at near-zero emissions using a variety of fuels.

• In materials, our success will be measured by the improvement in performance and cost effectiveness resulting from the introduction of new materials and processing tools into a variety of commercial and defense applications. The ultimate goal is to enable the completion of major national objectives through the use of improved materials and processing models.

Basic Energy Sciences

Our programs in basic energy sciences include research in the areas of materials, chemistry, geosciences, physics, and computations. In materials, we are studying interface science, superplastic deformation processes, and the phenomena important to high-power laser systems. We are also gaining an understanding of nanostructures, buried interfaces, and magnetic properties at the atomic level through the use of synchrotron radiation. In chemical sciences, we are using electron-beam ion traps to study the structure and interactions of highly charged atomic ions up to fully stripped uranium (U92+). We are also performing computer modeling of combustion processes with widely used hydrocarbon fuels in realistic environments. Our geosciences work focuses on understanding the chemical and physical interactions between rocks and fluids within the earth's crust, including the development of enhanced methods for hydrocarbon recovery. Our efforts in advanced energy projects focus on breakthroughs in lithium battery technology, new materials for advanced thermoelectric devices, and new processes for the synthesis of porous carbon aerogels.

Vision

Our programs in basic energy sciences should represent the finest scientific talent working in the best of facilities with a focus on fundamental yet mission-oriented research that benefits our society.

Goal

Our goal is to build new insight and understanding of the fundamental scientific processes that govern the behavior of energy, materials properties, and biological systems.

Issues

Changing federal priorities give an increasing emphasis on the conduct of fundamental research that has an identifiable long-term relationship to national needs. Our challenge is to select scientific endeavors that respond to this emerging requirement, while continuing to capture the importance of fundamental scientific insight.

Strategy

We will apply the extensive scientific and engineering expertise developed for our applied programs to identify and execute the underpinning scientific research that is essential to the long-range success of important DOE programs and that has collateral benefits to other federal and industrial programs.

Success Indicators

Our success will be defined by the quality of the individuals we attract to our programs, the value of our programs to government and industry, and the resource level our programs attract. The desire of the most highly qualified scientists and engineers to join us will characterize the quality of our scientific insight; the value attached to our programs by government and industry will define the success of our mission's orientation.

BIOSCIENCE

Biotechnology and Health

Biology and biotechnology research at Livermore is conducted as a multidisciplinary, team-research-oriented program. Our program maps directly onto the long-term goals of the DOE and the Office of Health and Environmental Research. In the nation and in the world, the quality of our science is highly competitive, as evidenced by our ability to attract funding from multiple sources.

Vision

Our program is driven by our vision of the 21st century—the century in which discoveries and technological developments in biology will revolutionize the practice of medicine, improve health care, enhance agricultural production, and heal the environment. This vision derives, in large part, from our participation in the Human Genome Project, an international effort to decipher the human genetic code. We plan to enter the next century with a creative, aggressive, and diverse workforce, with sufficient flexibility in core competencies to address the changing national scientific priorities.

Biomedical scientist Ed Salazar loads DNA samples into an agarose gel for analysis. He is working as part of the DNA Repair Group on a repair gene called ERCC2, which is involved in one form of the disease xeroderma pigmentosum.

Goals

- Unravel the genetic code in appropriate organisms to study the consequences of adverse environments on living systems.
- Characterize genes and their proteins that repair DNA damage and detoxify chemicals, and understand their role in reducing health risk from environmental exposures.
- Develop and apply novel engineering and computational resources to aid in biotechnology research.
- Improve human health care and facilitate future science with a view toward minimizing current and future costs associated with all components of health care.
- Ensure the transfer of the knowledge, science, and technology to industry, academia, and the general public.

Issues

- The high cost of doing business within the DOE environment has caused us to be noncompetitive for certain funding sources.
- We are concerned about adequate space, facilities, and funding to recruit, house, and maintain a stable, vibrant workforce.
- We need an increased allotment of equipment and general plant project dollars to remain scientifically competitive.

Strategies

- Maintain a high-quality genome center that provides the infrastructure needed to study the genes and proteins of any species.
- Identify, isolate, and determine the function of genes involved in DNA repair and susceptibility to disease.
- Maintain core biophysical resources for structural and functional analyses.

• Maintain core strengths in engineering and instrumentation to support the needs of our biotechnology projects.
• Establish a credible effort that contributes to the national health-care need for cost-effective technologies.

Success Indicators

• Ability to attract and retain highly competitive research funding.
• Ability to meet commitments to sponsors on time and within budget.
• Successful periodic, comprehensive, external peer reviews.
• Publication of our results in the open literature.
• Active participation in national and international collaborations.
• Participation in national and international meetings.
• Major awards, honors, and patents received by our scientific staff.
• Full compliance with the requirements for laboratory animal care, human subject research, recombinant DNA research, and environmental safety and health.

Science and Technology

Laboratory Directed Research and Development Program

Our Laboratory Directed Research and Development (LDRD) Program, funded at 6% of the Laboratory's total operating and capital equipment budgets, is an important source of innovation and vitality in the workplace.

Vision

The LDRD Program will foster excellence in science and technology that will drive the technical vitality of the Laboratory and will meet the changing DOE and national needs. We will also make significant contributions to the nation's science and technology base.

Goals

• Manage and leverage the Laboratory's resources carefully to ensure that the Laboratory's scientific expertise and key technologies are maintained and directed toward innovations that are applicable to our missions.
• Work to achieve a program portfolio that continually addresses important national needs and maintains a vital and innovative science and technology base.
• Use innovative research projects as an opportunity to attract and evaluate new staff.

Issues

• Because of declining program budgets, there is pressure to use LDRD funds to maintain Laboratory core competencies rather than engage in highly innovative and risky research.

Strategies

• Ensure that LDRD funds are used to advance an innovative science and technology infrastructure.
• Work to ensure that all major programs provide funding for an adequate technology base.
• Leverage our resources by collaborating with industry, academia, and other government laboratories.
• Provide the Laboratory's customers information about the benefits of LDRD by means of publications, presentations, and workshops.

Success Indicators

• Innovations in mission areas that can be traced to recent LDRD activities in the science and technology base.
• Ability to retain and attract a motivated and creative technical staff.
• The quality of intellectual output as measured by major prizes, citations, patents, and publications.
• The agreement by program managers that LDRD is a valuable investment.

Physics and Space Technology

Innovative research and development of new capabilities in physics, experimental science, and space technology are critical to the Laboratory's ability to address important national needs. These needs range from national security to global security, space exploration, health care, high-speed communication, environmentally conscious manufacturing, and science education.

We recently assessed our strengths and identified the following core competencies:
• Nuclear science and technology, including databases for neutrons, charged particles and photons, advanced particle detectors, nuclear structure, and reactivity.
• Properties of condensed matter, including equations of state, shock physics, properties of actinides, chemical physics of energetic materials, and synthesis and characterization of new materials at high pressures.
• Properties and characterization of novel electronic, optical, and magnetic materials, including nano-scale

simulations based on electronic structure calculations and molecular dynamics, microelectronics, and optoelectronic device physics and integration.
• Physics of radiation–matter interactions, including laser–plasma coupling, intense laser–atom interactions, effect of ionizing radiation on materials, high-energy density physics, and the physics of energetic particle beams.
• Modeling of complex physical systems, emphasizing large-scale codes integrating hydrodynamics, transport, and the treatment of electromagnetic fields with microscopic descriptions of nuclear, atomic, or chemical processes.
• Properties and characterization plasmas, including opacities, atomic processes, plasma spectroscopy, and diagnostics.
• Novel ion sources and traps for generating and confining highly charged atomic ions.
• Advanced instrumentation and sensors, including data acquisition systems suitable for very high or very low data rates, compact lightweight space-qualified cameras and multiband spectral imagers for remote sensing, and detectors with very high spectral, spatial, or temporal resolution.
• Space science and technology, including theoretical and experimental astrophysics and novel instrument payloads for a variety of airborne or space-based platforms.

On the basis of our strengths, we can make significant contributions to science-based stockpile stewardship—including the proposed National Ignition Facility, Accelerator Production of Tritium, and Accelerated Strategic Computing Initiative—as well as to nonproliferation and international security.

Vision

To continue to be world-recognized leaders in the areas of physics, experimental science, and space technology relevant to Laboratory programs.

Goals

• Conduct first-class physics research and technology development to enhance our competencies and to build new capabilities relevant to national needs.
• Be a key contributor to multi-disciplinary Laboratory programs.
• Strive for an organizational structure that cultivates expertise, enables innovation, nurtures effective collaboration with other R&D organizations, and values partnerships with our customers.
• Maintain a top-quality, flexible, and diverse workforce to accomplish the current missions and to fulfill the future needs of our organization.

Strategies

• Conduct R&D in scientific and technological thrust areas that anticipate the future needs of Laboratory programs in physics and space-technology disciplines.
• Develop and maintain cutting-edge, experimental facilities and computational capabilities to advance these thrust areas.
• Seek enhanced institutional support and funding from external sponsors to enable the development of new capabilities and the establishment of sustainable, physics-intensive programs.
• Encourage collaboration with universities, other national laboratories, industry, and other centers of excellence to facilitate the exchange of ideas and the migration of researchers to and from the Laboratory.
• Maintain the excellence and vitality of the workforce by continually rejuvenating the core staff and by conducting a vigorous postdoctoral research program.
• Use peer review to assess the quality of our work and staff, and seek advice from external reviewers such as the Physics and Space Technology Advisory Committee.

Success Indicators

• Positive assessment of our work by peers, both inside and outside the Laboratory, through their scrutiny of published documents and reports and through specific program review mechanisms.
• The quality and significance of our accomplishments, measured by customer affirmation of our capability, which includes them selecting us as their partners in solving their most challenging technical problems.
• Ability to attract and retain the highest quality workforce.
• The number and significance of awards and other formal recognition that our staff receive.

Chemistry and Materials Science

The fields and subfields of Chemistry and Materials Science provide a critical scientific and technological knowledge base necessary to assure the success of all

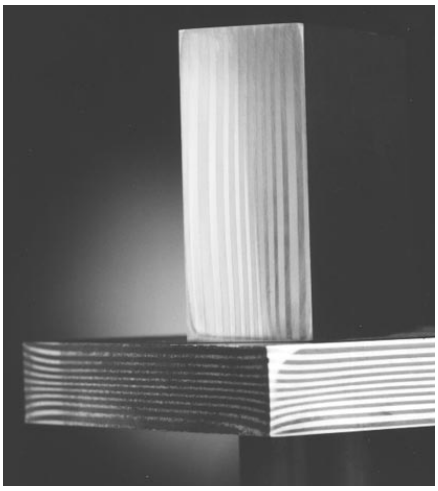
the major national programs at the Laboratory. Our skill in translating this technical and scientific excellence into technological innovation is a vital characteristic of the Department, and it is our continuing goal.

The Chemistry Department's ability to engineer novel materials (e.g., aerogels and multilayers) at the atomic or near-atomic levels, and to carry these materials forward to the processing and manufacturing sciences, has tremendous implications for new products and future laboratory needs. These diverse products include structural materials, energy-storage and energy-generation components, tailored coatings, and novel electronic, magnetic, and optical materials.

At the same time, our ability to provide specialized knowledge in energetic and special nuclear materials, manufacturing methods related to these areas, and exotic characterization techniques sustains our value to core mission programs.

We recently identified the following areas as our core competencies:

• Analytical chemistry and isotope sciences, including all major analytical instruments and custom, one-of-a-kind procedures, as well as world-class facilities for radiochemistry, nuclear particle detection and counting, and advanced mass-spectroscopy.
• Chemical engineering, including process modeling, systems integration, and pilot-plant-scale engineering.
• Metallurgy, including process metallurgy; thermomechanical processing, forming, and joining technologies; and ceramics, including cermets.
• Materials characterization, surface/interfacial science, surface-state chemistry, and a variety of atomic-resolution spectroscopies.
• Actinide chemistry, solid-state chemistry, polymers, and electrochemistry.
• Energetic materials, including synthesis, modeling, formulation, and testing at our High Explosives Applications Facility and at Site 300.
• Nanostructures, that is, the synthesis, processing, and characterization of engineered specialty materials such as aerogels, multilayers, and emissive microstructures.
• Materials theory, simulation, and modeling from *ab initio* quantum mechanical first-principles calculations, molecular dynamics simulations of processes, and constitutive and continuum mechanics applied to finite-element analysis of engineered systems.



An example of the type of superconducting, multilayered, laminated metal composite material that the Laboratory and Varian are developing as building blocks for electronic devices. It is designed for toughness and minimum fatigue as well as high vibration suppression and high damping.

Vision

We will be a world-class provider of chemistry, materials science, and processes to meet the current and future needs of Laboratory programs.

Goals

• Anticipate and initiate research and development projects relevant to current and long-term national technological and security needs, including important new areas such as science-based stockpile stewardship, the National Ignition Facility, and programs in energy and environmental research.
• Develop the necessary resources, including people, facilities, and capital equipment, to fulfill the vision.

Strategies

• Prioritize activities within our areas of responsibility on the basis of their relevancy to our core strengths.
• Seek funding sources inside and outside the Laboratory, including industrial partnerships in appropriate areas, to leverage and complement our internal investments.
• Create an exciting linkage with the academic/educational core in our nation.

Success Indicators

• A sustained high level of technical competence through continuous learning, relevant and interesting research in world-class facilities, and attraction of excellent new staff.
• The creation of programs and technology centers that have the

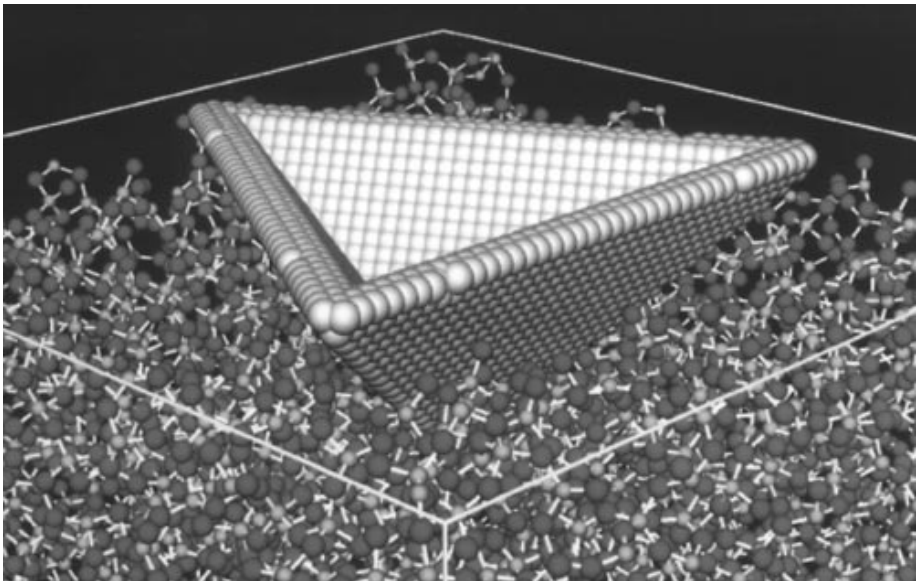
materials and process support needed to achieve their technical objectives.
• Enhancement of our national strength in materials and process science as evidenced through publications, award-recognized innovations, recognition of outstanding professional service, and strong links to the education of chemists and materials scientists.

Engineering

We are continuing our tradition of technological leadership and dynamic, innovative problem solving for our mission programs. We combine our own core capabilities and the expertise of industrial partners to achieve breakthrough engineering solutions to challenging scientific problems.

We continue to develop a set of core technologies that we view as essential to future national needs as specified in Laboratory programs. These include
• Microfabrication and microminiaturization technologies.
• Nondestructive evaluation and image processing.
• Large distributed control systems.
• Information technology and computer networking.
• Systems sciences and systems engineering.
• Computational mechanics, electronics and electromagnetics, and power conversion.
• Material characterization and fabrication processes.

We have continued to emphasize the need to be responsive to our customers—Laboratory programs, government agencies, and other external sponsors. Thus, we strive to provide quality support and innovative technical solutions in a most cost-effective manner. We have been continually examining our facilities and strategies to ensure a responsive, agile, and adaptive organization that is capable of meeting current and anticipated needs.



The ability to precisely machine ceramic surfaces like silica glass (modeled here) affects many different fabrication technologies and is central to constructing a wide range of sophisticated optics systems. To study the nanometer-scale deformation of fused silica, we pushed a diamond tip with a radius of about one nanometer into a smooth silica surface. We found that the silica surface responds much more elastically than did either the copper or silicon surfaces.

Vision

We will continue to maintain a world-class engineering capability that is recognized for its technical innovation, creativity, and reputation for responsiveness and customer focus. We will also maintain unique, cost-effective capabilities to carry innovative concepts to prototyping. We strive to provide and expect value added in all our partnerships.

Goals

• Support the Laboratory and the nation with high-quality engineering, institutional leadership, and technical management capabilities.
• Focus on state-of-the-art R&D to enhance our core strengths and ability to meet the needs of current and future Laboratory programs.
• Maintain a top-quality, diverse, and adaptive workforce.
• Support institutional needs in terms of people, facilities, and equipment.
• Support partnering with universities, centers of excellence, and industry; encourage personnel exchanges between engineering staff and university and industry partners.

Strategies

• Maintain a set of research focus areas to conduct program-oriented anticipatory research and to ensure high-quality engineering services.
• Acquire and maintain the technology base, equipment, computers, and facilities to support those research focus areas.
• Focus on sound environmental and business practices, safe work habits, and compliance with safety and security requirements.
• Continuously improve our engineering practices to perform tasks faster, better, and cheaper.

Success Indicators

• Contributions to the Laboratory's accomplishments as a world-class integrator of complex engineered systems.
• Being the collaborator of choice as reflected by the number of satisfied, repeat, and new partners and customers.
• Evidence of maintaining the highest quality staff and management personnel.
• Professional recognition through patents, awards, citations, society fellowships, conferences, and publications.
• Excellent records for safety and security and compliance with environmental requirements.
• Strict adherence to engineering core values.

Computation

Success in achieving DOE's missions increasingly depends on the enabling technologies of scientific computing, high-speed communications, and intelligent information storage and retrieval. Scientific computing and modeling technology expand basic understanding of complex problems across numerous scientific areas, including nuclear weapons design, alternative power sources, biomedical studies, environmental understanding, and, more recently, environmental restoration. High-speed communication networks enable an unprecedented sharing of resources, including remote control of physical experiments and long-distance scientific collaborations. Effective information management permits the timely extraction of information from the rapidly expanding databases currently being developed. Critical customer programs include stockpile stewardship, environmental remediation, global climate modeling, and the Human Genome Project. Each requires different combinations of computing, communications, and information management technologies to effectively provide solutions. To address critical DOE mission areas, LLNL's ability to exploit these enabling technologies must continue to grow.

For more than 40 years, Livermore computing has defined the leading edge. We are renowned for successfully applying computer modeling and simulation to large scientific and engineering problems. The Energy Sciences Network, developed and operated by LLNL for DOE Energy Research programs, is pushing forward the boundaries of high-speed global networks as it moves from today's 1.5-Mb/s links to tomorrow's 622-Mb/s optical networks. The National Storage Laboratory (proposed and spearheaded by LLNL) is developing new technologies for storing and retrieving enormous amounts of data at high bandwidths. These results and experiences provide a strong platform for building the next phases of these technologies.

Vision

Livermore will continue to provide stable computing platforms for today's ongoing needs and toward tomorrow's evolving platforms, where these enabling technologies will be more fully integrated. Information and communications technologies—such as massively parallel computers, gigabit networks, database management systems, high-performance storage systems, real-time control systems, and computer

To understand the basic mechanisms that determine how the material is removed, how surface damage occurs, and how diamond tools themselves wear, Laboratory researchers such as Christine Wu (above) study the atomic-scale processes that define surfaces in motion.

security—are maturing toward widespread use. These individual technologies must now evolve into an integrated environment of capabilities that can be exploited with ease by scientists and engineers. Examples of future interoperability include

• Efficiently moving a computational model to successively more powerful computers as the complexity of the problem demands, and automatically storing the results in the most cost-effective location.
• Remotely controlling physical experiments in real time, while gathering and analyzing the data for future experiments, and operating with the confidence that security is protecting the data's integrity.
• Cooperatively building pieces of a large database at distributed sites and efficiently responding to complex queries.

Goals

• Provide state-of-the-art technologies and facilities for computing, communications, and information management for LLNL and DOE-sponsored efforts.
• Provide computation and information expertise to researchers.
• Collaborate with academia and private industry to meet tomorrow's computing needs.
• Contribute creatively to and achieve the goals of the Accelerated Strategic Computing Initiative (ASCI).

Strategies

• Maintain a workforce well versed in state-of-the-art computer, network, and information technologies.
• Help guide LLNL and DOE management to select appropriate computers, networks, software, and supporting products and services to assure that appropriate computing resources are acquired and implemented.
• Apply our computing and networking experience to computation, communication, and information-sharing challenges of the DOE missions.
• Develop testbed environments on which to integrate key information and communication technologies.

Success Indicators

• The major programs at Livermore are satisfied with the level and quality of support provided by the Computation organization and recognize the importance of our contribution.
• Scientific computing, networking, and storage management at Livermore are recognized as world class.
• LLNL is the collaborator of choice by private industry. We are sought out for expertise and guidance in computing matters.

COLLABORATIONS

Industrial Partnerships and Commercialization

The Industrial Partnerships and Commercialization (IP&C) organization is actively pursuing dual-benefit opportunities. Over the years, we have invested heavily in the technologies and facilities needed for research and development (R&D) of the nation's strategic nuclear weapons stockpile. These unique R&D requirements have resulted in technical advances that, in some cases, exceed those applied in the commercial sector. In other technology areas, however, advances in the commercial sector have surpassed those within the DOE national laboratories. Thus, to ensure maximum return, our industrial partnering and commercialization activities are focusing on partnering opportunities to support and enhance our programmatic effort to meet important national needs in a cost-effective manner. At the same time we will provide opportunities for industries to tap into our cutting-edge technologies and facilities to bolster their global competitiveness. These collaborative efforts provide valuable institutional support, enhance DOE core competencies, support the needs of the industrial sector, and develop and maintain skills of technical staff to meet DOE mission requirements in defense, energy, and the environment.

Vision

We will strive to ensure that industrial partnering is an integral part of the way we achieve our programmatic goals in the most cost-effective manner while we contribute to the nation's competitiveness by forging partnerships and building alliances between Laboratory programs and U.S. industry, other DOE laboratories, academic institutions, and government agencies. We will manage Laboratory intellectual property to ensure the cost-effective use of our R&D resources to support DOE programmatic goals.

Goals

• Continue to pursue partnership opportunities to accomplish our programmatic goals in the most cost-effective manner.
• Pursue partnering opportunities with industries in which LLNL needs drive the high-technology market.
• Ensure that there is tangible value added to our R&D collaborators and to the U.S. economy.
• Continue to streamline and simplify the processes for establishing collaborative agreements.
• Ensure effective and efficient management of our industrial collaborations and of the Laboratory intellectual property.
• Ensure that Laboratory facilities and equipment are easily accessible to our industrial partners, as well as to other federal, state, and regional entities.

Strategies

• Develop in conjunction with representatives from Laboratory programs a long-term strategy for the IP&C organization.
• Work with the DOE and representative industry leaders to develop streamlined processes for R&D partnerships.
• Develop mechanisms to promote start-up companies based on Laboratory technologies.
• Continue to explore ways to provide effective support to small businesses, including working through regional technology alliances and similar entities.
• Increase the number of facilities available for use by our industrial partners and simplify the security requirements for accessing these facilities and the IP&C offices.
• Establish and implement a system for measuring performance, identifying deficiencies, and addressing any corrective actions.

Success Indicators

• Number of satisfied, repeat, and new partners.
• Demonstrated increase in cost-effectiveness in accomplishing DOE goals.
• Number, size, and type of industrial partnerships.
• Documented successful partnerships.
• Ability to meet stated goals, comply with budgets, and complete closeout reports.
• Number of user facilities and level of utilization.
• Number of license agreements.
• Value of royalty streams.

University Collaborations

The overall mission of our university collaborations is to contribute to the intellectual vitality of the university, Laboratory, and industrial communities by fostering cooperative basic and applied research. By facilitating the flow of ideas and people among our institutions, and by using the unique research facilities available at Livermore, we want to carry on innovative research programs that serve our missions and the objectives of our partners.

The principal vehicles for these activities are centers focused on Livermore research facilities and institutes that use resources distributed among the partners and K-12, college, and postdoctoral programs. In addition, we are coordinating our efforts with those of the UC Davis Department of Applied Sciences (at Livermore), of our Laboratory Directed Research and Development Program, and of our Industrial Partnering and Commercialization Program. All of these activities are described in Section 2.4 of this plan.

Vision

To date we have concentrated on scientific and technological projects in the areas of materials, plasmas, astrophysics, planetary physics, scientific computing, and instrumentation. Our intention is to engage more eclectic projects that bring to bear our partners' strengths in the social sciences and economics, as well as their complementary technical capabilities. Examples of such projects that are critical in our region are water resources management, earthquake hazard mitigation, waste management, air pollution, clean manufacturing. and health-care technology. We recognize that today's technological solutions must have public acceptance and support, particularly in the areas of energy and environment, but also for our national security activities. Our university collaborations afford the opportunity to do research that takes this broader context into account.

Goals

• Build upon the strength in the basic sciences that are the foundations of our important programs.
• Strengthen existing Livermore programs and foster new initiatives by providing access to university expertise, innovative ideas, and bright young people.

• Aid university–Laboratory–industry collaborations that enhance the ability of the private sector to provide the industrial base for national programs.
• Provide a broadened perspective to Livermore staff members via collaborations with university faculty and students in similar and complementary areas of study.
• Improve access to Livermore's unique research facilities by outside researchers.
• Provide a location and environment congenial to university collaborations and hospitable to students and faculty.
• Contribute to science education through enhanced classroom experiences and stimulating research environments.

Issues

• The Laboratory's University Relations organization is new, as is the broad scope of its responsibilities. Developing an effective, efficient organization to coordinate these activities within the Laboratory and with our partners is a current issue. One critical aspect is the mechanism by which we prioritize and select our initiatives.
• We have found the Laboratory's ability to move funds, resources, and people outside of the context of our traditional sponsor relationships to be a severe limitation on the flexible arrangements that are needed for these collaborations.
• The indirect costs of doing work at the Laboratory are still quite high in spite of significant cost containment and reduction initiatives.
• Many research initiatives that are expected to be important in the future do not map onto traditional government agencies or funding sources.
• We are concerned that the long-term relationship with the University of California remain viable and be enhanced in the future.

Strategies

• Develop strategic plans for specific new programs and institutes.
• Develop project-specific organizational structures and alliances that overlay and cross-coordinate line and institutional organizations.
• Develop sponsor-friendly business practices for nontraditional sponsor and partner relationships.
• Enhance both the technical and organizational relationships for these collaborations with the University of California administration, the multiple UC campuses, and the other UC-managed laboratories.
• Participate in national conferences and task forces directed at redefining federal agency responsibilities for future technical and social needs.

Success Indicators

• The extent to which university collaborations beneficially impact our missions and programs.
• The number of our collaborative research projects that make a direct and significant difference to our region or to the nation.
• The extent to which the university community has a greater knowledge of and access to the research capabilities of the Laboratory.
• The numbers of publications, university participants, Ph.D. students, and post-doctoral fellows that our university collaborations generate.
• The number of outstanding new Laboratory staff identified through these collaborations and the number of collaborators that subsequently find faculty positions.

Science Education

To compete successfully in the world marketplace, the U.S. needs a scientifically and technically literate workforce. At LLNL, the Science Education Program is helping to shape the future workforce by partnering the Laboratory's rich scientific and technical base with the education community to introduce new approaches to teaching science and math; to integrate Laboratory core competencies and technologies that enhance science education; and to provide students and educators with opportunities to conduct research and earn advanced degrees.

Our goals, strategies, and success indicators were developed collaboratively through our participation on the DOE Office of Defense Programs Education Task Force. Members of this task force included representatives from the Office of Defense Programs, LLNL, Los Alamos National Laboratory, and Sandia National Laboratories.

Vision

The Science Education Program has embarked on a new journey in its role as a catalyst for change within the education community. In addition to defining a new mission and vision, we defined a path along which our education partners enter and navigate through our world of science and learning. Those new to this world enter by way of our informal science activities. Then, they acquire basic scientific inquiry skills and are offered opportunities to immerse themselves in activities that allow them to explore a global scientific theme tied to the Laboratory core competencies. Finally, they move on to conducting

their own research, aided by Laboratory scientists and others.

Goals

The Science Education Program, as a catalyst for change, will use the unique resources of the Laboratory to facilitate partnerships and collaborations between Livermore and the global community to

- Contribute to systemic improvement in science, math, engineering, and technology education.
- Ensure a highly skilled, diverse workforce.
- Enhance scientific and technical literacy.

Issue

- The method and level of funding for these programs is uncertain.

Strategies

- Integrate our core competencies and science-based technologies with our educational efforts.
- Partner with post-secondary institutions.
- Adapt existing and emerging technologies for use in educational settings.
- Coordinate LLNL programs and activities with the local, state, or national systemic reform efforts.
- Focus efforts on multiple stakeholders.
- Strengthen Laboratory collaborations with educational institutions and other agencies.
- Provide educational and research opportunities for students.
- Provide enrichment opportunities for underrepresented teachers and teachers of underrepresented students.
- Provide access to Laboratory personnel, facilities, and equipment.
- Provide role models and mentors.
- Provide research opportunities, workshops, presentations, demonstrations, and hands-on science activities.

Success Indicators

- Presence of new tools and resources outside the Laboratory in an educational setting.
- Systemic reform collaborations with local, state, and federal organizations.
- Participation and ownership by multiple stakeholders.
- Increased number of students from underrepresented groups pursuing careers in science, math, engineering, and technology.
- Increased level of customer demand for our curriculum and resources.
- Increased interaction with Laboratory personnel.
- Electronic access to Laboratory and other technical information.
- Incentives for Laboratory personnel to participate.
- Measurably improved scientific and technical literacy.
- Measurably improved ability to use technical tools and equipment.

Institutional Infrastructure

Communication and Information

The Laboratory is a national center of applied science and technology dedicated to global security, global ecology, and bioscience. In this role we serve and involve diverse customers and stakeholders, from the scientific community and the leaders of the federal government to our local community and our own employees.

Our principal product is scientific and technological information that describes the research, development, and performance of prototype systems relevant to our missions. We are using the current explosion in communications technology to disseminate LLNL's scientific and technical information as widely as possible through implementing the Library of the Future. We also generate significant administrative information in managing our programs. Communicating this information to our various audiences is an enormous, complex responsibility.

Vision

To communicate effectively, both internally and externally,

- We will build a foundation of understanding, credibility, and trust between employees and management and with our audiences outside the Laboratory.
- We will provide immediate access to knowledge through a variety of media.
- We will build the Library of the Future, where users can get the information needed—rapidly, seamlessly, layer by layer—from sources inside and outside the Library.

Goals

- To be both responsive to and proactive with employees, our communities, and the media to assure openness and confidence in our communications.

• To continue our good record of accurate, balanced coverage in the news media, especially science coverage at the national level.
• To facilitate among various publics an understanding of Laboratory capabilities, programs, operations, and achievements.
• To present accurate and timely accounts of Laboratory developments, activities, and newsworthy events, particularly those that may generate public concern.
• To make our scientific knowledge readily accessible electronically worldwide and within the Laboratory as it is produced.
• To achieve this same access and accessibility for technological information within the constraints of partnering agreements and federal regulations.
• To provide information-retrieval tools that are progressively more sophisticated but remain consistent with formal industry standards.
• To continuously improve the capability of our administrative information systems to provide effective management controls through timely access to business information and rapid, cost-efficient operations.

Issues

• After a good beginning, can we continue to improve in openness and communication between our Laboratory and our diverse constituencies?
• Can we improve the frequency and reliability of communications with our employees?
• Can we maintain media relationships that yield balanced coverage and national exposure for our scientific achievements?
• Can we make an effective transition to the use of electronic media?
• Can we resolve the conflicting requirements of openness and security?

Strategies

• Survey key audiences to determine the level of awareness, understanding, trust, and support of the Laboratory and its activities.
• Upgrade managerial and staff communication skills and improve internal and cross-organizational communications.
• Target key audiences, implement focused communication plans, and regularly measure their knowledge of and attitudes toward the Laboratory.
• Continue and enhance proactive national and local print and broadcast media communication campaigns; target key coverage areas and large circulation; survey regularly for trends in knowledge and attitudes of both the journalists and the audiences.
• Develop and install the Library of the Future; educate the Laboratory management and staff regarding its use; use feedback to optimize its features and implementation priorities.
• Use commercial software products for managing and accessing scientific and administrative information; maintain continuous awareness of improvements in industrial practice.
• Maintain close contact with similar libraries that have embarked on similar projects, especially in the DOE complex, to ensure compatibility and avoid duplication of effort.
• Fund the development of the Library of the Future conservatively from existing Library funds.

Success Indicators

• Results from sponsor and customer surveys indicate the level of satisfaction with Laboratory efforts and accomplishments.
• Results of key audience surveys indicate improved awareness, understanding, trust, and support of the Laboratory and its activities.
• The number of queries into our electronic archive.

Human Resources

The cornerstone of the Laboratory's strength is its world-class workforce. Maintaining its vitality is a major objective as the Laboratory's mission changes. To retain and enhance this essential resource, we have identified two priorities in the near term: workforce planning and managing diversity (see also Section 3.2).

Vision

Laboratory management will continue to create a work environment that sustains workforce excellence and recognizes the diversity of our workforce as a source of strength and flexibility.

Goal 1

• Enhance the Laboratory's ability to attract and retain a workforce with the skills and flexibility required for our current and future missions through workforce planning and management.

Strategies

• Develop a workforce planning model that integrates all forms of staffing options to meet programmatic priorities.

• Address a strategy for the redeployment of career staff as a result of changing Laboratory priorities.
• Provide resources to employees in career planning and development.

Success Indicators

• The ability of programs to attract and hire needed personnel.
• The successful reintegration or retraining and placement of employees who were displaced from programs as a result of changing programmatic priorities.
• Resources are available to assist employees with career planning and development.

Goal 2

• Achieve a diverse and talented workforce.

Strategies

• Create a work environment where every segment of the employee population is valued and enabled to contribute to the goals of the work group and the Laboratory.
• Strengthen management commitment and accountability.
• Target hiring and recruiting efforts to achieve diversity and full utilization of minorities and women.
• Arrive at a common understanding and vision of diversity throughout the Laboratory.

Success Indicators

• A Laboratory-wide diversity plan that is tied to the Laboratory's strategic goals.
• Diversity initiatives to support recommendations.
• Periodic diversity training for managers and supervisors.
• Employee training program on how diversity affects day-to-day organizational tasks.
• Inclusion of diversity education in new employee orientation.
• Inclusion of diversity issues in personnel systems and policies.
• Increased diversity in recruitment, promotions, and retention consistent with our specific goals.

Environmental, Safety, and Health Management

Our Environmental, Safety, and Health (ES&H) Program helps to assure that the Laboratory puts the highest priority on the physical well-being of the workforce and the community and that it protects the environment. It also assures that the Laboratory is in compliance with applicable laws and regulations. In doing so, we aim to maximize cost-effectiveness and minimize negative effects on the workforce, the community, and the excellence of the Laboratory's work.

Vision

We will provide high-quality environmental, safety, and health conditions at the Laboratory, where every person has the means, ability, and desire to work safely and to protect the environment.

Goals

• Ensure the safety and health of employees, visitors, and the public.
• Preserve and restore the environment.
• Integrate the minimization of workplace and environmental risk and the control of hazards into the plans and actions of all Laboratory employees.
• Further reduce exposure to physical, biological, chemical, and radiologic hazards.
• Maintain our exemplary low incident and fire-loss rates.
• Proactively prevent pollution from LLNL operations.

Strategies

• Balance our priorities with our available resources to minimize human and environmental risk.
• Dedicate the resources necessary to achieve our ES&H objectives and to meet requirements.
• Comply with all federal, state, and DOE regulations.
• Develop and implement effective ES&H performance measures as outlined in Contract 48, Appendix F.
• Implement a program of continuous quality improvement and quality assurance.
• Develop an integrated ES&H program approach for increased collaboration between Health Services and Hazards Control.
• Implement a proactive accident prevention program.
• Help employees meet high environmental, safety, and health standards through training and performance evaluations.

Success Indicators

• Improved safety of employees, such as a reduction in injury-caused lost time.
• Improved cost effectiveness.
• Improved employee understanding.
• Improved audit results.

Management Practices

The Laboratory is expected to use sound management practices and assure proper stewardship of public assets and funds. We accept that responsibility.

Vision

The Laboratory will be a recognized leader in management practices that support assigned missions. These practices, achieved through continuous quality improvement, will result in customer satisfaction.

Goals

• To have management practices that support, not impede, achieving success in our scientific mission. For this goal, our customers are the managers of the technical programs.
• To have management practices that reflect excellence in business and that satisfy customer expectations. Our customers are the program sponsor, the DOE, and the University of California.

Issues

• Management practices will result in DOE's re-evaluation of the degree to which it conducts its oversight program.
• We wish to serve as a key provider of input as the DOE moves to de-federalize the procurement process and begins to apply commercial practices.

Strategies

• Self-assess current practices.
• Benchmark practices against "best in class."
• Re-engineer practices using continuous quality improvement.
• Encourage dialogue with customers to understand their expectations.
• Challenge inefficient or unnecessary practices.
• Increase benchmarking against private sector institutions.
• Increase training in management practices.

Success Indicators

• Reduced costs.
• Reduced number of process steps.
• Elimination of unnecessary bureaucracy.
• Timely support.
• Increased number of improved performance evaluations by customers.
• Increased number of beneficial practices by other institutions involved in our business.
• Increased employee effectiveness and satisfaction through awareness of good management practices.

Site and Facilities

The Laboratory's physical and programmatic diversity, rapidity of change, and funding uncertainties make the management of our capital plant and infrastructure very challenging. We have new facilities of the highest standards and old and temporary facilities, some of which cannot be brought to the equivalent of modern standards. We have simultaneous requirements for openness to our collaboration partners and the public, for the protection of defense restricted and industrial proprietary information, and for the safety and security of sophisticated equipment. Couple these conditions with very significant and rapid changes in the content of our programs, even within our traditional missions, with improved ES&H standards and diminishing capital resources. The scope of the challenge is clear.

Vision

• To create a physical environment that supports the present and future missions and visions of the Laboratory.
• To pass on these public assets to future generations in better condition than we found them.

Goals

• Enhance the physical image of the Laboratory commensurate with its standing as a nationally recognized center for basic and applied research and development.
• Consolidate and collocate functional groups into flexible facilities that foster creative collaboration.
• Ease external access to the Laboratory, while maintaining appropriate levels of security, to better facilitate collaborative research with universities, industry, and other government agencies.
• Replace or renovate temporary, outdated, and substandard facilities to provide modern, energy-efficient workspace.
• Ensure utility systems can provide present and future program support reliably and economically.
• Enhance road and pathway systems to provide safe, efficient circulation conducive to effective security and emergency response.

Issues

• Providing appropriate security while accommodating the accessibility needed for a mix of programs with various sponsors, collaborating agencies, and industrial and university partners.
• Maintaining and renewing our infrastructure within the constraints of dwindling funds, restrictions on the use of types of funding, and restrictions on capital procurement financing methods.
• Maintaining economic and ecological sustainability in land and facility use through an integrated, comprehensive planning process.

Strategies

• Achieve both adequate security and increased accessibility. We are planning to further reduce the contiguous portion of our site that is enclosed by fences and has limited access. The remainder of the site will be controlled at the level of industrial/property security, with each facility establishing a level of security appropriate to its specific programmatic needs and in accordance with DOE guidelines.
• Use individual program area plans to understand present and projected needs and interfaces as a means to integrate all program and institutional activities at LLNL into comprehensive Site Master Planning that is both dynamic and responsive to changing missions and priorities.
• Develop a Facility Assessment and Ranking System (FAaRS) as a tool for optimizing facility use, allocating scarce resources, and minimizing cost. FAaRS takes into account condition, current use, technical status, and the long-term potential and liabilities for each facility analyzed to identify prime facility candidates for removal or mothballing, renovation, or continued monitoring where status is uncertain or changing.
• Support the suggestion made at the Los Alamos On-Site Review, which stated that the current four “colors” of money be reduced, and favor a DOE “no-color money” policy.
• Re-examine, with the DOE/OAK Office, the lease-to-own mechanism for acquiring needed capital assets.
• Phase in a space-charge cost to all activities and develop other costing methods that will improve the equitability of the distribution of infrastructure costs.
• Consider special issues, such as university collaboration zones, industrial collaboration zones, and redevelopment zones.

Success Indicators

• Steady progress in assuring that the use of every square foot of facilities at LLNL provides value added to the national research effort.
• Steady completion rate of highest-priority infrastructure maintenance, renewal, and improvement projects.
• Decreased maintenance costs per facility unit.
• Reduction in backlog of maintenance.
• Reduction in substandard space.
• Results of user survey indicating improved site access and functionality for both federal programs and industry/university collaborations.
• Less energy usage, proving continuously improved energy efficiency.
• Specific and general improvements in site quality and environment.
• Endorsements by the Laboratory Site Planning and Capital Assets Management Working Group resulting from continuous total site overview.

Initiatives 1.3

The following initiatives are proposed as major additions to existing programs or as new directions within our missions. The related resource requirements presented here are not included in the detailed Program Resource Requirement Projections presented in Section 4.1 because they are not yet authorized program elements. Initiatives are provided for consideration by the Department of Energy. Inclusion in this Plan does not imply DOE approval of or intent to implement an initiative.

Assistant Secretary for Defense Programs

National Ignition Facility (GB)

The National Ignition Facility (NIF) Project supports the DOE mandate to maintain nuclear weapons science expertise required for stewardship of the stockpile. The President recently (September 1995) reaffirmed the importance of maintaining confidence in the enduring U.S. nuclear stockpile through science-based stockpile stewardship. Without underground testing, the weapons laboratories must continue to certify the safety and reliability of this country's nuclear weapons. The DOE's Defense Programs is developing a science-based stockpile stewardship program to meet this need.

A vital element of this program, NIF will provide the capability to conduct laboratory experiments that address the high-energy density physics and thermonuclear fusion issues important to performance in stockpile weapons.

The long-term goal of inertial confinement fusion (ICF) is to generate electric power. The NIF also will be used to establish the requirements for driver energy and target illumination for high-gain targets, and to develop materials and technologies needed for civilian fusion power reactors.

The ignition of an inertial fusion capsule in the laboratory will produce extremely high temperatures and densities in matter. Thus, the NIF will become a unique and valuable laboratory itself for experiments relevant to many areas of basic science and technology.

The Conceptual Design Report (CDR) for the NIF, begun after a Key Decision Zero in January 1993, was completed by a multilaboratory team led by Livermore in May 1994. The design consists of an approximately 17,000-m^2 Laser and Target Area Building containing a 192-beam, 40-cm-aperture Nd:glass laser and optical system, and a 10-m-diameter target chamber with associated controls and diagnostics. The total project's cost estimate (total estimated costs plus operating costs) of $1.1 billion, including contingency and escalation and schedule (FY 1996–2002) were validated by an Independent Cost Estimator team commissioned by the Department of Energy.

On October 21, 1994, the Secretary of Energy issued a Key Decision One for the NIF, which approved the construction Project as detailed in the CDR. In particular, Key Decision One authorized DOE to request the Office of Management and Budget to approve a Congressional line-item FY 1996 NIF project funding of $37.4 million (see Table 1.3-1) for advanced conceptual design, preliminary engineering design, optic vendor facilitation, and the National Environmental Policy Act activities. In addition, the Secretary declared Livermore as the preferred site for constructing the NIF. In February 1995, the NIF Project was formally submitted to Congress as part of the President's FY 1996 budget. Tables 1.3-1 and 1.3-2 show the resources required for this effort.

Contained Firing Facility (GB)

The flash x-radiography machine at Site 300, in conjunction with high-speed optical cameras, pin-dome technology, and multibeam velocimetry, constitutes the most versatile and complete explosives test facility in the world. The cumulative investment to date in this facility is $85 million. The proposed technical enhancement, at a cost of $49.7 million, would add a 2700-m^2 facility, including a reinforced firing chamber, a support staging area, and additional diagnostic space. This enhanced capability would make possible tests

of explosive charges up to 60 kg with improved environmental control and safety. Table 1.3-3 presents the construction costs for this facility.

Accelerated Strategic Computing Initiative (GB)

The Accelerated Strategic Computing Initiative (ASCI) is a program that will extend DOE Defense Programs' computational capability. The initiative's goal is to shift promptly from nuclear-test-based methods to compute-based methods for maintaining the safety, reliability, and performance of the U.S. nuclear stockpile.

Livermore and Los Alamos are working with industrial partners to develop massively parallel computing platforms. This project includes placing massively parallel CRI T3D machines at both Livermore and Los Alamos.

The ASCI program will achieve its goal by creating leading-edge computational modeling and simulation capabilities based on advanced simulation codes and high-performance computing technologies. The goal is to provide the ability to evaluate, maintain, and, as necessary, rebuild nuclear weapons and weapons components in the absence of

Table 1.3-1. NIF Project Budget Table (does *not* include LLNL ICF operating costs, such as Nova operations, which are in Table 1.3-2).

For Budget Authority (BA) for NIF Project related activities, all costs are in millions of dollars and are actual (A), target (T), or required (R) amounts, as indicated. All costs are in "as spent" year dollars, consistent with NIF project data sheets.

Fiscal year	NIF Project PACE funded construction[a,b]	NIF Project OPEX funded costs[a,c]	ICF Program OPEX funded NIF annual operating costs[d]	NIF ESAAB milestone schedule
1993	0	6.0 (A)	0	Justification of mission need, KD0
1994	0	6.0 (A)	0	Complete Conceptual Design Report (CDR)
1995	0	6.0 (T)	0	KD1, Advanced conceptual design
1996	37.4 (T)	23.6 (T)	0	Congressional project start, Title 1 design
1997	131.9 (T)	59.2 (T)	0	KD2, Title 2 design, KD3, start construction
1998	197.8 (R)	31.3 (R)	0	Continue construction
1999	198.8 (R)	15.4 (R)	0	Continue construction
2000	191.3 (R)	31.7 (R)	0	Continue construction, begin start-up activities
2001	75.4 (R)	37.5 (R)	17.6 (R)	Continue construction, begin experiments
2002	10.0 (R)	14.3 (R)	54.4 (R)	Complete construction and final ORR[e], project complete, KD4
2003	0	0	74.6 (R)	First full year of routine annual operation

[a] NIF national funding is shown for the total project, and is distributed among LLNL, LANL, SNL, and the University of Rochester.
[b] The estimated NIF construction cost of $842.6 M in as-spent dollars does *not* include costs for support facilities, estimated to be about $26 M.
[c] The OPEX required for the NIF includes the CDR, NEPA documentation, U.S. optics industry facilitization, and NIF facility start-up. The estimated total OPEX funding for the project is $231.0 M in as-spent dollars.
[d] Annual operating costs for the NIF will be provided from the National ICF Program OPEX funding and are *not* included in the NIF Total Project Cost (TPC) of $1,073.6 M. Annual operating cost is estimated to be $60.7 M in FY 1996 dollars.
[e] Operational Readiness Review (ORR).

Table 1.3-2. ICF Program Budget Table (does *not* include NIF construction or operation costs—see Table 1.3-1).

Budget Authority (BA) for the LLNL ICF Program activities. All costs are in millions of dollars and are actual (A), target (T), or required (R) amounts, as indicated. LLNL ICF Program costs are in "as-spent" year dollars in FY 1993, 1994, 1995, and 1996. After FY 1996, amounts are in constant FY 1997 dollars.

BA requirement numbers (operating and capital) reflect continuous Nova operations through FY 2001 by all three Defense Programs' National Laboratories as a national user facility for stockpile stewardship physics experiments. Beginning in FY 1997, experiments on Nova will include qualified experiments in areas such as high-energy-density physics by universities and industry.

If NIF is sited at LLNL, then additional dollars from the national ICF program would be available for NIF operating costs in support of beginning experiments in FY 2001 and of fully operational, ignition experiments in FY 2003.

Fiscal year	LLNL ICF Program operating costs	LLNL ICF Program capital equipment
1993	91.0 (A)	3.5 (A)
1994	77.6 (A)	3.8 (A)
1995	77.0 (T)	4.0 (T)
1996	85.1 (T)	2.3 (T)
1997	86.5 (T)	3.5 (T)
1998	100.0 (R)	10.0 (R)
1999	100.0 (R)	10.0 (R)
2000	100.0 (R)	10.0 (R)
2001	100.0 (R)	10.0 (R)

underground nuclear testing and with a drastically reduced weapons manufacturing infrastructure.

In addition, Livermore, Sandia, and Los Alamos are developing a high-speed communications link, which will create a virtual single campus, or SuperLab. The long-term goal is to permit pervasive collaboration and sharing of computer resources among the Laboratories, in support of both ASCI and Advanced Design and Production Technology (ADaPT).

The high-performance computing technologies that were developed as part of the ASCI program will directly support the U.S. technology base. Table 1.3-4 shows the resource requirements for this initiative.

Table 1.3-3. Resources required for construction of the Contained Firing Facility (BA in millions of FY 1997 dollars after FY 1996).

Fiscal Year	Budget Authority
1995	0.0
1996	6.6
1997	17.1
1998	19.3
1999	6.7
2000	0.0
2001	0.0

Assistant Secretary for Environmental Restoration and Waste Management

The following initiatives are proposed as major additions to existing programs or as new directions within our missions. The related resource requirements presented here are not included in the detailed Program Resource Requirement Projections presented in Section 4.1 because they are not yet authorized program elements.

Table 1.3-4. Resources required for the Advanced Strategic Computing Initiative (BA in millions of FY 1997 dollars after FY 1996).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1996	15.0	0.0	15.0	90
1997	27.0	0.0	27.0	115
1998	30.0	0.0	30.0	125
1999	30.0	0.0	30.0	120
2000	30.0	0.0	30.0	115
2001	30.0	0.0	30.0	110

Mixed Waste Management Facility (EW)

The Mixed Waste Management Facility (MWMF) initiative is a fully integrated, pilot-scale, demonstration facility. It will use treatment processes that are environmentally acceptable alternatives to incineration. Incorporating up to three separate treatment technologies, the MWMF will demonstrate the treatment of mixed waste by the use of surrogates and actual mixed waste from LLNL's inventory. Ultimately, demonstration data provided by MWMF evaluations will provide the basis for establishing full-scale treatment facilities within the DOE and in the commercial sector. The MWMF will also enable the Laboratory to fulfill the requirements of the Federal Facilities Compliance Act to dispose of on-site-generated, organic-based mixed waste by developing technologies to treat LLNL-generated waste. The MWMF is currently in the preliminary design phase. See Table 1.3-5 for resource requirements.

Table 1.3-5. Future resources required for the Mixed Waste Management Facility[a] (BA in millions of as-spent, escalated dollars).

Fiscal Year	Operating costs	CENTRC	Total cost	Direct FTEs
1995	0.7	7.0	7.7	39
1996	1.1	14.3	15.4	39
1997	2.8	10.2	13.0	35
1998	8.1	7.0	15.1	30
1999	8.0	–	8.0	20
2000	8.0	–	8.0	20
2001				

[a] Based on Project Baseline Revision 1.2, these projections contain proposed operating budget in out years after project completion.

Table 1.3-6. Resources required for the Genomics and Structural Biology Research Facility (BA in millions of FY 1996 dollars after FY 1997).

Fiscal year	Total estimated cost	Other project cost	Total project cost
1996	0.0	0.15	0.39[a]
1997	6.0	0.00	6.00
1998	22.0	0.14	22.14
1999	9.0	0.28	9.28
2000	0.0	0.00	0.00
2001	0.0	0.00	0.00

[a] Contains $0.24 from FY 1995.

Office of Energy Research

Genomics and Structural Biology Research Laboratory (KP)

The Biology and Biotechnology Research Program continues to grow, and now has a critical need for corresponding growth in office, laboratory, and support space. The 6500-m^2 Genomics and Structural Biology Research Laboratory will house Livermore's human genome and structural biology efforts and alleviate serious overcrowding in existing and substandard buildings. This new building will provide offices and laboratories for a staff of 150 at an estimated total project cost of $37.8 million. The conceptual design for this facility is now under way and will be submitted for validation as a line item for the FY 1997 budget. See Table 1.3-6 for resource requirements.

Structural Biology (KP)

We have initiated a new program in structural biology to expand our capabilities in three-dimensional structure analysis of proteins, nucleic acids, and the complexes they form with each other and with other molecules. This effort is relevant to the DOE's growing interest in structural biology and to increasing national interest in identifying how defects in molecular structure cause cancer and genetic disease. This program will directly support the human genome effort by producing the necessary tools

to predict the structure (and possibly the function) of proteins that belong to many of the gene families for which DNA mapping and sequencing information is becoming available. We currently have a state-of-the-art cryocrystallography and x-ray diffraction facility and will soon have a 600-MHz nuclear magnetic resonance facility. These facilities are currently funded through the Laboratory Directed Research and Development program and are in need of long-term stable support. Table 1.3-7 shows the resource requirements for this program.

Mammalian and Microbial Genomes Initiative (KP)

We have made valuable contributions to the biotechnology community, including chromosome-specific libraries, fluorescence in-situ hybridization techniques to paint whole chromosomes and to measure distance along DNA, informatics software, new DNA-sequencing instrumentation, robotics for laboratory automation, and flow systems for analysis and purification of cells and chromosomes. We are the primary international resource for human chromosome 19 clones and data. We would like to broaden our biotechnology base by using the technologies developed for the human genome project to study organisms of interest to those working in the areas of health effects, environmental remediation, and nonproliferation. We need increased funding to maintain and expand our mapping infrastructure and to substantially increase our efforts in DNA sequencing. Table 1.3-8 gives the resource requirements for this effort.

Center for Healthcare Technologies (KP)

In response to a call from industry and clinicians to assist in the development of new, cost-effective health-care technologies, we have formed a Center for Healthcare Technologies. This Center provides coordination, marketing, and strategic direction for the rapidly emerging interest in health-care technology at Livermore. We are seeking funding through cooperative research and development agreements (CRADAs), multiple federal agencies, and any other groups that have the desire to apply Livermore's core competencies to health care. We are working with DOE's Office of Health and Environmental Research on a Biomedical Technology Initiative. We are also seeking long-term stable funding from the DOE to provide a base of essential staff and seed funding for new projects.

Hydrogen as an Alternative Fuel (AR)

Alternative fuels that are nonpolluting and do not depend on imported supplies must be developed to ensure U.S. energy security. Use of nonpolluting energy systems will reduce the large amounts of air pollution in urban environments. The use of domestic energy sources will help decrease U.S. dependence on foreign sources and U.S. payments to

Table 1.3-7. Resources required for the Structural Biology Initiative (BA in millions of FY 1997 dollars after FY 1996).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1996	2.7	0.5	3.2	15
1997	3.0	0.6	3.6	17
1998	3.4	0.7	4.3	19
1999	4.7	0.8	5.5	25
2000	6.9	1.0	7.9	37
2001	10.7	1.3	12.7	57

Table 1.3-8. Resources required for the Mammalian and Microbial Genomes Initiative (BA in millions of FY 1997 dollars after FY 1996).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1996	9.6	3.3	12.9	53
1997	16.0	2.3	18.3	89
1998	21.6	3.0	24.6	117
1999	27.8	3.0	30.8	150
2000	31.0	3.0	34.0	167
2001	31.0	3.0	34.0	167

foreign entities (currently, these payments of $60 billion per year account for more than one-third of our nation's balance-of-payments deficit).

Many features of hydrogen make it a serious contender for improved transportation systems: it can be produced from numerous domestic sources, it can be used in an engine to significantly reduce emissions while maintaining performance, it is the primary energy source for the production of electricity in a fuel cell, it can be safely stored and transported, and it is already widely used in a wide range of applications.

Hydrogen can also be used in nontransportation applications: to store energy from off-peak electricity production, to generate electric power through the use of fuel cells, and to be a synthetic fuel for the fertilizer and chemical industries. Fuel cells can efficiently convert hydrogen fuel to electricity. Thus, hydrogen is particularly attractive as a power source for both electric vehicles and power plants. We are seeking funding from the Assistant Secretary for Energy Efficiency and Renewable Energy, and Office of Energy Research. Table 1.3-9 shows the resource requirements for this effort.

Our goal is to work with U.S. industry and other research institutions to develop hydrogen energy technologies as environmentally benign alternatives to the use of imported fossil fuels. Aggressive programs for developing hydrogen-powered vehicles are already well established in both Japan and Europe.

Table 1.3-9. Resources for Hydrogen as an Alternative Fuel (BA in millions of FY 1997 dollars after FY 1996).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1996	4.5	0.0	4.5	14
1997	5.6	0.2	5.8	16
1998	2.9	0.1	3.0	7
1999	2.9	0.1	2.9	7
2000	2.9	0.1	2.9	7
2001	2.9	0.1	2.9	7

Table 1.3-10. Resources required for the Electronic Commerce Initiative (BA in millions of FY 1997 dollars after FY 1996).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1996	3.5	0.0	3.5	14
1997	5.0	0.1	5.1	20
1998	3.8	0.0	3.8	15
1999	2.5	0.0	2.5	10
2000	2.5	0.0	2.5	10
2001	2.5	0.0	2.5	10

Interagency Sponsors

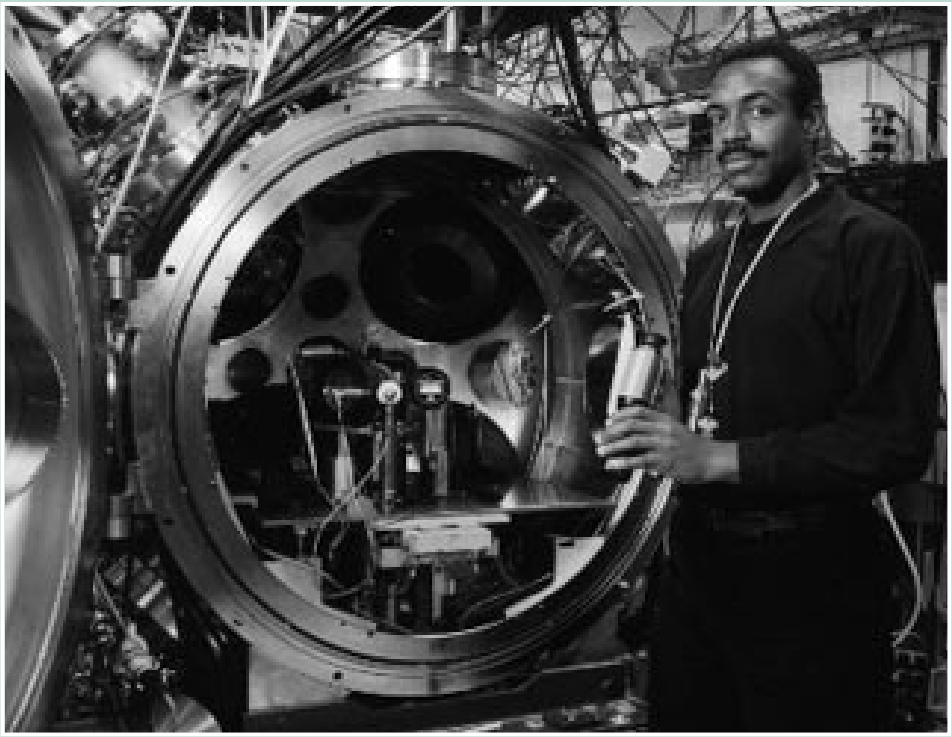
Electronic Commerce

We applied our Electronic Commerce expertise to automating procurement of commodity items at Wright-Patterson Air Force Base in late 1992 with remarkable success. After application to more than 50,000 procurements, the average cost per item has dropped by more than 10%, the administrative time by 67%, and the manpower by more than 75%. Furthermore, more than 97% of the awards are made to small and disadvantaged businesses based solely on price competitiveness, allaying the fear that this benefit might be lost. We have applied these techniques to the procurement system at the Veteran's Administration Hospital (Long Beach) with comparable results, and we are now adapting them to our own business functions.

Based on these successes, LLNL is planning a Center of Excellence in Electronic Commerce to expand its application to partnerships with major U.S. banks, to the development of concurrent engineering tools for the DoD, and possibly to a program for on-line access to medical records. In addition, Livermore will provide this technology for the DOE Defense Programs for future stockpile stewardship and management. Table 1.3-10 shows the required resources for this initiative.

Section 2

Scientific and Technical Programs



Department of Energy Sponsors 2.1

In this section, we describe the Laboratory's scientific and technical programs organized by DOE sponsor. Following those descriptions is our work for Department of Defense and other non-DOE sponsors. Finally, we describe the special cross-cutting programs. Table 2.1-1 is a summary of the funding for our major programs.

Table 2.1-1. Major program operating fund summary (in millions of dollars); from FY 1997 budget submission, April 1995; not including construction or equipment.

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
Defense Programs				
GB-01 Stockpile Stewardship	211.8	178.6	198.3	246.4
GB-01-06 Technology Commercialization	45.0	55.5	55.4	6.8
GB-02 Inertial Confinement Fusion	77.6	77.0	85.1	86.5
GB-03 Stockpile Management[c]	0.4	10.9	13.7	15.7
GB-05 Program Direction	6.5	5.8	5.0	4.8
GB-05-06 Emergency Management	0.0	0.6	0.7	0.8
GB-06 Program Direction	6.4	3.4	2.2	1.9
GE-03 Supporting Service	2.0	4.4	3.9	4.0
Total[d]	**349.7**	**336.2**	**364.3**	**366.9**
% of Total Laboratory Operating Funding	40.8%	39.0%	37.4%	37.9%
Nonproliferation & National Security				
GC Verification & Control Technology	50.1	36.2	42.0	44.0
GD Nuclear Safeguards & Security	3.8	6.1	12.5	10.3
GH Nuclear Safeguards & Security	3.2	5.2	4.5	1.6
GJ Export Control	9.3	11.4	20.0	21.0
NB Emergency Preparedness	0.3	0.0	0.0	0.0
NT Intelligence	6.9	6.0	7.7	7.8
Total	**73.6**	**64.9**	**86.7**	**84.7**
% of Total Laboratory Operating Funding	8.6%	7.5%	8.9%	8.7%
Fissile Materials Disposition				
GA Materials Disposition	0.0	7.8	12.5	13.4
Total	**0.0**	**7.8**	**12.5**	**13.4**
% of Total Laboratory Operating Funding	0.0%	0.9%	1.3%	1.4%
Energy Research				
AT-00 Magnetic Fusion Energy (MFE)	0.0	0.0	0.0	0.0
AT-05 MFE Applied Plasma Physics	13.4	12.0	16.1	17.4
AT-10 MFE Confinement System	4.6	4.9	6.6	14.5
AT-15 MFE Development & Technology	7.2	7.1	8.5	9.0
AT-20 MFE Planning & Projects	0.0	0.0	0.0	0.0
AT-25 MFE Planning & Projects	0.8	1.6	2.3	5.0
AT-30 Inertial Fusion Energy	0.0	0.0	0.0	0.0
KA High-Energy Physics	1.1	1.2	0.8	0.6
KB-01 Nuclear Energy Physics	0.0	0.0	0.0	0.0
KB-02 Heavy Ion Physics	0.2	0.3	0.6	0.6
KB-03 Nuclear Theory	0.1	0.1	0.3	0.3
KB-04 Low-Energy Physics	0.4	0.3	0.6	0.6
KC-02 Materials Science	2.1	2.8	3.4	4.2
KC-03 Chemical Sciences	0.2	0.5	0.5	0.8

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.
[c] The Nuclear Emergency Search Team and Atmospheric Release Advisory Capability programs moved from GB-01 in FY 1994 to GB-03 in FY 1995.
[d] National Ignition Facility funding is not included.

Assistant Secretary for Defense Programs

Even with the recent worldwide changes, nuclear dangers still exist. The Laboratory's national security challenge is to contribute to the reduction of those dangers by

- Ensuring the safety, security, and effectiveness of the U.S. nuclear stockpile without nuclear testing.
- Ensuring the safe, secure, and timely dismantlement of nuclear weapons.
- Developing and applying technologies in support of U.S. nonproliferation and counter-proliferation policies.
- Participating in the restructuring of the DOE weapon production complex.
- Using and enhancing industrial capability to support DOE Defense Programs (DP) and to improve industrial competitiveness.
- Advising the government on national and international nuclear weapon issues.

The defining basis for our nuclear core expertise is these responsibilities and anticipated future national security needs. In the sections that follow, we discuss the program activities and facilities devoted to these mission areas. Table 2.1-2 (p. 55) shows

projected funding from the DOE Assistant Secretary for Defense Programs.

Stockpile Stewardship

Infrastructure and Core Competencies

Effective stewardship of the stockpile without the use of underground nuclear testing will require a broad-based set of elements for the technological infrastructure and skilled personnel with competence in critical areas. The elements include

- Advanced numerical simulation capability, using state-of-the-art computer architectures and improved codes.
- Hydrodynamic test facilities, including modernization of Site 300, to provide contained firing capability and to improve radiographic capability.
- High-energy-density physics facilities, including the Nova laser, ultra-short pulse lasers, and the planned National Ignition Facility (NIF).
- Materials laboratories to support an enhanced stockpile surveillance program.
- Mechanical and electronic fabrication and nondestructive test facilities.
- Energetic materials facilities.
- Atmospheric and geologic test and analysis capabilities.

Execution of the stockpile stewardship and maintenance program will place significant demands on this infrastructure. Success depends on retention and recruitment of personnel with critical weapon skills. The principal strategy for providing the necessary capabilities within a restricted budget is to consolidate among Department of Energy facilities

Table 2.1-1, continued. Major program operating fund summary (in millions of dollars); from FY 1997 budget submission, April 1995; not including construction or equipment.

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
KC-04 Engineering/Math/Geoscience	1.6	1.8	2.4	2.5
KC-05 Advanced Energy Projects	1.0	1.3	0.7	0.0
KC-07 Applied Mathematical Science	29.5	35.8	35.1	37.5
KP-00 Biological/Environmental	0.0	0.0	0.0	0.0
KP-01 Analytical Technology	0.1	0.1	0.1	0.0
KP-02 Environmental Research	1.2	0.4	0.4	0.4
KP-03 Health Services	0.9	0.9	1.8	1.8
KP-04 General Life Sciences	11.4	11.8	14.5	15.1
KP-05 Carbon Dioxide	5.9	6.2	6.7	6.7
KP-06 Medical Applications	0.0	0.0	0.0	0.0
Total	**81.7**	**89.1**	**101.4**	**117.0**
% of Total Laboratory Operating Funding	9.5%	10.3%	10.4%	12.1%
Environmental Restoration & Waste Management				
EW-11 Corrective Actions	0.2	0.0	0.0	0.0
EW-20 Environmental Restoration	28.8	26.0	29.7	29.8
EW-31 Waste Management	30.7	29.8	30.8	24.9
EW-40 Technology Development	10.9	5.3	5.3	5.4
EX-60 Program Direction	0.0	0.0	0.3	0.3
Total	**70.6**	**61.1**	**66.1**	**60.4**
% of Total Laboratory Operating Funding	8.2%	7.1%	6.8%	6.2%
Environment, Safety, & Health				
HA-01 Environment, Safety & Health	5.6	4.6	8.7	9.0
HP-01 Nuclear Safety Policy	0.9	0.7	1.2	1.4
HR Epidemiologic Activities	1.8	1.9	2.5	2.8
HS Security Evaluation	1.3	1.2	1.5	1.5
NR-00 Radiological Oversight	0.0	0.0	0.1	0.1
NS-01 Nuclear Safety - Standards	0.1	0.1	0.1	0.2
NS-06 Nuclear Safety - Initiatives	0.1	0.0	0.3	0.3
Total	**9.8**	**8.5**	**14.4**	**15.3**
% of Total Laboratory Operating Funding	1.1%	1.0%	1.5%	1.6%
Nuclear Energy				
AF-12-10 Light Water Reactors	1.0	0.0	0.0	0.0
AF-20 Advanced Reactor R&D	0.1	0.0	0.0	0.0
AJ-05 Naval Reactors	0.3	0.3	0.3	0.4
CD-10-04 Highly Enriched Uranium	0.1	0.2	0.0	0.0
CD-10-06 Nuclear Safety	0.0	0.3	0.0	0.0
CD-10-07 Maint. of Leased/non-Leased	0.2	0.0	0.0	0.0
CD-10-08 AVLIS	3.9	0.0	0.0	0.0
CD-10-09 Technology Partnerships	0.3	0.2	0.3	0.3
CD-10-12 Program Management Services	3.0	2.0	2.0	2.0

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Table 2.1-1, continued. Major program operating fund summary (in millions of dollars); from FY 1997 budget submission, April 1995; not including construction or equipment.

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
CD-10-13 Transparency Measures	0.8	5.2	5.5	6.8
CD-10-15 Depleted Uranium Hexafluoride	0.0	0.0	1.0	0.8
KK-05 Policy and Management - NE	0.2	0.2	0.0	0.0
Total	**9.9**	**8.4**	**9.1**	**10.3**
% of Total Laboratory Operating Funding	1.2%	1.0%	0.9%	1.1%
Civilian Radioactive Waste Management				
DB Nuclear Waste Fund	15.5	12.8	0.0	0.0
Total	**15.5**	**12.8**	**0.0**	**0.0**
% of Total Laboratory Operating Funding	1.8%	1.5%	0.0%	0.0%
Fossil Energy				
AA Coal	0.3	0.1	0.1	0.3
AB Gas	0.3	0.2	0.1	0.1
AC Petroleum	1.9	2.2	3.5	3.0
CB Naval Petroleum Reserve	0.0	0.0	0.0	0.0
Total	**2.5**	**2.5**	**3.7**	**3.4**
% of Total Laboratory Operating Funding	0.3%	0.3%	0.4%	0.4%
Energy Efficiency & Renewable Energy				
AK Electric Energy Systems	0.1	0.1	0.0	0.0
AR Energy Storage Systems	0.6	1.2	5.0	6.0
ED Industrial Sector	0.5	0.3	0.3	0.3
EE Transportation Propulsion	0.3	0.1	1.1	1.1
EE Transportation/Materials Technology	0.0	0.3	0.8	0.8
Total	**1.5**	**2.0**	**7.2**	**8.2**
% of Total Laboratory Operating Funding	0.2%	0.2%	0.7%	0.8%
Human Resources & Administration				
WM Contractual Services	0.6	0.6	1.1	1.1
Total	**0.6**	**0.6**	**1.1**	**1.1**
% of Total Laboratory Operating Funding	0.1%	0.1%	0.1%	0.1%
Policy, Planning & Program Evaluation				
PE-01 Environmental Analysis	0.1	0.0	0.0	0.0
Total	**0.1**	**0.0**	**0.0**	**0.0**
% of Total Laboratory Operating Funding	0.0%	0.0%	0.0%	0.0%
Science Education & Technical Information				
KT University & Science Education	1.0	1.3	2.4	2.7
KV University & Science Education	0.0	0.0	0.0	0.0
Total	**1.0**	**1.3**	**2.4**	**2.7**
% of Total Laboratory Operating Funding	0.1%	0.2%	0.2%	0.3%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

and, where possible, construct national facilities with broad capabilities such as the proposed NIF. A secondary strategy is for programs with similar technical requirements to share infrastructure and technology development costs. Some of these collaborations are described in this section.

Weapon Physics

In the past, when detection of aging problems or discovery of design or engineering weaknesses required modifications to critical weapon subsystems, reliability and confidence were maintained through recertification by underground testing. Future "fixes" will require recertification by a combination of non-nuclear tests and modeling. We plan to continue to develop a better understanding of the complex physics involved in weapons systems performance and improve the scientific understanding required to accurately assess the safety and performance of weapon subsystems for long-term stockpile assignment.

Our experimental and theoretical weapon physics program will use high-power lasers, hydrodynamic test facilities, and x-ray simulators to study important issues involving shock waves, turbulent mixing, plasma opacity, atomic physics, equations of state, radiation flow, radiation effects, plasma physics, and neutron cross sections. In addition, we will improve our diagnostic capabilities so that we can make better measurements in the high-energy-density regime. Finally, in concert with our experimental effort, we will develop improved theoretical models and computational methods in order to establish a significantly better understanding of

the weapon physics regime. The ultimate goal is to establish an understanding of weapon performance that is as close to a first-principles basis as possible.

This year, we successfully completed a wide array of experiments at the Nova laser. They were in the areas of compressible hydrodynamic instability, radiation flow, implosion, equation of state, and opacity. A particular highlight was the demonstration of an x-ray laser interferometer capable of measuring material densities in weapon physics experiments to very high accuracy. In addition, we successfully completed plasma physics and atomic physics experiments using the ultra-short-pulse lasers, the Janus laser, pulsed power facilities, and the Electron Beam Ion Trap. These experiments are, in turn, driving improvements in our theoretical models.

Table 2.1-1, continued. Major program operating fund summary (in millions of dollars); from FY 1997 budget submission, April 1995; not including construction or equipment.

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
Field Management				
WB In-House Energy Management	0.5	0.5	0.7	0.7
Total	**0.5**	**0.5**	**0.7**	**0.7**
% of Total Laboratory Operating Funding	0.1%	0.1%	0.1%	0.1%
Work for Integrated Contractors	**28.3**	**44.0**	**65.5**	**83.3**
% of Total Laboratory Operating Funding	3.3%	5.1%	6.7%	8.6%
Work for other DOE Installations	**47.3**	**35.2**	**24.4**	**19.9**
% of Total Laboratory Operating Funding	5.5%	4.1%	2.5%	2.1%
TOTAL DOE[c]	**692.6**	**674.9**	**759.5**	**787.3**
% of Total Laboratory Operating Funding	80.8%	78.3%	78.1%	81.2%
Department of Defense	**103.1**	**72.9**	**94.0**	**89.7**
% of Total Laboratory Operating Funding	12.0%	8.5%	9.7%	9.3%
NASA	**5.1**	**3.2**	**3.3**	**2.4**
% of Total Laboratory Operating Funding	0.6%	0.4%	0.3%	0.2%
U.S. Enrichment Corporation	**38.5**	**40.0**	**50.0**	**40.0**
% of Total Laboratory Operating Funding	4.5%	4.6%	5.1%	4.1%
Other Federal Agencies	**8.1**	**26.3**	**27.1**	**28.0**
% of Total Laboratory Operating Funding	0.9%	3.1%	2.8%	2.9%
Non-Federal Agencies	**10.0**	**44.2**	**39.0**	**21.8**
% of Total Laboratory Operating Funding	1.2%	5.1%	4.0%	2.2%
TOTAL NON-DOE	**164.8**	**186.6**	**213.4**	**181.9**
% of Total Laboratory Operating Funding	19.2%	21.6%	21.9%	18.8%
TOTAL LABORATORY[c]	**857.4**	**861.5**	**972.9**	**969.2**
% of Total Laboratory Operating Funding	100.0%	100.0%	100.0%	100.0%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.
[c] National Ignition Facility funding is not included.

Computations and Modeling

The Accelerated Strategic Computing Initiative (ASCI) is planned as an integrated, three-Laboratory, high-performance, computing development that will provide the capability to model, analyze, and resolve issues regarding the performance of an entire nuclear weapons system in all its detail. The required advance in computation speed and memory of 1,000 to 10,000 times will be based on massively parallel processing. It is planned that this capability will be achieved in collaboration with industry by the year 2010.

The ASCI will build on the core capabilities of the three Laboratory partners, and will guide and give context to the ongoing core computation and industrial partnering activities. Some of these relevant activities are described below.

As a major initial step, the three DOE Defense Program laboratories will be linked with a secure wide-area-network using encryption on the Energy Sciences Network (ESNet). This secure network has several remarkable benefits:

• Nuclear weapons scientists and engineers will be able to collaborate much more closely than ever before.
• Secure computing resources will be shared across the DP complex.
• Critical nuclear weapons archives will be more accessible, within the appropriate strictures of need-to-know.

The implementation of this network entails close teamwork among the Laboratories and between Defense Programs and Energy Research. Initial operational capability is anticipated on October 1, 1995, with improvements in speed and functionality, including secure links to DOE/HQ, phased in over the next several years.

Livermore currently operates the Secure Computing Facility, one of the world's largest and most powerful computer centers dedicated to scientific and engineering R&D. It operates two Cray supercomputers (a YMP-864 and a YMP-8128) and a Meiko 256-node massively parallel processor. These machines are connected to each other and to other computing and storage resources by a combination of FDDI and HIPPI high-speed networks. A cluster containing 24 Cray J90 processors will be delivered this year.

The Facility for Advanced Scalable Computing Technology (FAST) provides computer resources to support collaborative, institutional, and unclassified defense-related research. FAST contains a Meiko 48-node parallel processor and a National Storage Laboratory (NSL) Unitree 1-terabyte archive, which will be increased to 20 terabytes this year. FAST has network connections to the National Energy Research Supercomputer Center (NERSC) and the National Storage Laboratory (NSL).

We collaborate with researchers within DOE and U.S. industry. For example, the Synthetic Seismic Data Set, a massive calculational effort producing 2 terabytes of data, is being generated on massively parallel processors at the Livermore, Los Alamos, Oak Ridge, and Sandia laboratories and stored at FAST for the Gas and Oil National Information Infrastructure program. The Scalable Input/Output Facility, supporting DOE's SuperLab program, will demonstrate scalability of disk bandwidth with the size of the computer. We are also exploring wideband secure links that will connect the computer systems of the ASCI partners.

DYNA3D has been a heavily used computational tool for stockpile assurance, especially for the Surety Program modeling of thermal, mechanical, and chemical effects in accident environments. ParaDyn, a parallel version of DYNA3D, is being developed for current and future massively parallel computers. In FY 1995, we will complete the first version of ParaDyn for Meiko and Cray T3D massively parallel computer systems. A goal of this project is to demonstrate performance in the range of 10 to 100 gigaflops for applications modeling between 100,000 and 1,000,000 elements using the full 256 processors available on either of our parallel computers.

Hydrodynamic Test Facilities

Hydrodynamic testing remains the only direct experimental means for evaluating the safety and reliability of the weapon primaries of the enduring stockpile. LLNL's facilities for energetic materials and hydrodynamic research constitute the state of the art within the nuclear weapons complex. The integration of containment tanks, modern diagnostics, and computer-controlled firing and data acquisition at our High Explosives Application Facility allow us to conduct experiments in a more controlled and expeditious manner than is possible at any other U.S. facility.

Table 2.1-2. Defense Programs operating funds (in millions of dollars).

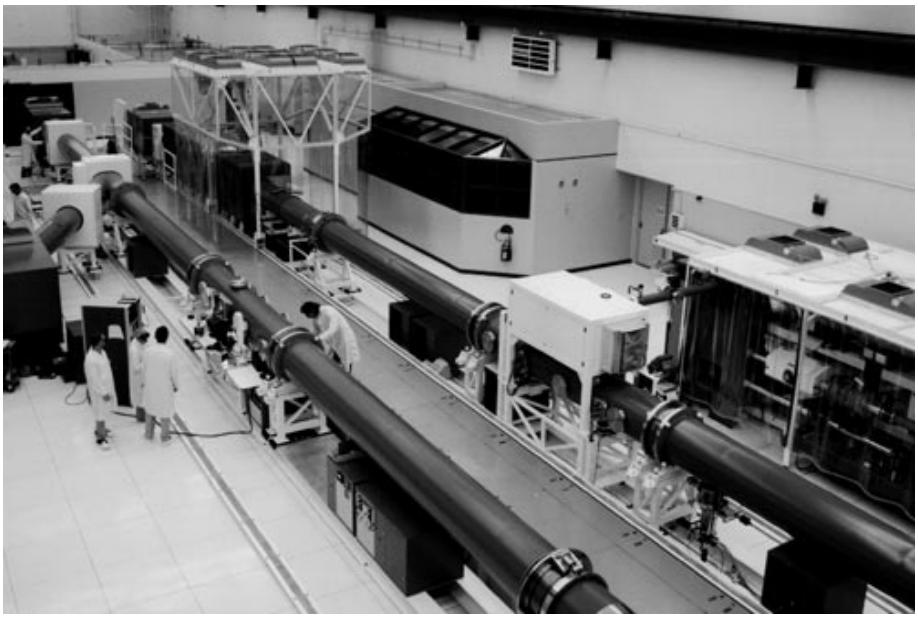
Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
GB-01 Stockpile Stewardship	211.8	178.6	198.3	246.4
GB-01-06 Technology Commercialization	45.0	55.5	55.4	6.8
GB-02 Inertial Confinement Fusion	77.6	77.0	85.1	86.5
GB-03 Stockpile Management	0.4	10.9	13.7	15.7
GB-05 Program Direction	6.5	5.8	5.0	4.8
GB-05-06 Emergency Management	0.0	0.6	0.7	0.8
GB-06 Program Direction	6.4	3.4	2.2	1.9
GE-03 Supporting Service	2.0	4.4	3.9	4.0
Total	**349.7**	**336.2**	**364.3**	**366.9**
% of Total Laboratory Operating Funding	40.8%	39.0%	37.4%	37.9%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Bunker 801 at Site 300 remains the most versatile and complete hydrodynamic testing facility in the world. The flash x-ray (FXR) accelerator combined with the newly developed gamma-ray camera allow us to conduct device-implosion imaging experiments at densities never before possible. Other diagnostic capabilities of Bunker 801 include laser holography, laser velocimetry, high-speed optical cameras, and pin-dome technology. Ten more beams of our velocimetry system are now under construction. This summer we began modifying the FXR accelerator to deliver multiple pulses with improved resolution. As funding allows, we will upgrade Bunker 801 to accommodate full containment of the high-explosive detonation and its products, thus ensuring continued use of the facility under increasingly restrictive environmental regulations.

The Big Explosives Experimental Facility under development at the Nevada Test Site will allow us to conduct hydrodynamic and shaped-charge experiments using larger high-explosive charges than can be fired at Site 300. Planned diagnostics for this facility include x-ray radiography, target-penetration-rate switches, streak cameras, fast-framing cameras, laser image converter cameras, and multibeam laser velocimetry. Structural qualification tests began during spring 1995 with initial experiments beginning in the fall.

We continue planning for the Advanced Hydrotest Facility, which will be built at the Nevada Test Site. This flash x-ray machine's multiple temporal and spatial pulses will be more powerful and versatile than the FXR. Prototype electronic modules are under construction and will be tested this year. This machine will enable us to make CAT-scan-like movies of an imploding device, allowing us to assess the effect of the high explosive on the weapon radiation case. This capability will help us evaluate affects of repackaging warheads into new configurations and will also serve as a testbed for studying the disablement of terrorist nuclear devices.



The Beamlet laser, a full-scale, single-beam prototype of the NIF design demonstrated laser fluences at infrared wavelengths equivalent to those required for the NIF.

Inertial Confinement Fusion

The weapons-support mission of the Inertial Confinement Fusion (ICF) program is to fully exploit high-energy-density plasmas formed in ICF experimental facilities for nuclear weapons physics and weapons effects research. We need to improve capability beyond existing laser facilities now being used for this mission. The primary goal of the ICF program is a fusion high-gain laboratory facility, and an intermediate goal is a glass laser-driven, fusion ignition laboratory facility.

Fusion ignition (self-heating of the fusion fuel by alpha particles) and energy gain (a fusion energy yield that exceeds the laser driver energy) would give the DOE new ways to approach activities in nuclear weapons research that are compatible with nuclear test bans, would provide new basic scientific research capabilities for the nation, and would allow the nation to pursue the possibility of power generation by ICF.

In support of DOE's fusion ignition and gain goal, the ICF

program at LLNL has established its technical activities within seven elements: target physics experiments, target design/theory, laser technology, optics manufacturing, target chamber technologies, target diagnostics, and target components/fabrication.

The ICF program, using the Nova glass laser, is addressing the ignition target physics issues described by the National Academy of Sciences (NAS) Nova Technical Contract. These experiments include hydrodynamically equivalent implosion physics and hohlraum laser-plasma interaction physics. Additional target physics experiments include exploration of advanced ICF concepts, such as the fast ignitor-petawatt laser project, to better understand the science of ignition. The principal design code, LASNEX, continues to be enhanced. The Nova laser facility at Livermore will continue to conduct ignition target optimization studies in support of the NIF target designs and weapons physics experiments in support of science-based stockpile stewardship.

In concert with the Title I and Title II design activities for the NIF project in FY 1996 and 1997, Livermore will support the development of laser technology, optics manufacturing, target technology, and diagnostics. These technology development activities will ensure design optimization and cost minimization of the NIF. They are a necessary component of the ICF base program in order to provide high confidence in the performance, schedule, and cost goals of the NIF project.

Target-chamber development activities include characterizing target debris and radiation threats to target chamber hardware as well as developing means to cope with these threats. Target diagnostics, such as x-ray, neutron, gamma ray, and optical detectors, will be improved to meet the requirements of future experiments at Nova and at future ICF facilities, such as the NIF. Target components and fabrication development will include fuel capsule and hohlraum manufacturing technologies such as cryogenic fuel layer formation and cryogenic support systems.

Phebus–France: High-Energy Laser–Matter Interactions

Livermore has had technical interactions for many years with the Centre d'Etudes de Limeil-Valenton (CEL-V), a research center under the administration of the Commissariat a l'Energie Atomique (CEA) of France. One important result of these interactions was the construction at CEL-V of the Phebus laser, a two-beam version of the ten-beam laser at Livermore used for inertial confinement fusion and weapons-physics research.

In 1994, DOE and CEA signed a ten-year, government-to-government agreement for Cooperation in Research, Development, and Applications of High Energy Lasers and High Energy Laser-Matter Interaction Physics. Under this agreement, DOE and CEA agreed to share (1) responsibility and cost for developing technology that is required to build the NIF and the Laser Megajoule Project, a NIF-equivalent facility planned for construction in France, and (2) costs for unclassified, collaborative experiments on Nova.

Each year, the specific technical activities to be undertaken are summarized in a written Task Statement that must be approved by DOE and CEA. DOE and CEA subsequently assign responsibility for performing the work specified in the Task Statement to one or more of their research laboratories. To date, the majority of work under the agreement has been assigned to LLNL and CEL-V, although during the past year, both Sandia National Laboratories and Los Alamos National Laboratory have also participated.

Radiation Effects

Radiation hardness experiments are performed when we need to test the nuclear hardness, i.e., the resistance to radiation, of a weapon. To certify the nuclear hardness of weapons in the absence of nuclear testing, we use advanced x-ray facilities that can produce threat-level environments in most portions of the x-ray spectrum. The Saturn x-ray facility at Sandia, Albuquerque, and the Decade machine under construction near Manchester, Tennessee, can meet some of our testing needs. The planned NIF will be an excellent testbed for the radiation effects of nuclear environments on weapons and other complex systems. capability that is not available in any other current or planned facility. We will be able to use this family of simulators to test the radiation hardness of all stockpile warheads, satellites, and other hardware.

Nuclear Weapon Information

As more and more weapon scientists and engineers retire from the Laboratory, we will become ever more reliant on having a compiled, comprehensive record of our past experience in weapon development and testing. To complete this database, we will need to do considerable research, analysis, and organization of the data for weapon design and weapon experiments; development of a computer archive to preserve the database; and perhaps additional non-nuclear experiments for some devices and systems to complete this database. Active re-analysis of past test data with our improved simulation models will be a major part of this effort. This task will also be coordinated within the DOE weapons complex.

Industrial Partnerships

In order to enhance the technical base needed for the weapons program, we are active in several partnerships with industry. In one project, we are using an adaptation of our software to model the forging and extrusion of complex three-dimensional parts. In other projects, we are using our expertise in electromagnetics to develop

- Gyrotrons that could be used to heat the plasma in the magnetic fusion reactors.
- Codes that calculate radar cross sections of aircraft and electro-magnetic interference in microcircuits.
- Microwave tubes for satellite communications.
- Plasma torch reactors that treat mixed (radioactive and chemical) waste.

We are also pursuing enhance-ment of many of our weapon development technologies while advancing medical practices and health care. For example, we are using neural net technology to improve patient monitoring instrumentation and radiation flow codes to analyze the flow of optical photons in flesh for the development of new noninvasive medical instruments.

In addition to these activities, we are

- Developing high-bandwidth photonic systems for commercial communication and computer networking. These systems will help reduce costs associated with the National Information Infrastructure.
- Adapting imaging technologies that were developed for nuclear testing for a variety of military and environmental applications.
- Developing low-cost manufacturing technologies.
- Applying the Laboratory's versatile DYNA3D code to the needs of several U.S. industries.

Stockpile Management

In years past, a large weapon production complex provided the capability and capacity to rapidly fix problems with stockpile weapons. Today many elements of the production complex have already been shut down, and manufacturing capabilities are being consolidated at fewer sites. It will not be practical or cost effective to meet future manufacturing needs by keeping many of the old processes or facilities on "standby." Clearly, a different approach is needed. The new approach to manufacturing must provide the capability to fix stockpile anomalies before they become serious problems. In addition, manufacturing technologies must to be developed that eliminate the need for large facilities and infrastructure.

Advanced Design and Production Technologies (ADaPT)

At the Laboratory, we are working on several technologies to provide cost-effective manufacturing capabilities to replace and refurbish aging weapon components. We are responsible for developing a pit-reuse capability that would permit the reuse of old plutonium components if necessary to fix a problem in the stockpile. In addition, we are developing a precision casting process for plutonium that will significantly reduce cost and the waste it generates. This process can be applied to rebuild pits destroyed in the current surveillance program. We are also developing precision casting, spinforming, and machining techniques to replace the current methods of rebuilding uranium parts destroyed in the surveillance program. These efforts draw on the uranium processing and laser capabilities developed in the LLNL Uranium AVLIS program.

Enhanced Surveillance

We are expanding current surveillance efforts, including active preventive maintenance, focused archiving, and capabilities in physics, engineering, chemistry, and material

science. New surveillance technologies, coupled with enhanced predictive capabilities for the effects of aging materials on component and weapon performance, are needed so that we can detect potential safety or reliability problems long before they become serious. Without such improvements in our surveillance capabilities, a major concern will be the possibility of a common-mode failure nullifying a large fraction of the enduring stockpile.

Within the Laboratory, we are working to improve the science of enhanced surveillance so that we can better understand and predict effects of aging on weapons. These efforts are the key to an affordable manufacturing capability because they enable a more systematic refurbishment and preventative maintenance program rather than an expensive and high production-rate replacement program when aging effects are found. We are in the process of establishing an enhanced material database (using surveillance and dismantlement data) and developing sophisticated computational techniques to better analyze these data. We are also developing improved nondestructive evaluation techniques using scanning tunneling microscopes and atomic force microscopes to allow us to look at the effects of corrosion on an atomistic level. We are conducting R&D activities in the use of advanced sensors and nondestructive techniques to allow self-diagnostics of weapon components in a more detailed and fundamental way, greatly enhancing the effectiveness of stockpile surveillance. We are working with DOE to plan and implement a three-lab program in this area.

PEIS Support

The Programmatic Environmental Impact Statement (PEIS) for the Weapons Complex Reconfiguration has been divided into two statements: a Tritium Supply and Recycling PEIS and a Stockpile Stewardship and Management PEIS (SSMPEIS). We are working with DOE/Albuquerque to develop proposals to bound the future nuclear weapons complex with a goal of making much smaller and more efficient SSMPEIS. LLNL employees are participating on all eight working teams plus the steering committee, helping to determine the preferred alternative for the configuration of the entire complex. A record of Decision is expected by August 1996.

Technology Development

We are continuing the efforts started last year to develop technologies that will greatly improve the efficiency of the future weapons complex.

- Electron-beam melting of uranium alloys has proceeded to the point where we can meet the specification for weapons-grade material in modest-sized ingots. Future work will focus on producing full-size ingots and installing the mechanism that will allow machine-chip recycling.
- Continuing efforts on near-net-shape casting of uranium have demonstrated the value of being able to use process modeling to predict the outcome of experimental runs. This has greatly reduced the need for experimental iterations and has produced sound parts in useful sizes.
- We installed a spinforming machine that has the potential to produce all of the uranium and uranium alloy parts required for weapons in the enduring stockpile. We are modeling this process in order to develop it as rapidly as possible.

We expect that additional funds will be made available next year to pursue more of the technologies and creative ideas that are necessary to reduce the costs and increase the efficiency of the nuclear weapons enterprise.

As appropriate, we will conduct technology demonstrations that exercise the entire range of our development capabilities, from device design and engineering to component fabrication. Some demonstrations will be applicable to the reconfiguration of the weapon production complex and to our stockpile surveillance and maintenance efforts. Others will have broader, dual-use applications to satisfy national needs other than defense.

Dismantlement and Long-Term Storage

Warhead dismantlement requires care and attention to technical detail. The process must be safe, technically sound, and environmentally acceptable—i.e., it must not expose workers to undue hazards or create excessive waste—and it must be consistent with modern environmental, safety, and health standards. As weapons experts, we are overseeing dismantlement procedures and processes to ensure that these requirements are met. We stress the importance of this task with the following example.

In 1992, the W48 dismantlement stopped because a pit cracked during disassembly. This incident caused the Laboratory to perform the research and development to support a new disassembly process using new materials. This developed process will be used for future W48 disassembly.

When dismantlement of a weapon is completed, we face the problem of storage of weapon components. The storage of these critical components must be done in a safe and secure manner. We are currently examining how to store and evaluate the condition of the components for the long term.

Nuclear Safety

We provide technical support in a number of areas relating to nuclear safety and facility safety:

• Preparing Environmental Assessments and risk and accident analyses for the transportation of highly enriched uranium and low enriched uranium within the U.S. and from Russia.

• Participating in developing and reviewing DOE/DP's ES&H Management Plan.

• Modernizing the DOE personnel security databases and system for controlling visitor authorization to nuclear weapons data.

• Providing safety analysis and risk assessment support for DOE's DP facilities.

• Developing software for preparing seismic hazard maps and guidelines for system qualifications related to ground shaking.

• Developing a clearing house of data, codes, and documentation of our studies in the areas of natural phenomenon hazards for use by external clients. (This work is jointly funded by the Nuclear Regulatory Commission.)

• Supporting the implementation of the Laboratory Integrated Prioritization System (LIPS) in DOE facilities to improve the budgeting for ES&H activities. (This work is performed through Los Alamos.)

• Providing safety oversight support for nuclear explosives operations.

• Providing criticality safety benchmarks to support facility operations.

Atmospheric Release Advisory Capability (ARAC)

Our Atmospheric Release Advisory Capability, operated by the Regional Atmospheric Sciences Division, provides real-time emergency predictions of the atmospheric transport and deposition of radioactive, chemical, and particulate materials. Originally developed to provide emergency response guidance for nuclear weapons or reactor accidents, ARAC's missions have been expanded to include response to industrial or transportation accidents, major fires (such as the Kuwaiti oil fires), and predictive modeling for hazards assessment and response planning.

ARAC currently serves more than 70 DOE, DoD, and Department of the Navy reactor sites. Its expansion to a national capability for predicting the transport, diffusion, and dispersion of toxic, reactive, and radioactive materials is being proposed.

Artist's rendering of the new Atmospheric Emergency Response Facility at LLNL. This building will house the national ARAC operations and training center. Construction began in August 1994, and we expect to move into the facility in January 1996.

Defense Technology (DOE/ DoD Collaborations)

Under the terms of a Joint DOE/ DoD Memorandum of Understanding (MOU) on topics related to Non-Nuclear Munition Technology, the DOE and DoD equally share the funding for R&D activities of mutual benefit. Cited below are some examples of work undertaken under the auspices of the MOU. Other direct

DoD funded efforts are reported in Section 2.3.

Energetic Materials

The DOE and DoD both share a concern regarding the safety of their weapon systems to both normal handling and abnormal (accidental or threat) stimuli. The DOE issues revolve around nuclear weapon safety, while, for the DoD, the survivability of launch platforms and ammunition storage depots, as well as the reduction of hazards in accidents, are the motivations for the use of insensitive high explosives. We are synthesizing and formulating new explosives that are inexpensive and promise improved performance for DoD applications. We are also developing extrusion-cast and paste explosives for new precision and multistage munitions that are of interest to both DoD and DOE.

We are exploring enhanced conventional bomb loads that preserve safety and significantly improve performance. On the higher end of the scale of energetics, we are exploring approaches that fill the gap between conventional organic explosives and nuclear weapons. These approaches involve hydrides and extended-network metastable elements. Still further up the scale of energetics, we are investigating nonfissioning metastable nuclear isomers.

Demilitarization

Anticipating a ban on open burning and open detonation of excessed energetic materials, we are developing alternative means of environmentally sound disposal. These include recycling when possible, destruction by molten salt oxidation, other oxidation methodologies, and plasma torches. These technologies are also of interest for other DoD disposal requirements such as pyrotechnics and chemical warfare agents.

Special Munitions

For the DoD, we are developing several new designs for shaped charges and explosively formed, projectile-penetrating munitions as well as multistage demolition munitions to attack reinforced targets such as bridge piers. Developed under joint DoD and Department of the Army funding, the penetrating augmented munitions was recently transferred to U.S. industry for engineering development. The DOE interest in this area lies in using these concepts for nuclear-safe destruction of errant or improvised nuclear devices. In addition, the code design and bench marking experimental diagnostics have been mutually beneficial.

Hydrodynamics Codes

To support new special munition design and analysis of lethality and survivability, we have developed a new generation of hydrodynamics codes. CALE, our two-dimensional, Arbitrary Lagrangian-Eulerian code, has been distributed to the DoD and defense industries. We are completing a three-dimensional version of the code called 3DALE. The 3D codes have been of great significance for enhanced understanding of the response of nuclear weapons to various accident scenarios. The DoD interest lies in warhead design as well as target vulnerability and lethality assessments.

Conflict Simulation

We have a long-term interest in developing and applying high-resolution combat-simulation software. We require this capability in order to assess both nuclear and conventional weapon military use and effects. Our Conflict Simulation Laboratory has the ability to simulate a wide scope of operations. For example, it can be used to analyze combat scenarios as well as to plan and rehearse strategies for protecting headquarters or nuclear/conventional weapon storage depots against theft, sabotage, or terrorism. Because this capability supports such a diverse set of software tools, it can also be used to simulate drug interdiction or emergency law-enforcement tactics, to model rescue and relief efforts for disasters (e.g., fires, oil spills, floods, hurricanes, or earthquakes), and to model urban traffic flow. The DoD, especially the Army, has found it to be of great use in training battlefield commanders and to develop tactics for joint war fighting scenarios.

Office of Nonproliferation and National Security

Table 2.1-3 shows projected funding from this office.

Intelligence Assessments

The Laboratory has been supporting the U.S. intelligence community for 30 years with technical assistance for U.S. policies designed to

Table 2.1-3. Nonproliferation and National Security operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
GC Verification & Control Technology	50.1	36.2	42.0	44.0
GD Nuclear Safeguards & Security	3.8	6.1	12.5	10.3
GH Nuclear Safeguards & Security	3.2	5.2	4.5	1.6
GJ Export Control	9.3	11.4	20.0	21.0
NB Emergency Preparedness	0.3	0.0	0.0	0.0
NT Intelligence	6.9	6.0	7.7	7.8
Total	**73.6**	**64.9**	**86.7**	**84.7**
% of Total Laboratory Operating Funding	8.6%	7.5%	8.9%	8.7%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

The TAISIR and GRATIS instrument package just before launch on a high-altitude balloon. TAISIR provided high-resolution images of thermal emissions on the Earth from space, while GRATIS provided images of astronomical gamma-ray sources.

discourage the proliferation of nuclear weapons and encourage the exclusively peaceful use of nuclear technology. We track the nuclear developments in both Non-Proliferation Treaty (NPT) signatory countries and non-NPT countries. We support the U.S. Government in negotiations with countries such as India, Kazakhstan, North Korea, Russia, South Africa, and Ukraine as well as in daily efforts to manage U.S. exports in compliance with federal law and international commitments.

We see a substantial need to expand our ability to support the government in analyzing foreign nuclear-weapon programs in order to better cover new areas of concern, such as dismantlement, fissile material production and cutoffs, weapon security, use doctrine, and other weapons of mass destruction.

Support to the International Atomic Energy Agency (IAEA)

LLNL has been helping the IAEA meet its new technical challenges following the post-Gulf War revelation of Iraq's extensive nuclear weapons program. Specifically, we have

- Provided personnel for inspections in Iraq and helped the IAEA assess findings. As an accredited member of the IAEA Network of Analytical Laboratories, we have analyzed numerous samples from ongoing field trials of environmental sampling techniques, which are expected to be important for detecting undeclared activities.
- Developed an analyst workstation that is being tested by the IAEA for use in managing and assessing comprehensive information on a country's nuclear programs.

• Established sister-laboratory relationships with selected foreign laboratories, including facilities in Morocco and Argentina, under the IAEA technical assistance program.
• Developed field-portable forensic analysis techniques for identifying proliferant activities.

Detecting and Monitoring Nuclear Weapon Activities

The DOE Office of Research and Development has tasked the national laboratories with developing sensors that can detect signs of an existing or emerging capability to produce nuclear, chemical, or biological weapons. With a multidisciplinary approach, we are continuing to investigate several remote-sensing technologies for this purpose with the goal being smaller, simpler instruments for field use. We have also
• Determined the vulnerability of U.S. uranium-enrichment diffusion technology to compromise during on-site inspections.
• Developed radiation techniques to detect and characterize nuclear materials from their intrinsic nuclear radiation. In collaboration with scientists from the Russian nuclear weapons laboratories, we have begun to define techniques to allow greater confidence and transparency in the dismantlement of nuclear weapons, while protecting classified information.
• Developed smaller, more sensitive, unattended, remote monitoring systems that are now being used for cooperative monitoring of Iraq.
• Begun to develop a new generation of sensors to enable the detection and characterization of nuclear proliferation activities from remote platforms.

Emergency Response and Measures Against Nuclear Smuggling

Major portions of this program are supported by the DOE Office of Emergency Operations, under the Deputy Assistant Secretary for Military Applications, as well as the DOE Office of Nonproliferation and National Security. We support the Nuclear Emergency Search Team (NEST), the Accident Response Group, the Federal Radiological Management Assessment Center, and the Radiological Assistance Program. We coordinate the DOE Threat Credibility Assessment Program, and we oversee the Emergency Preparedness Program for the Livermore Laboratory site. For the past several years, we have also provided participants for the United Nations Special Commission and for IAEA inspections and analyses of the Iraqi nuclear weapons program, as requested by the DOE.

This year, we
• Initiated a research program to develop methods for forensic analysis of confiscated samples from trafficking incidents. By characterizing seized samples and packaging materials, we may be able to determine diversion points and transport routes.
• Invented tools that NEST can use in the field to assess a nuclear threat.
• Implemented several new concepts for disabling nuclear devices in the field.
• Developed a concept demonstrating that the U.S. could employ certain operational procedures and technologies that would make it difficult for a terrorist group to successfully transport a nuclear device to its intended target. These same measures could be used to safeguard storage sites for nuclear materials and weapons in foreign countries as well as in the U.S., thereby further reducing the possibility that terrorists could gain access to the means of posing a nuclear threat.

Arms Control Support, Treaty Verification and Threat Reduction in the Former Soviet Union (FSU)

In a major new thrust, we are assembling a Laboratory-wide network of expertise to support the government in its interactions with weapon scientists and institutions in the states of the FSU. The goal is to help speed dismantlement and defense conversion in the FSU and to build confidence between the U.S. and the new republics. We also are continuing our traditional arms-control activities, which include providing analytical and technical support to treaty negotiators and developing equipment to monitor compliance.

Recently, we have
• Provided Laboratory people to serve as the DOE member and scientific advisor to the START delegation in Geneva.
• Developed and negotiated procedures for the use of radiation-detection equipment in distinguishing nuclear and non-nuclear warheads during inspections.
• Provided Laboratory personnel to act as DOE's chief technical advisor in Geneva for the Comprehensive Test Ban negotiations, the chief technical advisor for DOE's R&D program, and as the chairperson or co-chairperson of three of DOE's seven Comprehensive Test Ban Treaty technology areas.

• Developed seismic detection algorithms to be used in monitoring compliance with the Threshold Test Ban Treaty; we have advised the policy community on the capabilities and limitations of our monitoring system.
• Developed a risk assessment system that allows treaty negotiators to analyze the costs and benefits of contemplated protocols for the Biological Weapons Convention (BWC). The system was successfully used in the BWC interagency process.
• Provided two liquid abrasive cutters to Russia, a mobile radiation detection laboratory to Belarus, and an atmospheric dispersion computer model to Belarus, Kazakhstan, and Ukraine in support of the Safe and Secure Dismantlement initiatives supported by Nunn-Lugar funding.
• Participated in activities aimed at extending material protection, control, and accountability of nuclear weapons usable materials to the Russian Federation, Kazakhstan, Belarus and Ukraine.
• Placed about 150 contracts on a lab-to-lab basis for technical services that directly support our programs.
• Participated in U.S. Government initiatives such as the International Science and Technology Centers in the Russian Federation, Russia, Ukraine, and the DOE/State Industrial Partnering Program. Under the aegis of the Industrial Partnering Program, LLNL is developing partnerships with U.S. industry and FSU institutes to commercialize mature technologies for the international market.
• In the area of the protection and control of weapon-usable nuclear materials, we are supporting a multilaboratory effort to improve the safeguards and security at Russian nuclear-weapons-related facilities. This includes the transfer of methods, technology, equipment, and training.

Safeguards and Security Planning for Protection of Russian Material

We are developing training classes and other materials to transfer to Russia the methods and technology used by the U.S. in managing the security of nuclear facilities. The goal is to improve Russian safeguards and security methods.

Electronic Systems for Safeguards and Security

• We are developing an integrated system for the electronic transfer of personnel security data between DOE offices and the Office of Personnel Management. The goal is to reduce the time required to process DOE security clearances and to increase productivity.
• We are developing modernized, integrated databases for personnel security. The goals are to integrate these databases with the processing of security clearances, eliminate redundancies, and provide the infrastructure for complex-wide access control.
• We are developing a complex-wide automated access control system to permit the use of DOE standard badges in access control systems throughout the DOE complex.
• We are developing an approach to evaluating the security of the computerized systems that account for nuclear materials. The goal is to reduce the risk that such systems could be used to cover up the theft of nuclear materials.
• In collaboration with the Martin Marietta collaborative research and development agreement (CRADA) team, we are working with the Argus software development team to develop and test the features needed for a commercial access security system based on the LLNL-developed Argus system.

Table 2.1-4. Fissile Materials Disposition operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
GA Materials Disposition	0.0	7.8	12.5	13.4
Total	**0.0**	**7.8**	**12.5**	**13.4**
% of Total Laboratory Operating Funding	0.0%	0.9%	1.3%	1.4%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Computer Security Technology Center

The Computer Security Technology Center supports a computer security R&D program at Livermore. This project includes an operational incident response group (Computer Incident Advisory Capability) and an R&D group. The R&D group researches security issues and develops tools to enhance the security posture of computer systems and networks. Our projects include

• Security Profile Inspector, which performs security assessments of UNIX- and VMS-based operating systems and reports system configuration vulnerabilities, bad passwords, and system-file integrity violations.
• Network Intrusion Detector, which monitors Ethernet activity on local area network segments and looks for suspicious traffic and connections.
• Text Analysis Project, which helps determine whether sensitive or classified information exists on unclassified computer systems.
• NetMap, which provides a single point of security management for network change detection, unauthorized cross-connect detection, and security validation checks.

Office of Fissile Materials Disposition

Table 2.1-4 shows projected funding from this office.

Disposition of Fissile Material

Presidents Clinton and Yeltsin have declared strong interest in disposing weapons-grade plutonium and concern about plutonium being separated from spent commercial reactor fuel in European and Japanese reactors. To this end, the Fissile Materials Disposition Program is being integrated across the U.S. Government by a DOE-led interagency working group in which Livermore participates. Our roles are to assist in engineering the safe and secure storage of the excess materials; to examine methods for conversion of plutonium metal to pure oxide in preparation for disposition, for which we have already demonstrated an efficient and waste-free direct process called HYDOX; and to evaluate disposition options.

Three principal options are available for plutonium disposition: burning in existing reactors, immobilization in either glass or ceramic, and burial in a deep borehole. We are providing support for the reactor option by evaluating the use of existing commercial and advanced light-water reactors to burn fissile material. We have also prepared an issues assessment of licensing and cost issues conversion of the oxide to fuel for these reactors in a U.S.-based Mixed Oxide (MOX) facility or in existing European facilities. We are also examining the requirements for emplacing the spent fuel (and for immobilized forms discussed below) in a geological repository such as the proposed Yucca Mountain site. We have concluded that this is possible with acceptable modifications to the repository designs.

For burning Russian material, we have focused attention on using VVER 1000 light-water reactors. If suitably modified for both safety and plutonium disposition, this type of reactor could be very effectively used in a timely and cost-effective manner. The Russians, however, are still more interested in a breeder-reactor fuel cycle that would include recycling, but the financial resources required for such an approach are not currently available in Russia and may not be for a very long time.

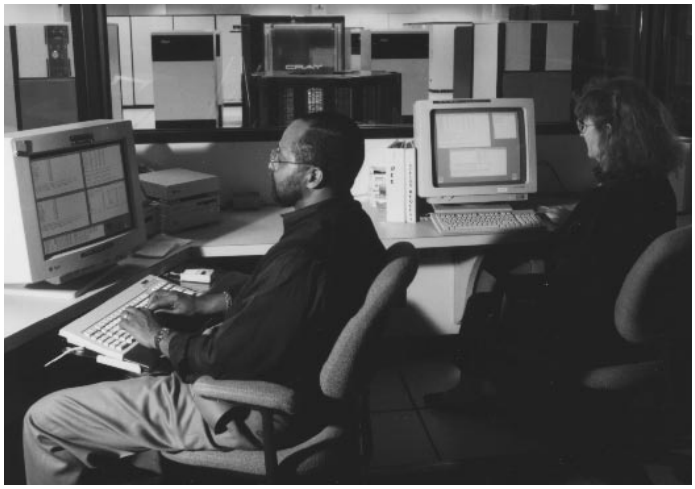
In an analysis of immobilization processes and facilities, we found that glass and ceramic immobilization methods are the leading processes. Either a new plant or, perhaps, significant modifications to the Defense Waste Process Facility (DWPF) at Savannah River could be used to immobilize this fissile material as a glass.

For deep borehole storage, we find that either an immobilized form or perhaps the pits, scraps, and residues can be emplaced. Spiking the materials with fission products is not necessary because the emplacement is surreptitiously inaccessible. Very deep borehole drilling technology has been demonstrated, but regulatory requirements and site characterization sufficient to assure isolation from the biosphere are major uncertainties.

Livermore also is performing safeguards and security studies for each of these options and is providing the information needed for the DOE Programmatic Environmental Impact Statement (PEIS) for the immobilization and borehole disposition options.

Disposition of Surplus Fissile Material

Many activities are underway following the issuance of Presidential Decision Directive-13, which includes provisions for declaring stocks of fissile materials, declaring significant quantities of the stocks as excess and then taking action to prevent subsequent reuse of the excess materials in weapons applications. We are involved in the following:
• We are studying DOE transparency measures for the U.S. purchase of 500 tonnes of Russian highly enriched uranium from dismantled nuclear weapons.
• To encourage the Russian Federation to remove excess fissile material from weapons, we will work with them to



LLNL's National Energy Research Supercomputer Center (NERSC) provides high-end computing services to the national community under Energy Research funding. This system serves 500 users at 200 national and international institutions.

study an alternative approach that consists of burning the excess plutonium in a once-through fuel cycle using light-water reactors.

Safeguards and Security of Nuclear Materials Disposition

We provide support for the PEIS for the secure disposition of excess weapons nuclear material. We are developing analyses for the *record of decision* as to which disposition approaches should be used to deal with excess materials.

Table 2.1-5. Energy Research operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
AT-00 Magnetic Fusion Energy (MFE)	0.0	0.0	0.0	0.0
AT-05 MFE Applied Plasma Physics	13.4	12.0	16.1	17.4
AT-10 MFE Confinement System	4.6	4.9	6.6	14.5
AT-15 MFE Development & Technology	7.2	7.1	8.5	9.0
AT-20 MFE Planning & Projects	0.0	0.0	0.0	0.0
AT-25 MFE Planning & Projects	0.8	1.6	2.3	5.0
AT-30 Inertial Fusion Energy	0.0	0.0	0.0	0.0
KA High Energy Physics	1.1	1.2	0.8	0.6
KB-01 Nuclear Energy Physics	0.0	0.0	0.0	0.0
KB-02 Heavy Ion Physics	0.2	0.3	0.6	0.6
KB-03 Nuclear Theory	0.1	0.1	0.3	0.3
KB-04 Low Energy Physics	0.4	0.3	0.6	0.6
KC-02 Materials Science	2.1	2.8	3.4	4.2
KC-03 Chemical Sciences	0.2	0.5	0.5	0.8
KC-04 Engineering/Math/Geoscience	1.6	1.8	2.4	2.5
KC-05 Advanced Energy Projects	1.0	1.3	0.7	0.0
KC-07 Applied Mathematical Science	29.5	35.8	35.1	37.5
KP-00 Biological/Environmental	0.0	0.0	0.0	0.0
KP-01 Analytical Technology	0.1	0.1	0.1	0.0
KP-02 Environmental Research	1.2	0.4	0.4	0.4
KP-03 Health Services	0.9	0.9	1.8	1.8
KP-04 General Life Sciences	11.4	11.8	14.5	15.1
KP-05 Carbon Dioxide	5.9	6.2	6.7	6.7
KP-06 Medical Applications	0.0	0.0	0.0	0.0
Total	**81.7**	**89.1**	**101.4**	**117.0**
% of Total Laboratory Operating Funding	9.5%	10.3%	10.4%	12.1%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Office of Energy Research

Table 2.1-5 shows projected funding from this office.

Scientific Computing

National Energy Research Supercomputer Center

The National Energy Research Supercomputer Center (NERSC) provides high-end computing services to the user community under Energy Research funding. This facility serves 4,500 accounts at 130 national and international institutions. This year, we extended and improved NERSC services in a number of ways. Specifically, we

- Dedicated time on the Cray C90 to users with highly parallel applications. Access to the full memory and 16 Gbytes of disk space in the C90 allows runs to be completed in hours instead of weeks.
- Added the first massively parallel machine to the NERSC computing

floor. This machine, a Cray T3D with an initial configuration of 128 processing elements, will be used as a development and production tool for leading-edge application codes.
• Launched, in collaboration with Livermore Computing, the Advanced Computing Initiative in Science and Engineering. Researchers at the Laboratory, all UC campuses, and Lawrence Berkeley National Laboratory can access two massively parallel systems: a 256-processor Cray T3D and a 48-processor Meiko CS-2 to develop advanced applications.
• Completed the first year of affiliation of the Center for Computational Sciences and Engineering (CCSE) and NERSC. In addition to continuing its core program in applied mathematics research, CCSE made significant progress on its deliverables for the DOE High-Performance Computing and Communication Grand Challenge Project on computational fluid dynamics and combustion dynamics.

Our plans for the future include
• Acquiring a production massively parallel computer. We expect a system (about 200 processors) to arrive late in 1995. We may upgrade to a system featuring about 500 processors in 1996.
• Completing a Unified Production Environment, which focuses on the organization of traditional services into an integrated unit. The Unified Production Environment will present an intuitive service interface through which NERSC users will request computing services independent of which machines provide the services.
• Providing new technology-based storage systems. These include IBM 3494 robotic systems; an IBM RS/6000 with 100 gigabytes of disk cache; and NSL-Unitree commercial software. Although the initial system will add only a few terabytes of storage, technological upgrades in 1995 and 1996 will allow the NERSC storage environment to grow into hundreds of terabytes.

Energy Sciences Network

The Energy Sciences Network (ESNet) is a nationwide, computer data-communications network that supports multiple-program, open scientific research. Operated 24 hours a day by the networking staff of NERSC, ESNet provides reliable, state-of-the-art networking services to the DOE and to major energy-research facilities throughout the country.

ESnet began operational deployment of a T1 (1.5-Mbit/s) circuit-based backbone in late 1989 with 19 major sites. Today, it serves as a "backbone," interconnecting more than 30 research laboratories with each other and with other networks. ESnet can process several protocols, including DoD Internet Protocol, DECnet Phase IV, and Open Systems Interconnection Connection Less Network Protocol. Plans for carrying the next generation of internet protocol are now underway.

The volume of network traffic more than doubled in 1994. Upgrades in network facilities are necessary to handle the growth as well as new applications that also require higher performance network support. Accordingly, we installed a temporary upgrade to the core of the backbone at T3 (45 Mbit/s) rates.

The plan for moving ESnet to significantly higher performance includes establishing an agreement with a U.S. data communications vendor to incorporate emerging "fast-packet" technology into ESnet. This project is in response to advanced requirements generated by the energy-research community and is DOE's contribution to the National Research and Education Network, which is a major objective of the High Performance Computing and Communications Initiative. The plan includes performance support of greatly improved speeds, potentially up to 622 Mbit/s for some sites.

We selected Sprint to provide these advanced services and signed a multiyear contract. We recently connected six major energy-research facilities to this new communications service and nearly completed testing for contractual compliance. We expect to begin to carry "production" traffic during early 1995.

Applied Mathematical Sciences

The Applied Mathematical Sciences Program at Livermore focuses on the design, development, and analysis of numerical technology to solve large-scale scientific and engineering problems arising in DOE mission areas that involve energy, environmental, and industrial technologies. Funded by DOE's Office of Scientific Computing, this research is problem-driven by prototype applications that are being developed in collaboration with DOE programs here, as well as with colleagues at other national laboratories, and in industry and academia. Research activities include topics in computational fluid dynamics, flow in porous media, particle transport, plasma process modeling, and general numerical methods for solving large-scale differential and algebraic systems.

Fusion Energy

Tokamak Physics Experiment

A national team led by LLNL developed a preconceptual design for a steady-state advanced tokamak that was selected as the design basis for the Tokamak Physics Experiment (TPX), which will be constructed at Princeton Plasma Physics Laboratory. We are playing a major role in the design and construction of TPX. Recently, we

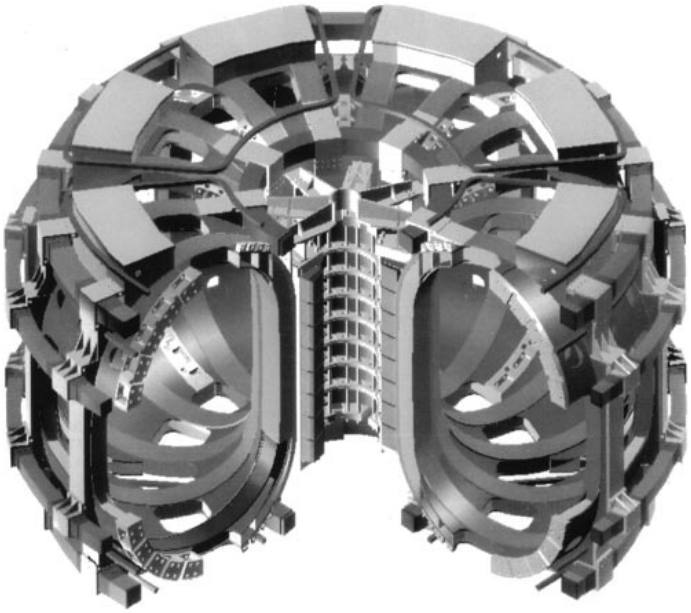
- Completed the conceptual design review.
- Completed the preliminary design with magnet contractors.
- Oversaw industrial development of superconducting strands.
- Developed a practice conductor.

Collaboration on DIII-D

A team of Livermore scientists, engineers, and technicians is collaborating with researchers from General Atomic Inc. (San Diego) in experiments on their DIII-D tokamak. We are focusing our efforts on plasma edge and divertor physics and on advanced tokamak issues. Edge physics behavior is critical in determining the character of the power flow from the confined plasma to the divertor. A thorough understanding of advanced tokamak physics will be required for the successful design of a tokamak reactor. Recently, we

- Installed new diagnostics, including a Thomson Scattering System, in the divertor area.
- Participated in edge physics experiments on DIII-D.
- Provided project management for the radiative divertor program.
- Improved the numerical codes used to analyze DIII-D data and guide the design of the radiative divertor program.

We are responsible for the superconducting magnet systems for the planned Tokamak Physics Experiment. This will be the first tokamak with fully superconducting magnetic field coils using advanced conductors.



International Thermonuclear Experimental Reactor (ITER)

The ITER is an international collaboration among the European Community, Japan, Russia, and the U.S. to design and construct a 1500-MW (thermal) experimental reactor. We provide personnel to the Joint Central Team and perform research and development for the ITER, with particular emphasis on the magnets, design engineering, and physics. Recently, we

- Assumed the leadership for the materials properties handbook, the interim structural design criteria, and assembly tasks.
- Developed advanced scenarios that allow steady-state operation at full fusion power.
- Optimized the poloidal field system (in collaboration with Oak Ridge National Laboratory), resulting in greater operational flexibility at reduced cost.
- Designed (in collaboration with General Atomics) a plasma position and shape control system.
- Optimized (in collaboration with General Atomics) electron cyclotron current drive scenarios.
- Tested a Japanese full-scale conductor.
- Established a process for chromium plating of superconductor strands for both ITER and TPX.
- Provided electromagnetic, structural, and thermal analysis for the ITER model coil effort in the U.S.

Advanced Fusion Assessment Program

We perform conceptual studies and modeling of novel or relatively

unexplored ideas for advanced fusion reactors. Our efforts focus on both the underlying physics and the ultimate reactor potential. We seek, generate, and evaluate ideas for fusion reactor concepts that have potential for improvement in cost, simplicity, and ease of development over conventional concepts. Recently, we

• Conceived a novel method of nonthermonuclear fusion with an order-of-magnitude increase in the cross section for some advanced fusion fuels.

• Re-evaluated data from previous spheromak experiments and demonstrated energy confinement times consistent with magnetic turbulence.

• Analyzed a new, magnetic fast ignition for inertial confinement fusion that should increase the gain from a target by a factor of 10.

• Designed a compact, high-power-density fusion neutron source based on a continuous flow pinch.

MFE Theory and Computations

Our activities include theoretical and computational research on the physics of the open-field-line scrape-off layer at the edge of a tokamak; gyrokinetic simulation of turbulence-induced transport in plasmas; development of Corsica, a comprehensive simulation of a toroidal magnetic fusion device; and theoretical computational modeling of plasma diagnostics. Our goal is to develop an understanding of phenomena observed in present experiments and to develop predictive capabilities that will enable us to optimally design future devices. Recently, we

• Studied the parameter dependencies of ion-temperature-gradient-driven turbulence in tokamaks and compared them with fluid simulations and experimental data. We also developed a massively parallel version of code.

• Developed models for scrape-off layer turbulent transport and the role of drifts in producing asymmetries and altering boundary conditions in scrape-off layers. These are being incorporated into our UEDGE code, a major tool for understanding and controlling the intense heat fluxes hitting the surfaces that bound a tokamak plasma.

• Developed demonstration codes coupling turbulence simulation to a plasma transport code, and coupling core and edge-region transport codes as part of the Corsica project. The previously released version of Corsica is used for modeling DIII-D and ITER.

• Developed a multidimensional theory of electromagnetic wave propagation, reflection, and scattering by density fluctuations in a spatially nonuniform plasma. A suite of new computer codes has improved the understanding of wave reflectometry, an important diagnostic to measure plasma profiles and fluctuation characteristics.

Heavy Ion Sources

Under DOE Energy Research auspices, we are pursuing the application of heavy-ion accelerators as drivers for inertial fusion energy (IFE). These accelerators are projected to offer favorable efficiency, pulse repetition frequency, availability, and longevity. Focusing of the beams onto

Cooling channels are being milled into the first high-power 476-MHz cavity for the PEP-II accelerator, in a numerically controlled five-axis machine in the Building 321 shop.

the target will be affected by magnetic fields, rather than by solid optics that might be damaged by the target explosions. Thus, the use of such accelerators to propel beams of heavy ions onto indirectly driven targets is the leading approach for IFE.

We are participating with Lawrence Berkeley and Sandia National Laboratories in the national Heavy Ion Fusion (HIF) program by working on

- High-current ion induction accelerators.
- The accelerator–target interface.
- The design and evaluation of the targets.

The four major elements in the Livermore HIF accelerator research program are

- Planning, engineering, and execution of the Elise accelerator project with LBL. Elise—the first stage of the accelerator, which is central to the Induction Linac Systems Experiments program—received DOE approval at the Key Decision One level.
- Development of improved driver concepts, especially a prototype recirculating induction accelerator.
- Theoretical and numerical modeling to support the above efforts.
- Studies of plant-scale driver accelerators and beams.

Research on the accelerator–target interface involves three activities:

- Computer simulations and theoretical analyses of beams as they are compressed and focused onto the targets.
- Beam–target interaction.
- IFE power-plant studies to guide the overall effort.

Research on ion-driven targets involves two activities:

- Target-design calculations using the tools and techniques developed by the ICF Program.
- Experiments on Nova and National Ignition Facility (NIF) designs to have a better understanding of HIF targets.

High-Energy and Nuclear Physics

B-factory

We are a partner with the Stanford Linear Accelerator Center (SLAC) and Lawrence Berkeley National Laboratory (LBNL) in the design and construction of the B-factory, a Presidential initiative. The B-factory, which will be commissioned in 1999, will consist of a high-luminosity, asymmetric-energy electron-positron collider and a detector. The purpose of the project is to study the origin of the breaking of a fundamental symmetry in nature that gave rise to the predominance of matter over antimatter in our universe. Our responsibilities in the design and construction of the accelerator include high-power RF cavities; the high-speed, distributed ion-pumping system; wiggler magnets for beam-emittance control; beam transport sections; a complex magnetic lattice for the electron-positron collisions; and power conversion. We share project management responsibility with SLAC and LBNL. For the detector, we are responsible for the specification and procurement review of the Italian-funded superconducting magnet coil and engineering of the high-resolution detector (containing 10,000 cesium iodide crystals) for gammas and electrons. With a consortium of Italian universities and laboratories, we share responsibility for the 3000 m^2 of muon chambers. Livermore scientists are leading the physics simulations for this detector.

Mechanical engineer Don Masquelier works on a miniaturized flow cytometer, which uses fiber-optic data collection inside the flow stream. Compared with conventional flow cytometers, this instrument's novel signal-detection system yields a signal that is less noisy and an order of magnitude stronger.

Nuclear Physics

Our Nuclear Physics Program has four components.

We are participating in experiments at GAMMASPHERE to study superdeformed nuclei. The focus is on understanding nuclear-shape isomerism, which can be viewed as an electromagnetic analog of fission isomerism. We have mapped the

region of superdeformation near atomic mass number 190, and are elucidating the nuclear structure associated with the second well of the nuclear potential energy surface.

Livermore is responsible for the design and construction of three magnetic spectrometers for the PHENIX detector, which will search for the quark gluon plasma at the Relativistic Heavy Ion Collider to be built at Brookhaven National Laboratory (BNL). We are coordinating work for the central drift chambers of the PHENIX detector, which is being fabricated in Russia.

We are participating in experiments at the Alternating Gradient Synchrotron at BNL to probe nuclear matter at extreme conditions. The focus is on understanding the production mechanisms and angular distribution of reaction products resulting from nucleon–nucleon collisions that create nuclear matter at densities as high as five times normal.

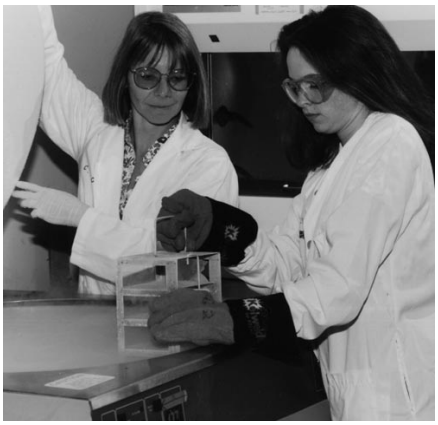
We are continuing to develop a new high-energy nuclear database for use in such diverse applications as radiation oncology, accelerator production of tritium, and accelerator transmutation of waste. For this database, we have completed evaluations of neutron-induced reactions up to 100 MeV for hydrogen, carbon, nitrogen, phosphorous, and calcium. We are the first nuclear data center to use a high-energy, microscopic, evaluated, and processed database in application-oriented calculations. We are developing the capability to model photonuclear processes for energies up to 140 MeV.

Health and Environmental Research

Health and Biotechnology

Health and Biotechnology is multidisciplinary and draws on expertise throughout the laboratory to conduct its research. Our existing core competencies and resources fall into five major areas: tools for assessing exposure; genomics infrastructure; structural biology, bioinformatics, and bioinstrumentation. Recently, we have

- Improved collection of x-ray diffraction data by cooling protein crystals to 125K. We attained the highest resolution (1.0-Å) data set ever achieved for a single crystal of a protein.



Biomedical scientist Cindy Thomas (left) and summer student Sarah Henson remove samples from a liquid nitrogen tank. Viable cells are routinely frozen for later use as part of epidemiological studies to quantify damaging exposures in several populations, including smokers, pesticide workers, and "liquidators" (cleanup workers) from the Chernobyl nuclear power plant accident.

- Generated a metric physical map of chromosome 19 that spans 90% of the chromosome in 51 ordered islands of overlapping clones.
- Completed the generation of the entire set of flow-sorted cosmid and lambda libraries for Phase II of the National Gene Library Project.
- Developed chromosome painting probes for the mouse in order to evaluate the persistence of chromosome damage following exposure to ionizing radiation. This work received an R&D 100 Award.
- Cloned the human repair gene XRCC3 and showed that it is required for chromosome stability and resistance of cells to a wide variety of DNA-damaging agents.
- Developed fabrication technology for building an array of micromachined channels for DNA sequencing via electrophoresis, which achieved a resolution of 500 base pairs.

Health Effects

Our health effects research integrates studies in three areas: DNA repair, the genetics of cancer susceptibility, and biodosimetry. This work derives from our historical focus on issues relevant to DOE. It has now broadened to include the interests of other customers, such as the National Institutes of Health. We have made major contributions to the study of DNA damage and repair, specifically in identifying, isolating, and characterizing human DNA repair genes. We are also interested in genes that confer susceptibility to cancer, such as those involved in DNA repair, xenobiotic metabolism, and regulatory control.

Genomics

We are one of three DOE Human Genome Centers. In the course of developing a very-high-resolution map of human chromosome 19, we structured our operations to create some unique, multidisciplinary research capabilities. Consequently, it has become relatively straightforward to isolate and characterize genes of interest in almost any species. Much of our emphasis is now shifting to gene discovery and high-throughput DNA sequencing. We played a major role in initiating the IMAGE consortium, an international effort to create a freely available resource of all human DNA clones. Although most of this effort focuses on human chromosome 19, the methods and technologies extrapolate directly to other species. We are using our knowledge base to extend our research to DNA sequence-based forensics and comparative analysis of the mouse genome. Protein structure-function prediction is of major interest as we try to decipher the overwhelming amount of DNA sequence data that is being generated.

Structure-Function Analysis

Cancer and human disease are often caused by defective proteins or damage produced by small molecules that bind to and alter the structure of DNA. To understand how proteins become defective and determine how chemicals in our environment damage our DNA, we must elucidate the structure of these molecules at very high (atomic) resolution. This can only be accomplished using techniques such as x-ray diffraction or high field nuclear magnetic resonance spectroscopy. In many cases, the structure and function of many proteins produced by disease-related genes are not easily deduced experimentally. Consequently, improvements in existing computational methods for predicting the structure and function of unknown proteins from their amino acid sequences would greatly enhance our ability to understand the molecular mechanisms responsible for genetic diseases and cancer. Our capabilities in high-resolution structure prediction and analysis have been greatly enhanced through the recent addition of our structural biology effort.

About 25% of Belarus is radioactively contaminated. The incidence of thyroid cancer in children living in Belarus has been steadily increasing since the Chernobyl accident in 1986 and is now at alarming levels. We are reconstructing thyroid doses to children from milk.

Radiation Oncology

We are developing an all-particle Monte Carlo code called PEREGRINE, which uses the new Livermore nuclear databases to calculate the dose distributions in the human body from radiation therapy. PEREGRINE is intended for patient treatment planning with all currently used radiation types. Together with nuclear and atomic data, PEREGRINE uses patient CAT scan information to calculate the dose at the resolution of the medical imaging apparatus (~1 mm). The goal of the PEREGRINE project is to allow the radiation oncologist to maximize the dose delivered to the tumor volume while minimizing the dose to healthy regions, particularly critical structures in the proximity of the tumor.

Health Care

We have formed a Center for Healthcare Technology, which draws on expertise developed in the defense programs. Our goals are to coordinate health care technology efforts across the entire laboratory, to initiate new

thrust areas, and to establish a credible effort that contributes to national health care needs for cost-effective technologies. The Center focuses on applications in diagnosis, screening, prevention, minimally invasive medicine, and information management.

Climate and Atmospheric Sciences

The Laboratory's Global Climate Research Division, the Regional Atmospheric Sciences Division, and the Program for Climate Model Diagnosis and Intercomparison execute major projects for the DOE Office of Health and Environmental Research (OHER).

In support of OHER's Computer Hardware, Advanced Mathematics, and Model Physics Program, the Global Climate Research Division has developed global atmospheric, oceanic, and chemistry models for massively parallel computers. The Division also develops and tests models to examine the linkage of atmospheric trace gasses, aerosols and particulates, chemical and transport processes, and climate change. Recently, these models revealed that scattering from aerosols and particulates offsets, to some extent, the warming caused by greenhouse gases. Further analysis has shown that the predicted pattern of temperature change derived from the models is increasingly evident in the historical record of temperature change.

The Regional Atmospheric Sciences Division, which supports OHER's Atmospheric Radiation Project, uses its mesoscale models to improve our understanding of cloud-radioactive feedback in global climate modeling. It also designs experiments and develops algorithms for the project's experiment support team.

The Program for Climate Model Diagnosis and Intercomparison coordinates and implements an international assessment and intercomparison of global atmospheric general circulation models to improve their ability to simulate climate and climate change processes. It also develops tools and standards for systematic testing, intercomparison, and validation of these models by focusing on such topics as cloud forcing and feedback, low-frequency variability, and spatial variation.

We are also developing codes for modeling the carbon cycle using fully three-dimensional representations of the atmosphere, ocean, and terrestrial biosphere. Our models will be validated with experiments using very sensitive nuclear chemistry techniques. In addition, we will use data from past atmospheric testing for evaluating models of transport and accumulation. Lastly, we are developing other radiochemical analysis techniques to assess groundwater quality and flow and to evaluate contamination problems.

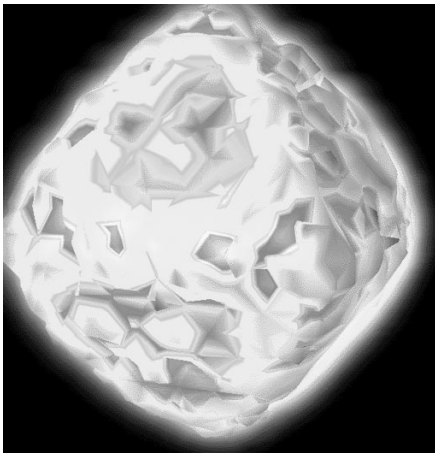
Atmospheric Radiation Measurement Program (ARM)

The ARM program, involving atmospheric measurements and modeling, is intended to improve our understanding of processes that affect atmospheric radiation (light and heat), especially the influence of clouds and the role of cloud radiative feedback. The program's goal is to provide a better description of these processes in climate models. Measurements are being made in continental, tropical, and polar locations. We are involved in collaborations with ARM Science Team members and quality assurance of data from ARM instruments. We are developing algorithms to assimilate and streamline the delivery of ARM data based on concise statements of the science objectives, methodology, and data needs for each site. We are developing methods to perform "quick look" quality control of individual data streams using consistency checks among various instruments and between different observations of similar parameters.

Basic Energy Sciences (BES)

Materials Sciences

The Materials Sciences program is directed toward the fundamental understanding of materials and



This crystal growth model shows heat emanating from it as material solidifies and facets grow.

processes that are important to the Laboratory's mission. In metallurgy and ceramics, we are investigating the role of interfaces in the performance of engineering materials and the development of superplastic forming processes. Our optical materials program continues to improve understanding of the phenomena that are important in designing high-power laser systems, while the remainder of our solid-state physics effort focuses on the study of nanocrystalline materials and novel coatings. Our materials chemistry projects use synchrotron radiation to obtain detailed atomic characterization of buried interfaces and for direct measurement of magnetic properties at the atomic scale.

Chemical Sciences

We are using the LLNL Electron Beam Ion Traps to study the structure and interactions of highly charged atomic ions all the way to fully stripped uranium (U92+). In atomic spectroscopy, our research focuses on high-resolution, high-accuracy measurements of transition energies in few-electron heavy ions to determine quantum electrodynamics corrections and nuclear-size effects on energy levels. In the area of electron–ion collisions, we are investigating both recombination and ionization. Recombination measurements focus on heavy ions, where we have observed quantum interference between two different modes of recombination (dielectronic and radiative). We are also measuring electron impact ionization rates for hydrogen- and helium-like ions for which no previous experimental data exist.

In the area of chemical kinetics, we are concentrating on the computer modeling of combustion relevant to laboratory and actual-use environments, with special emphasis on hydrocarbon fuels that are widely used. Specific applications include the kinetics of engine knock in internal combustion engines, the kinetics of cool flames and multistage ignition, and the influence of pressure and molecular structure of the fuel on combustion parameters.

Table 2.1-6. Environmental Restoration & Waste Management operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
EW-11 Corrective Actions	0.2	0.0	0.0	0.0
EW-20 Environmental Restoration	28.8	26.0	29.7	29.8
EW-31 Waste Management	30.7	29.8	30.8	24.9
EW-40 Technology Development	10.9	5.3	5.3	5.4
EX-60 Program Direction	0.0	0.0	0.3	0.3
Total	**70.6**	**61.1**	**66.1**	**60.4**
% of Total Laboratory Operating Funding	8.2%	7.1%	6.8%	6.2%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Geosciences

The Geosciences Research Program focuses on understanding the chemical and physical interactions between rocks and fluids (aqueous, hydrocarbons, and melts) within the earth. Theory and experiments are used to characterize the chemistry of reactive transport and to develop methods for underground imaging of rock and rock/fluid properties. Advances in these areas support DOE's missions in basic and applied energy research, fossil energy development, environmental remediation, and nuclear waste disposal.

Recent accomplishments include the

- First experimental determinations of mineral/aqueous fluid partitioning of trace elements at elevated temperatures and pressures and implications for fluid metasomatism.
- Discovery of the role of low-frequency shear weakening of clay-bearing sandstones in the failure of the I-5 highway interchange during the 1994 Northridge, California, earthquake.
- Discovery of a change of three orders of magnitude in diffusion coefficients for transition metals across the Earth's transition zone.
- Discovery of the effect of joint-propping on enhancing the fracture permeability of crystalline rock masses.
- Elucidation of the kinetics of petroleum destruction in geologic formations by use of ^{13}C-labeled tracers.
- Development of a new theory relating bulk poroelastic properties of rocks to their microstructures.

Important future objectives for the Basic Energy Sciences (BES)

geosciences program include development of new techniques for characterizing mineral–fluid interfaces, continued development of models for poroelasticity and fracture mechanics, and continued work on understanding the physics and chemistry of reactive transport within the earth.

Advanced Energy Projects

We are fabricating and characterizing thin-film, solid-state lithium batteries using sputtering techniques developed for multilayer x-ray optics. The batteries, typically 3 to 5 mm thick, consist of layers of Li, LiNCl, and TiS_2 sequentially sputtered in vacuum. For the first time, we have produced entire batteries without breaking vacuum. The resulting pristine interfaces allow us to study the electrochemical process free of contamination. Advanced co-deposition techniques will allow us to blend the composition at the interfaces for optimal performance. Applications include on-chip power supplies for sensors and critical electronic components. In the area of advanced thermoelectric devices, we are investigating the synthesis of nanostructured materials in experiments to determine the possible existence of a theoretically predicted phenomena, based on the quantum well effect, that would represent a breakthrough in performance. We are also exploring the development of a solgel process for the synthesis of porous carbon membranes and foams. We expect that these new materials will result in the development of improved energy storage devices.

Assistant Secretary for Environmental Restoration and Waste Management

The DOE Assistant Secretary for Environmental Restoration and Waste Management sponsors Laboratory activities in environmental restoration, waste management, and technology development. Table 2.1-6 shows projected funding from this DOE Assistant Secretary.

Environmental Restoration

Remediation Technology

LLNL conducts fundamental and applied research to develop, demonstrate, and commercialize innovative technologies for solving environmental problems. The main sponsor for environmental restoration and waste management research and development is the DOE Office of Environmental Management (EM). Key business areas include research and technology development for site investigation, in-situ remediation, and ex-situ waste destruction applications. Supporting technologies include groundwater modeling for contaminant fate and transport, risk assessment, waste minimization, and process automation through intelligent systems. In recent accomplishments, we have

• Completed a downhole treatability test of microbial filter technologies at Cape Canaveral, Florida. This test demonstrated the robustness of the technique in treating a broad range of

Air-monitoring stations are part of LLNL's environmental surveillance network.

volatile organic compound (VOC) contaminants, and was jointly funded by DOE/EM-50 and NASA.

• Completed a revolutionary in-situ microbial filter huff-and-puff field test at the Chico, California, airport. This was the first in-situ bioremediation of trichlorethylene- (TCE-) contaminated ground water to single-digit parts-per-billion concentration levels known to have been successfully completed in the U.S. or internationally. It was funded by DOE/EM-50 with industrial support in kind from Brown and Caldwell Inc.

• Completed dynamic underground stripping at the Livermore site's gasoline spill. This technology successfully removed thousands of gallons of gasoline from the subsurface in less than one year of field operations at a normalized unit cost of approximately $60–70 per cubic yard of soil treated.

• Developed an advanced fiber-optic-based sensor system for remotely characterizing highly radioactive wastes from the Hanford tanks.

Future environmental technology research and development efforts will meet defense complex needs for in-situ detection and monitoring of contaminants, in-situ remediation of nonaqueous phase liquid and metal contaminants, ex-situ low-temperature and nonthermal treatment of hazardous and mixed wastes, and integrated approaches to accelerate site cleanup design and operation.

Site Restoration

Our Environmental Restoration Program is investigating and remediating contaminated soil and groundwater at the main Livermore site and Site 300. Remediation includes the evaluation, selection, and implementation of relevant environmental restoration technologies. To accomplish our work, we develop and apply innovative, state-of-the-art methodologies, technologies, and processes. We also

• Ensure compliance with environmental, regulatory, and DOE requirements.

• Conduct our activities in a cost-effective, safe manner.

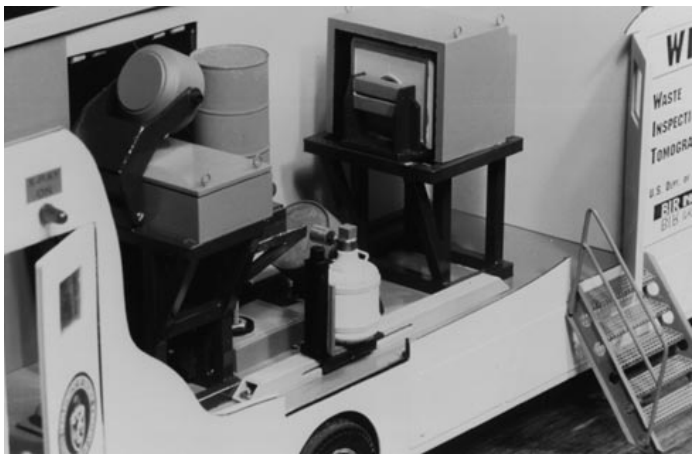
• Cooperate and participate with others in the research, development, demonstration, testing, and evaluation of environmental restoration technologies.

• Provide and manage a series of well-characterized and instrumented testbeds to assist in the development of a broad suite of investigation and remediation technologies and approaches.

Much of the Livermore site groundwater problem is the result of activities conducted by the previous tenant, Livermore Naval Air Station, during World War II. Because the VOCs exceed drinking-water standards and are in groundwater within three miles of a municipal water supply, the Environmental Protection Agency (EPA) has placed the Laboratory on the National Priorities List for cleanup. Other environmental problems, such as leaking underground tanks and closure of hazardous waste-management facilities, are also managed under this program.

At the main Livermore site, the Record of Decision that documents the selection of the proposed remediation of groundwater that was found to contain VOCs was completed in mid-1992. Cleanup officially commenced in FY 1993; remediation is ongoing. The development of state-of-the-art computer models has led to development of strategies to achieve more cost-effective site remediation.

Site 300 has also been placed on the National Priorities List. Site 300 environmental restoration activities are being conducted under a Federal Facility Agreement between the DOE, the EPA, the California Department of Toxic Substances Control, and the



A waste-inspection tomography unit allows inspectors to measure the radiation inside drums without opening them. The unit provides sharper images than other radiographic techniques and is safer and less expensive.

California Regional Water Quality Control Board. Restoration activities are addressing such problems as tritium in the groundwater in the northern part of the site, closure of an active landfill, and cleanup of TCE and high-explosive compounds in groundwater at other parts of the site.

Most of the remedial investigation work and some of the feasibility study work has been completed, as has the closure of the old high-explosive, rinse-water lagoons, two Resource Conservation and Recovery Act landfills, and inactive water-supply wells. A site-wide Remedial Investigation Report was completed in 1994. The Federal Facility Agreement specifies due dates for submittal of regulatory documents leading to initiation of cleanup. Interim cleanup is currently being performed on TCE-contaminated groundwater in three areas in the southeastern corner of Site 300.

We are applying the concept of optimized remediation ("smart" pump-and-treat) of groundwater at the Livermore site. A major milestone that was identified for environmental restoration activities in the five-year plan was the completion of designs for three investigation areas at Site 300 (Building 834, the high-explosives process area, and Pit 6), as well as the gasoline spill area at the Livermore site. Completing a remedial action implementation plan for Buildings 833 and 850 and completing Records of Decision for Buildings 833 and 801/865 were also identified as major milestones.

Waste Management

Activities for the management of hazardous, radioactive, and mixed wastes (wastes that contain both radioactive and chemically toxic materials) at the Laboratory include

- Waste operations of treatment, storage, and disposal.
- Supporting functions of data maintenance, report and procedure preparation, quality assurance, and waste characterization.
- Waste pollution prevention.

State of California inspections of the Laboratory's Treatment, Storage, and Disposal Facilities at Site 300 in 1994 and at the main site in 1995 cited no violations. The Site 300 inspection was the first inspection with no violations in over five years since the state began conducting hazardous waste inspections. The main site followed with the same results and prompted the state agency to once again applaud LLNL for its compliance efforts. The main site permit application, although determined by the agency to be complete, has been put on hold pending resolution of issues California has raised on the Health Risk Assessment (HRA) submitted in support of the permit application. Our Explosive Waste (EW) storage facility permit application for Site 300 remains on file with the state agency. No action has been taken since we responded to a Notice of Deficiency (NOD) in 1994. We are reworking the HRA submitted in support of the EW Treatment Facility and will submit it in late summer 1995. We are also responding to a NOD issued against Site 300 Building 883 for a permit-renewal application to store hazardous waste containers.

To maintain compliance, we continue to emphasize a strong surveillance and audit program and improved training. We implemented an operations control system to track waste from generator to disposal. As a result, we have brought our waste-storage procedures into compliance with storage-duration limitations. Development of waste-acceptance criteria (WAC) for all our waste types has become an important part of the program. Implementation of the WAC program will occur this year.

An active line-item construction project, the Decontamination and Waste Treatment Facility (DWTF) along with overall waste minimization activities are the long-term solutions to waste management. This facility is proposed to replace and modernize scattered and outmoded waste-management facilities; it will combine mixed waste treatment development facilities with waste management facilities to minimize program expenditures and overall costs.

Using the best technology available, the DWTF will process and treat most of the mixed and radioactive waste created at LLNL and provide interim storage for all waste streams. The DWTF is now in the design phase.

Additional low-level radioactive waste stream disposal applications were approved by the DOE Nevada Operations Office, and we continue to ship this waste to the Nevada Test Site. Until the Nevada Test Site is authorized to receive mixed waste, we must continue to store most mixed waste on site. We recently received permission from DOE to ship two mixed waste streams of soil and debris to a licensed commercial mixed waste disposal site . We have begun to solidify filter cake wastes to enable disposal. Because mixed waste is difficult to treat, we are now

focusing waste-minimization efforts on mixed-waste streams.

The characterization of "legacy waste" (waste not certified at the time of generation) will be a major project for the next two to three years. We will lease a portable real-time radiography system to aid in the initial characterization before waste containers can be opened. Facilities are being designed so that drums and boxes of mixed, transuranic, and low-level waste can be opened safely after the wastes have been examined and counted.

We will continue to test and implement technologies to improve the treatment of aqueous radioactive and mixed waste. We will also develop and implement new techniques to treat and stabilize nonaqueous radioactive and mixed waste for disposal.

Pollution prevention and waste minimization activities at LLNL are performed both by the Environmental Protection Department's Pollution Prevention Group and by Laboratory programs. Pollution prevention includes activities that reduce or eliminate the generation of waste (both hazardous and nonhazardous) before it becomes a pollutant. The "three R's" of pollution prevention—reduce at the source, recycle, and reuse—are the key to LLNL's successful pollution prevention efforts.

Our pollution prevention activities have focused on systematically analyzing major LLNL hazardous waste streams, helping characterize how and where waste is generated, and identifying what can be done to reduce its quantities or hazards. Recent pollution prevention efforts have identified all major waste streams and recycling opportunities at LLNL. In addition to hazardous waste generation, over 6,000 tons of solid, nonhazardous wastes are generated each year at the Laboratory. Major Livermore recycling efforts are now in place and have significantly reduced the nonhazardous waste streams of the Laboratory. We recycle many products, including white and colored paper, batteries, cardboard, tires, reusable metals, oil and diesel fuels, solvents, and chlorofluorocarbons.

Scientists from Livermore and from the Russian Academy of Sciences, Institute of Industrial Ecology, pose for a photo on a street in Yekaterinburg, Russia, following lab-to-lab discussions on their pollution prevention project.

Waste Treatment

The Mixed Waste Management Facility (MWMF) project is developing restoration and waste-treatment technologies for the ongoing cleanup of the DOE complex and for the cleanup of wastes generated by the processing of special nuclear material. Although our immediate focus is on LLNL waste streams, the technologies we are developing are applicable throughout the DOE complex. Many of our development programs are team efforts with industry. Thus, we expect that our technologies will play a significant role in the commercial sector.

Incinerator-Alternative Technologies

We are developing technologies that will replace incineration as a

process for treating or destroying hazardous and mixed wastes. These technologies are for cleaning up stored waste and the waste resulting from the processing of special nuclear material. Incinerator-alternative technologies such as mediated electrochemical oxidation, molten salt oxidation, direct wet chemical oxidation, ChemChar (reverse-burn pyrolysis), and photolytic destruction will avoid the release of hazardous chemicals into the environment and the generation of nitrogen oxides and other toxic gases. As technologies mature, they will be integrated into the MWMF project for demonstration at pilot-plant scale. Mediated Electro-Chemical Oxidation and Molten Salt Oxidation have been selected for initial demonstration.

Robotic Handling Systems

We are developing robotics and remote technology for future hazardous and mixed waste treatment facilities under the sponsorship of the DOE Technology Development. Activities focus on working with industry to adapt existing systems to meet DOE needs and on developing technology to make next-generation systems smarter.

In support of these activities, we have

- Demonstrated a robot able to use three-dimensional machine vision and grasp objects.
- Demonstrated automated robotic waste sorting.
- Demonstrated automated robotic decontamination of metal surfaces.
- Completed the glove box robot development program with IBM.

Tele-robotic systems may used to handle waste in the MWMF. We are also developing robotics for shared (human/machine) control of remote systems, waste retrieval from underground storage tanks, and waste characterization and sorting.

Assistant Secretary for Environment, Safety, and Health

The DOE Assistant Secretary for Environment, Safety, and Health funds two activities of the Health and Ecological Assessment Division (see Table 2.1-7).

The first is a study to determine whether the Marshall Islands, where atmospheric nuclear weapons tests were conducted in the 1950s, are now suitable for resettlement. This decision requires detailed knowledge of the radionuclide transport pathways through the biosphere and food chain, and the ability to make dose projections for alternative living patterns. A research program to evaluate various potential countermeasures to reduce the dose to returning populations is an important part of the project. Results are reviewed and audited by the Marshallese government.

The second is a study on dose reconstruction and epidemiology for those affected by the Chernobyl accident and nuclear-weapons installations. Our Chernobyl-related work is a collaborative project with scientists from Russia, Ukraine, and Belarus to study radiogenic diseases,

Table 2.1-7. Environment, Safety, and Health operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
HA-01 Environment, Safety, & Health	5.6	4.6	8.7	9.0
HP-01 Nuclear Safety Policy	0.9	0.7	1.2	1.4
HR Epidemiologic Activities	1.8	1.9	2.5	2.8
HS Security Evaluation	1.3	1.2	1.5	1.5
NR-00 Radiological Oversight	0.0	0.0	0.1	0.1
NS-01 Nuclear Safety - Standards	0.1	0.1	0.1	0.2
NS-06 Nuclear Safety - Initiatives	0.1	0.0	0.3	0.3
Total	**9.8**	**8.5**	**14.4**	**15.3**
% of Total Laboratory Operating Funding	1.1%	1.0%	1.5%	1.6%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

with special emphasis on childhood-thyroid cancers and leukemia. More recently, we have begun working with Russian scientists in an effort to study the relationships between human exposures derived from the Mayak Complex and the subsequent induction of cancers among those exposed.

Office of Nuclear Safety Policy and Standards

Natural Phenomena Hazards Policy and Standards

We provide technical support for the development of DOE orders and standards related to natural phenomena hazards. We also help DOE develop guidelines on computer use in safety and environmentally critical applications.

Deputy Assistant Secretary for Safety and Quality Assurance

Packaging Certification and Training

To protect the health of the public and employees, we have reviewed Safety Analysis Reports related to the transportation of radioactive material. We have also prepared and presented training courses on the safe packaging and transport of radioactive materials.

Deputy Assistant Secretary for Nuclear Facility Safety

Packaging and Transportation Technical Support

We provide technical assistance to the Packaging and Transportation Division related to the safety of packaging and transporting radioactive materials. We perform assessments; support the development of policies, standards, and orders; and develop training.

Table 2.1-8. Nuclear Energy operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
AF-12-10 Light Water Reactors	1.0	0.0	0.0	0.0
AF-20 Advanced Reactor R&D	0.1	0.0	0.0	0.0
AJ-05 Naval Reactors	0.3	0.3	0.3	0.4
CD-10-04 Highly Enriched Uranium	0.1	0.2	0.0	0.0
CD-10-06 Nuclear Safety	0.0	0.3	0.0	0.0
CD-10-07 Maint. of Leased/non-Leased	0.2	0.0	0.0	0.0
CD-10-08 AVLIS	3.9	0.0	0.0	0.0
CD-10-09 Technology Partnerships	0.3	0.2	0.3	0.3
CD-10-12 Program Management Services	3.0	2.0	2.0	2.0
CD-10-13 Transparency Measures	0.8	5.2	5.5	6.8
CD-10-15 Depleted Uranium Hexafluoride	0.0	0.0	1.0	0.8
KK-05 Policy and Management - NE	0.2	0.2	0.0	0.0
Total	**9.9**	**8.4**	**9.1**	**10.3**
% of Total Laboratory Operating Funding	1.2%	1.0%	0.9%	1.1%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Table 2.1-9. Civilian Radioactive Waste Management operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
DB Nuclear Waste Fund	15.5	12.8	0.0	0.0
Total	**15.5**	**12.8**	**0.0**	**0.0**
% of Total Laboratory Operating Funding	1.8%	1.5%	0.0%	0.0%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Office of Nuclear Energy

Uranium Handling

We provide a broad spectrum of environmental and safety support to the Office of Uranium Programs. We are currently performing engineering and cost analyses for the selection of a long-term management strategy for

depleted uranium hexafluoride. We support DOE's nuclear safety upgrade program at the gaseous diffusion enrichment plants. LLNL scientists and engineers are assisting DOE in developing and implementing transparency measures for the purchase of 500 metric tons of highly enriched uranium from the former Soviet Union. Table 2.1-8 shows projected funding from this office.

Office of Civilian Radioactive Waste Management

Yucca Mountain Project

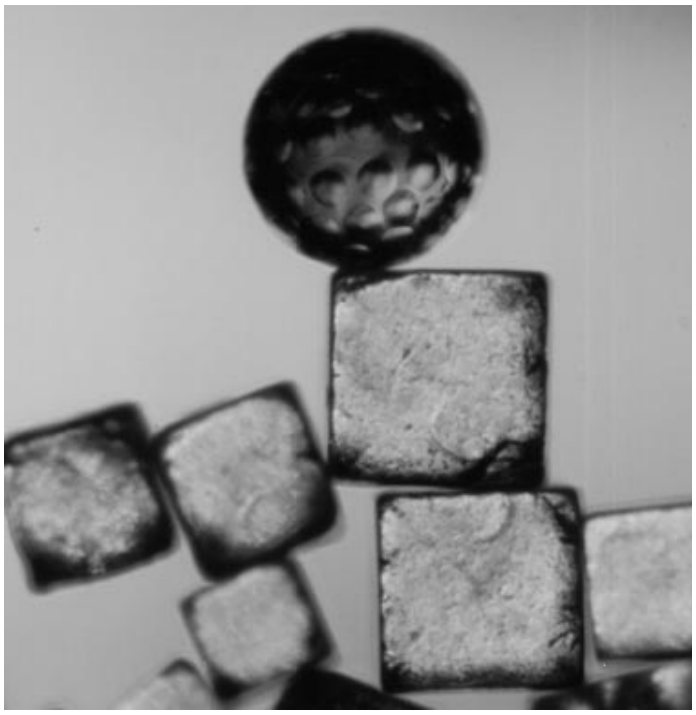
DOE's Office of Civilian Radioactive Waste Management sponsors Laboratory research on disposal of high-level nuclear waste and spent nuclear fuel. In response to Congressional inquiries and DOE desires to minimize the number of contractors at the Yucca Mountain characterization site, Livermore has joined as a partner with the prime management and operating contractor, TRW. As a partner, we are participating in studies for a potential nuclear waste repository at Yucca Mountain, Nevada. Our responsibility is to design the engineered barrier system, which includes the container to hold the waste, and to assess the waste's interactions with its immediate environment. Table 2.1-9 shows projected funding from this office.

The major elements of this program are

- Defining the physical and chemical environment in which the waste packages must function.
- Selecting materials and preparing design specifications for the waste containers.
- Characterizing the behavior of waste materials in the repository environment.
- Developing mathematical models and computer codes for predicting the long-term function and durability of these systems.

Our recent focus has been on site characterization and repository performance issues. We provided conceptual and technical support for an emplacement strategy called "extended dry out," in which heat from decaying waste would be used to drive moisture from the repository. This strategy would enhance the natural system's performance. By eliminating water from the repository, we eliminate the potential problems associated both with container corrosion and with the most credible transport mechanism (water-borne transport) of radionuclides. We are developing conceptual models, computer codes, laboratory experiments, and field tests to demonstrate the validity of this "extended dry out" concept.

We are also developing, assessing, and documenting a waste package design that meets the performance requirements for the engineered barrier system stipulated by the Nuclear Regulatory Commission in 10 CFR 60. The engineered barrier design will continue to evolve as we obtain data from site characterization and as we complete more detailed phases of the design.



This 0.5-mm-diameter plasma–polymer-coated capsule is formed around a hollow microsphere. Shown here above grains of table salt, the capsule is part of our evolving research to develop materials for the proposed National Ignition Facility.

Assistant Secretary for Fossil Energy

The DOE Assistant Secretary for Fossil Energy sponsors Laboratory research on gas, oil, and oil shale. Table 2.1-10 shows projected funding from this office. Our research efforts, which primarily relate to producing conventional oil and gas, include

- Developing a prototype system for handling California and Texas oil and gas production data.
- Developing an improved method for converting oil-well log data to a digital format.
- Studying the physics of well perforation.
- Improving completion technology for natural gas storage.
- Designing shaped charges as seismic sources.
- Performing deterministic modeling of neutron well logging.
- Upgrading heavy oil.
- Converting natural gas to methanol.

Recently, we have used cross-well electromagnetic topography to image the steam plume formed during thermal recovery of California heavy oil. We have also identified chemical agents that can extract metals from heavy crude oils.

Table 2.1-10. Fossil Energy operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
AA Coal	0.3	0.1	0.1	0.3
AB Gas	0.3	0.2	0.1	0.1
AC Petroleum	1.9	2.2	3.5	3.0
CB Naval Petroleum Reserve	0.0	0.0	0.0	0.0
Total	**2.5**	**2.5**	**3.7**	**3.4**
% of Total Laboratory Operating Funding	0.3%	0.3%	0.4%	0.4%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Table 2.1-11. Energy Efficiency and Renewable Energy operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
AK Electric Energy Systems	0.1	0.1	0.0	0.0
AR Energy Storage Systems	0.6	1.2	5.0	6.0
ED Industrial Sector	0.5	0.3	0.3	0.3
EE Transportation Propulsion	0.3	0.1	1.1	1.1
EE Transportation/Materials Technology	0.0	0.3	0.8	0.8
Total	**1.5**	**2.0**	**7.2**	**8.2**
% of Total Laboratory Operating Funding	0.2%	0.2%	0.7%	0.8%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Assistant Secretary for Energy Efficiency and Renewable Energy

Refinery of the Future

We are participating in a multilab effort to develop a Refinery of the Future initiative. This effort would focus on downstream activities in the petroleum refinery industry and would collaborate with appropriate industrial organizations (e.g., National Petroleum Refinery Association and the American Petroleum Institute). The primary areas of interest to the industry are environmental analysis, modeling, and processing. Particular expertise at LLNL includes site characterization, atmospheric and hydrology modeling, chemical process modeling, catalysts, combustion modeling, and new materials. Table 2.1-11 shows projected funding from this office.

Hydrogen as a Fuel

We have a comprehensive program to demonstrate the application of hydrogen for transportation. We are examining

infrastructure requirements for widespread hydrogen deployment and for hydrogen storage (e.g., adsorbed on carbon aerogels, cryogenic or high-pressure storage) both onboard vehicles and between production and distribution sites. We are also modeling the use of hydrogen in hybrid vehicles, studying the combustion properties of hydrogen, designing an engine to take advantage of those properties, and producing hydrogen from municipal solid waste (MSW). The project of storage and integration into vehicles is done in collaboration with Sandia National Laboratories, Livermore.

Hydrogen Production from Municipal Waste

In collaboration with Texaco Inc., we are developing a hydrothermal treatment process to convert MSW to hydrogen; the overall process would use the Texaco gasifier to produce hydrogen from the carbon slurry resulting from the MSW treatment. The ultimate goal is to evaluate the relative technical and economic feasibility of using MSW as a feedstock for hydrogen production, taking into account alternate feedstocks and processes as well as the societal and environmental benefits of recycling MSW.

Optimized Hydrogen-Fueled Internal Combustion Engine

We are modeling and designing a piston engine and generator that is the mechanical equivalent of the fuel cell. We are optimizing the engine for hybrid vehicles to use hydrogen or hydrogen–natural gas mixtures. The goal is to develop a hydrogen-fueled engine with greater than 45% brake thermal efficiency and with NO_x emissions less than 100 ppm. We have also developed a hybrid vehicle evaluation code, and we have delivered an optimized engine cylinder head to Sandia National Laboratories, California, for testing.

Chemical Kinetic Modeling of Hydrogen Applications

We are developing models of the detailed chemical kinetics of fuel oxidation and NO_x and pollutant emissions in zero or one-dimensional formulations. We are identifying the most important subscale processes in the combustion of hydrogen and hydrogen–natural gas mixtures. The goal is to simplify the detailed combustion kinetics for use in multidimensional fluids mechanics codes used for engine combustion modeling.

Hydrogen Storage in Engineered Microspheres

We are developing glass microspheres to use for the safe, economical bulk transport of hydrogen. Glass microspheres of 0.05–0.5 nm diameter with 1-μm thick walls are heated to 200–400°C under hydrogen pressure to trap the hydrogen inside the microspheres at high pressure. The goal is to demonstrate hydrogen-to-microsphere mass fractions as high as 10% and a hydrogen bed density of 20 kg/m^3.

Hydrogen Infrastructure Studies

We are studying the state—and the costs—of technologies that could facilitate the introduction of hydrogen as a transportation fuel. These technologies are for small-scale production, distribution, storage, and transfer to the vehicle system. We have shown that

- Used in an advanced hybrid-electric vehicle, the cost of hydrogen fuel per mile made by steam reforming of natural gas and distributed to small fleets would be about one-half the fuel cost per mile of gasoline in today's average car.
- The fuel costs for advanced hybrid-electric cars fueled with liquid hydrogen at today's delivered costs are about the same as for today's average gasoline vehicle.

Energy Storage: Fuel Cells and Supercapacitors

Decreasing the thickness of the electrolyte leads to lower operating temperatures, more efficient electrode materials, higher energy and power densities, improved durability, and, hopefully, reduced cost. Future work will focus on developing multicell stacks and associated manifolding.

We are also developing high-energy-density supercapacitors based on both aerogels and nanoengineered multilayers. These devices have potential for energy storage in numerous applications, including electric and hybrid vehicles.

Rapid Prototyping and Multilayer Coating Manufacturing

Many manufacturers have expressed a strong interest in industrial coating processes ranging from net-shape forming for rapid prototyping of tooling to multilayer coatings for turbine blades. The goal of the Rapid Prototyping and Multilayer Coating Manufacturing Project is to enhance LLNL competencies in e-beam physical vapor deposition to meet

Table 2.1-12. Human Resources and Administration operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
WM Contractual Services	0.6	0.6	1.1	1.1
Total	**0.6**	**0.6**	**1.1**	**1.1**
% of Total Laboratory Operating Funding	0.1%	0.1%	0.1%	0.1%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Table 2.1-13. Policy, Planning and Program Evaluation operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
PE-01 Environmental Analysis	0.1	0.0	0.0	0.0
Total	**0.1**	**0.0**	**0.0**	**0.0**
% of Total Laboratory Operating Funding	0.0%	0.0%	0.0%	0.0%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Table 2.1-14. Field Management operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[b]
WB In-House Energy Management	0.5	0.5	0.7	0.7
Total	**0.5**	**0.5**	**0.7**	**0.7**
% of Total Laboratory Operating Funding	0.1%	0.1%	0.1%	0.1%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

current industrial needs. Using our vapor rate monitor and control systems, we have the ability to intelligently control the vapor source and, therefore, the vapor deposition of multi-element materials. The project will contribute to industrial process efficiency, energy conversion and utilization technologies, and DOE manufacturing capabilities.

Low-Temperature Solid Oxide Fuel Cell

We are using advanced vapor deposition techniques to develop pinhole-free multilayer solid oxide fuel cells. By producing high-quality layers of 0.1–1.0 µm thickness, the operational temperatures can be reduced from 1100°C to 450–650°C. We have completed the first cell using a yttrium-stabilized zirconia layer of 1 µm thickness.

Hydrocarbon Combustion Modeling

We have developed and tested a computer model for analyzing the combustion in industrial burners and have applied that model to the problem of reducing the emissions of NO_x and unburned hydrocarbon and volatile organic compounds. Our model will make it possible to design economical burners that comply with the Clean Air Act.

Resource Recovery

We are using x-ray computed tomography on well cores to measure the geothermal resources at The Geysers, California, which produces

1500 MW of electrical power. We also seek to improve the technology for producing geothermal energy.

Assistant Secretary for Human Resources and Administration

Computer Incident Advisory Capability (CIAC)

CIAC is DOE's computer incident response team. It handles incidents by

- Assessing the nature and extent of damage.
- Providing appropriate technical resources.
- Coordinating solutions or "patches."
- Verifying incident-relevant information.
- Advising on damage control and recovery.
- Providing assistance to law enforcement.
- Issuing bulletins and advisories.

In addition, CIAC delivers comprehensive, customized workshops on information technology security. CIAC also carefully tracks the latest technology trends, product introductions, and system and network security threats and vulnerabilities. CIAC services are available 24 hours per day, 7 days per week, and are free of charge to the DOE community. Table 2.1-12 shows projected funding from this office.

Assistant Secretary for Policy, Planning, and Program Evaluation

Assessments of the Potential of Energy Technologies

Livermore performs technical analysis to provide DOE with assessments of the potential of various energy technologies to impact the strategic goals of the U.S. The goal is to identify the most important technologies in energy R&D. Livermore will establish criteria for assessment and establish an expert panel to objectively perform the assessments. Table 2.1-13 shows projected funding from this office.

DOE Field Offices and Other Laboratories

Table 2.1-14 shows projected funding from this office.

Pantex Plant—Security Systems Upgrades

We are providing the Pantex Plant with a variant of the Livermore-developed Argus security system. The system is designed to provide access control, intrusion detection, and alarms for Pantex's plant-wide security system.

Idaho National Engineering Laboratory—Electronic Security Systems

We are providing software and hardware to prepare the Idaho Chemical Processing Plant for future conversion to the Argus security system. We are also assisting in the conceptual design of the Idaho National Engineering Laboratory's Personnel Access Control and Security Enhancement System.

Nuclear Criticality Safety Support to Oak Ridge Field Office

We have assembled a team of criticality safety professionals to provide support to the Portsmouth Diffusion Plant.

Safeguards and Security Support to Savannah River Operations Office

We have developed and evaluated advanced approaches for analyzing safeguards and security at the Savannah River Site. We have demonstrated a virtual reality model of safeguards and security measures.

Technical Support to Albuquerque Operations Office

We support the Nuclear Explosives Safety Division in reviewing activities related to the transportation of radioactive materials within the DOE complex.

Department of Defense Sponsors 2.2

Many of the Department of Defense (DoD) -sponsored programs at Livermore fall within the scope of the future war fighting capabilities established by the Joint Chiefs of Staff and the Joint Requirements Oversight Council. They are to

- Maintain near-perfect, real-time knowledge of the enemy and communicate situational awareness to all U.S. forces in near-real time.
- Engage regional forces promptly in decisive combat on a global basis.
- Employ a range of capabilities suitable to actions at the lower end of the full range of military operations that allow achievement of military objectives with minimum casualties and collateral damage.
- Control the use of space.
- Counter the threat of weapons of mass destruction and future ballistic and cruise missiles to the continental U.S. and deployed forces.

The Laboratory undertakes work for the DoD if the proposed work

- Is consistent with and complementary to DOE and Laboratory missions .
- Would not adversely impact work on a particular facility's assigned programs.
- Would not place the facility in direct competition with the private sector.
- Would not create a potential burden to commitment of DOE resources.

In FY 1994, the DoD was the largest sponsor of Laboratory work outside the DOE, funding 12% ($103 million) of our operating budget. This includes work for the Office of the Secretary of Defense, the Joint Chiefs of Staff, the Advanced Research Projects Agency, the Ballistic Missile Defense Organization, the Defense Nuclear Agency, and the Departments of the Army, Navy, and Air Force. (See Table 2.2-1.)

Office of the Secretary of Defense

Counterproliferation

We execute projects for DoD pertinent to counterproliferation of weapons of mass destruction (WMD). These projects build on core competencies developed generally for DOE programs.

We are developing jointly, with Los Alamos National Laboratory, a laser-illumination detection and ranging (LIDAR) system capable of detecting clouds of dispersed biological or chemical agents on the battlefield. This system is designed to be mounted on the Army's Blackhawk helicopter and is able to determine the presence of such clouds as well as their range and extent. With it, a battlefield commander can provide warning to troops in the field so that they can don protective gear in a timely fashion. Our contribution to this project is to develop the eye-save laser upon which the LIDAR is built.

In preparing for potential attacks on targets that contain WMD, the DoD requires technical information on the character of those targets. We are a member of a team of laboratories and other agencies, directed by the Defense Nuclear Agency, that is investigating the use of unattended ground sensors for this purpose. Such sensors can potentially provide targeting information and act as bomb damage assessors.

The ASTD/AE(CP) is sponsoring several systems studies relevant to counterproliferation technologies. LLNL is a participant in these. Among our tasks are analyses to determine the efficacy of biological and chemical-agent battlefield detection technologies and studies to evaluate techniques for disposing of terrorist WMD. In doing this work, we will rely in part on the combat simulations we have developed for the armed services.

The credible possibility of the delivery of a stolen or terrorist weapon of mass destruction to a population center or military target requires that we develop and evaluate defense architectures against the threat of covert or paramilitary attack, including selection of sensor and other technologies, search and detection logic, and operational plans. This analysis will require more sophisticated computer simulation testbeds to evaluate the elements of a viable defense. The program will also support the Wide Area Nuclear Detection program and the Counterproliferation Initiative under

Table 2.2-1. Department of Defense operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[a,b]
Department of Defense	**103.1**	**72.9**	**94.0**	**89.7**
% of Total Laboratory Operating Funding	12.0%	8.5%	9.7%	9.3%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

the Assistant Secretary of Defense for Atomic Energy.

We have developed a risk assessment system that allows treaty negotiators to analyze the costs and benefits of contemplated protocols for a Biological Weapons Convention (BWC), successfully used in the BWC interagency process during the past year.

This work is now complete; however, the methodology and the spreadsheet decision-aid tools are applicable to a number of other problems (e.g., evaluating options for Cooperative Threat Reduction or for plutonium disposition) and are being promoted accordingly.

As part of the broader topic of counterproliferation, our Proliferation Interdiction Response Analysis effort evaluates the military, economic, political, and industrial consequences of intervention in specific countries, facilities, and situations connected with the production or acquisition of weapons of mass destruction. Included in the capability is the Livermore's Atmospheric Release Advisory Capability (ARAC) calculational capability. We have provided preliminary option and consequence analyses for several scenarios to agencies including the Commanders in Chief of the Strategic Command, Special Operations Command, and National Proliferation Center.

One of our future objectives is to complete a general production path analysis to enable efficient generation of critical node analyses for additional countries and facilities as needs arise. Another goal is to enhance our information management code, Watson, and incorporate it directly into the analysis architecture.

Joint Chiefs of Staff

Conflict Simulation Systems

We have a long-term interest in developing and applying high-resolution combat simulation systems. Our Conflict Simulation Laboratory has the ability to simulate a wide scope of operations. For example, it can be used to analyze combat scenarios as well as plan and rehearse strategies for protecting headquarters or weapon storage depots against theft, sabotage, or terrorism. Because this facility supports such a diverse set of software tools, it can also be used to simulate drug interdiction or emergency law-enforcement tactics, to model rescue and relief efforts for disasters (e.g., fires, oil spills, floods, hurricanes, or earthquakes), and to model urban traffic flow.

The DoD, through its military service elements, funds the following projects:

• Joint Tactical Simulations, first released in FY 1995, provides an open-architecture implementation of entity-level distributed interactive simulation. It allows simultaneous simulation of field combat with seamless transition to urban operations, including combat within multiple story buildings.

• Joint Conflict Model is a Joint Task Force exercise driver with entity-level simulation. It is the first entity-level constructive simulation linked to remotely operated platform simulators through distributed interactive simulation communications protocols.

In the last year, one of the simulations was used by the U.S. Army to perform operational planning in areas of regional conflict.

Advanced Research Projects Agency (ARPA)

Vapor Phase Manufacturing Program

The goal of this project is to develop laser-based, real-time vapor density and composition sensors to monitor vapor species essential to the vapor phase manufacturing missions. Specific applications of the vapor density and composition sensors include the processing of metal matrix coatings, thermal barrier coatings for manufacturing high-temperature turbines, and manufacturing of high-efficiency photovoltaic solar cells and high-temperature superconductors. We will demonstrate intelligent processing monitor and control in a production prototype environment using the laser-based sensors. A California-based optics company is expected to commercialize the sensor and control technology. Livermore will transfer its optical-transport, signal-detection, and processing technology to industry for commercialization.

Diamond Cold Cathode Technology for Field Emission Displays Manufacturing

The goal of this project is to develop the manufacturing technology for synthetic diamond-thin film cathodes for use in large-area, high-performance, low-cost flat panel displays. We will work with two large-field-emission display manufacturers to develop large-area, low-cost, field emitters using our high-power-pulsed laser ablation technology. These components will be used to build flat

panel video displays for both commercial and military applications.

Microfabricated Chambers for Chemical Reactions

Microfabricated chambers that perform the polymerase chain reaction (PCR) for chemical reactions would be an invaluable tool for many biotechnology applications. One immediate application is the construction of chambers that can perform a procedure to amplify (make copies of) DNA. This procedure would be useful for diagnostic testing both in the laboratory and in the field. We have tested several reaction chambers, instrument controllers, and detection methodologies on four different PCR systems. Our results show that we can simultaneously amplify eight targets on human DNA that represent mutation sites associated with cystic fibrosis.

Optical Computer Interconnects

The goals for the distributed-computing testbed are to demonstrate the application and performance of parallel processing using optoelectronic interconnects. The testbed will consist of several workstations interconnected with 32-channel fiber-optic communication links (16 Gbit/s each). The total aggregate communications bandwidth of the network will be more than 100 Gbit/s. This testbed will provide the opportunity to investigate the performance and reliability of optical interconnect technologies.

Optoelectronic Device Packaging

The high cost of optoelectronic device packaging is primarily a result of the difficulty of aligning and attaching the optical fiber pigtails to device waveguides. In partnership with a U.S. industrial consortium, we are developing an automated optoelectronics packaging machine that uses machine vision and robotics to perform the fiber alignment and attachment step quickly, thereby greatly reducing labor costs. This work relies on Livermore-developed techniques that use silicon micromachining to align parts, couple light, and attach critical components and optical fiber to a common silicon optical bench. The overall goal of this project is to reduce the cost of optoelectronic components by an order of magnitude.

Field Emission Flat Panel Display Technology

Livermore is participating in a dozen industrial collaborations in flat-panel display technology: eight in various aspects of display design and fabrication and four in flat-panel display manufacturing equipment. Funding is derived from ARPA, DOE, and industry. Two of the ARPA-sponsored projects in field emission displays are summarized here.

Field-emission displays are essentially cathode-ray tubes with an electron source at every spatial element of the screen rather than a single electron source that is scanned over the area of the screen with its intensity modulated for the desired intensity at each spatial element. Thin-film processing facilities in the Livermore Center for Microelectronics and Optoelectronics are used to develop and produce manufacturable field-emitter cathodes with deep submicron gate and emitter geometries. These small geometries allow the low voltages needed to reduce the power consumption of the field-emission display to a fraction of today's active matrix liquid-crystal panel. Novel cathode materials are also being explored to further reduce operating voltage and power by reducing the work function of electron-emitting surfaces. Livermore analytical capabilities are used to characterize emission properties, morphology, and chemical composition of field-emitting surfaces.

Another crucial component for field-emission display is the structure that separates the cathode from the phosphor plate anode. Like a cathode-ray tube, the field-emission display panel is evacuated, so a spacer structure must be employed to keep the cathode and anode from bending or breaking under atmospheric pressure. This structure must also be invisible to the viewer of the display, so very narrow, tall structures must be used. Livermore is researching a novel fabrication technology based on silica aerogel materials for manufacturing such structures inexpensively.

Ballistic Missile Defense Organization (BMDO)

The Laboratory's work to support the BMDO has taken on a major change as we have moved from performing integrated system response to ballistic missile boost phase (RAPTOR/TALON) to smaller projects focusing on key technologies for space-based and airborne surveillance.

Kinetic Kill Vehicle Sensor

In the next three years, we will develop a detection and tracking sensor for a kinetic kill vehicle for use either in space or on an airborne platform (manned or unmanned). We will also provide the Applied Physics Laboratory with sensors and related components for use in cooperative experiments with the Russians. Livermore sensors will be used in the experiments to track the deployment of spacecraft.

Space-Based Surveillance System

We are participating with BMDO, the Space Warfare Center, and Phillips Laboratory in a project, named COMET, that involves flying a space-based surveillance system to provide real-time theater tactical information. The project will span two years, including a satellite launch in late 1995.

Propulsion Technologies

We are also collaborating with Phillips Laboratory on two propulsion-related efforts: one to expand the technology of pumped propulsion to bipropellant systems and one to improve the lightweight performance of monopropellant systems. This three-year collaboration will result in propulsion systems for microsatellites and in peroxide bi-propellant capabilities for reusable rocket platforms.

National Test Facility Security System Upgrades

We are producing and supporting the hardware and software required to operate the Argus security system at the National Test Facility. Other work includes researching retrofits for a swipe badge reader to accommodate the new Air Force standard badges and upgrading existing computer systems to support the Argus security system.

Diamond-Turned Optics

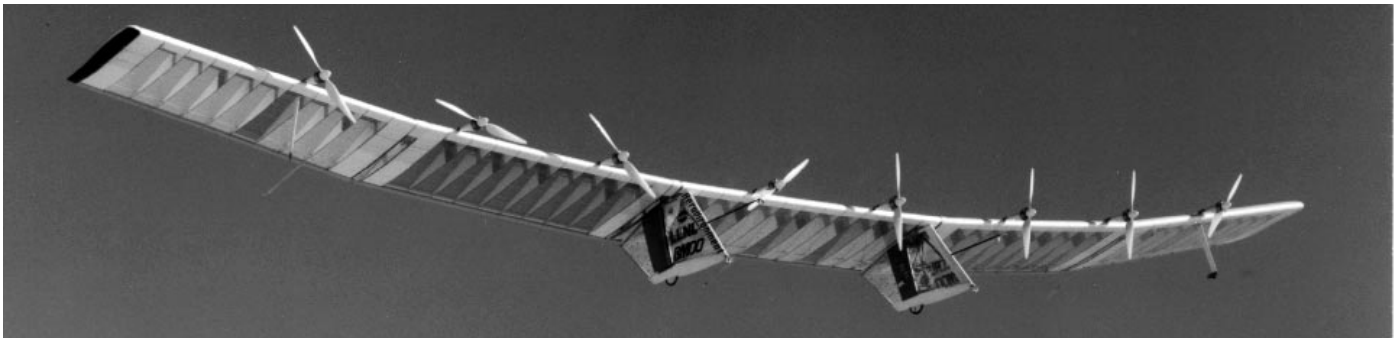
We continued to operate the Large Optics Diamond Turning Machine for the BMDO program. Recently, we completed the construction of two lightweight beryllium mirrors for the Keck astronomical telescope in Hawaii. The Keck telescope construction is a joint California Institute of Technology and University of California project. Our Large Optics Diamond Turning Machine was the only machine tool capable of fabricating these highly precise mirrors.

In conjunction with BMDO's Alpha Chemical Laser Program, we successfully machined and delivered to TRW an annular optical prototype that demonstrated the viability of directly machining large single-crystal silicon optics.

Defense Nuclear Agency (DNA)

Advanced Numerical Methodology

Our Center for Computational Sciences and Engineering (CCSE) is funded by the DNA to develop advanced numerical methodology. This numerical methodology supports DNA's current programmatic efforts in advanced munitions concepts and counterproliferation. We are now working on fundamental investigations of turbulently mixing combusting propellants and mesoscale atmospheric simulations. The methodology is based on our unique techniques for combining



The Pathfinder is shown in flight. The upward curve of the wing results from lift, and this curvature of the wing puts its structural components in the condition of least load. However fragile Pathfinder might look, its flexibility and light weight allow it to withstand high wind gusts as it climbs to high altitude.

high-resolution finite difference methods with adaptive mesh refinement, which focuse computational effort only where it is required for accuracy. This makes three-dimensional simulations practical with today's computers.

Multiple DoD Offices

Each of the following programs is funded by more than one office within the DoD. The individual sponsors are indicated in the program summaries.

Advanced Conventional Weapons Systems

The Advanced Conventional Weapons Systems Program encompasses a wide spectrum of hydrodynamic design, advanced materials, simulation and modeling codes, advanced diagnostics, and electronic combat. The various projects apply to issues involving tactical battlefield warfare, counterproliferation, and operations other than war. The program includes work sponsored by the Office of the Secretary of Defense; the Advanced Research Projects Agency; the Departments of the Army, Navy, and Air Force; and the U.S. Marine Corps.

Examples of current and future projects include

- Kinetic energy weapons for use in both antiarmor applications and non-nuclear kill of missile-launched weapons of mass destruction.
- Multistage munitions for demolition and attack of hard, buried targets.
- Enhanced high-density materials for deep penetrating weapons.
- Lightweight, highly efficient armor for land vehicles, aircraft, and soldiers.
- New concepts in explosively formed jets or projectiles for attacking heavy armor.
- Insensitive high explosives and ultrahigh-energy-density materials.
- Advanced three-dimensional Arbitrary Lagrange Eulerian hydrodynamics codes with state-of-the-art constitutive models of materials under high dynamic stress.
- Advanced modeling for gas and fluid dynamics of explosion phenomena, and structural response to shock, blast, and penetration.
- Less-than-lethal technologies for military operations other than war.
- Neural network chip technology for smart fuses.
- Data compression and automatic decision making.
- Electronic combat both as defensive and offensive weapons.
- Advanced materials such as fiber composites for launch systems.
- Nanostructures for high-energy power sources and coatings for aircraft engine turbine blades.
- Sensors and data processing for mine detection and clearing.
- Demilitarization procedures for munitions, including methods for the environmentally benign decomposition of explosives and other military materials.

High-Power Radiofrequency Countermeasure Techniques

In cooperation with several Department of Defense agencies, we have been investigating high-power electromagnetic fields to deny the use of electronics systems by hostile forces through disruption and interrogation of their systems. Specifically, we are looking at methods to counter high-precision munitions, diminish the effectiveness of navigation systems, interfere with command and control and information systems, and interrogate electronics for characterization purposes.

Warhead Design Technology

Warhead simulation calculations (hydrocodes) were incorporated into a nonlinear optimization scheme for the U.S. Army. Forward and backward optimization modes permit the accurate determination of material properties from warhead experiments and optimization of warhead shape to maximize a particular figure of merit, such as depth of penetration. This is a natural, but heretofore unachievable, application of these very large computer codes and will revolutionize warhead design technology.

Advanced Materials

Livermore fiber composite technology has transitioned to the sabot of the Army's M829A2 tank round (type-classified) and is influencing development of the high-capacity artillery round and next-generation composite sabot designs.

High Explosives

CHEETAH, a new thermo-chemical code for predicting the performance of high-explosive formulations, was distributed for testing to Beta users at DoD laboratories and technical centers. CHEETAH, a successor to the Livermore-developed TIGER code, is presently used to develop the explosive fills for the next generation of hard target munitions. This work was done under the memorandum of understanding between the DOE and the DoD's Office of Munitions.

Demilitarization Molten-Salt Destruction

We built a bench-scale unit that demonstrates the use of molten carbonate salts for disposing of energetic materials and other hazardous organic materials. Our unit was used to destroy more than 15 different materials that DoD (Army) and DOE need to dispose of. This method was shown to be harmless to the environment. We began construction of a pilot-scale unit that is large enough to satisfy the needs of some technical centers and R&D facilities. In the future, we will transfer the pilot-scale unit to Wright Laboratories at Eglin Air Force Base for final development. Thereafter, the unit is expected to be used for routine organic waste disposal.

Department of the Army

Modular Armor

For military vehicles, we are developing armor modules that are designed to defeat direct-fire kinetic-energy projectiles, shaped-charge warheads, and chemical threats. We have successfully demonstrated the technical feasibility of modular armor concepts and completed experimental sensitivity studies. In the next phase of the project, we will perform experiments in our ballistics laboratory to address key premanufacturing and engineering issues and to evolve our designs toward a full-scale technology demonstration.

Department of the Navy

Laser Radar

We have delivered a high-energy, solid-state laser with unique long-pulse capability to the Naval Research and Development Innovative Science and Experimental Facility at Cape Kennedy, Florida. This laser is being used for coherent doppler radar measurements of launched vehicles. We are continuing to support and upgrade the system throughout the Navy's experimental program.

Alameda Naval Air Station FastTrack Project

LLNL is working with the University of California, Berkeley, and the Lawrence Berkeley National Laboratory to test innovative site investigation and cleanup technologies at the Alameda Naval Air Station. Projects include

- Seaplane lagoon investigations to characterize contaminated sediments and devise methods for their isolation or remediation.
- In-situ microbial filter technologies for landfill isolation and remediation beneath a designated wetlands.
- Enhanced bioremediation for treating hydrocarbon and metal soil contaminants.
- Underground imaging for in-situ remediation process monitoring and control.

Kara Sea/Russian Naval Waste Assessment

We provide vulnerability and safety assessments of the Arctic and Pacific Ocean environment concerning the nuclear waste generated and disposed of by the Russian naval program.

Department of the Air Force

Satellite Imaging

A high-power, multibeam, long-pulse, solid-state laser system is under construction for the Air Force Phillips Laboratory's Active Imaging Testbed Program at the Starfire Optical Range in Albuquerque, New Mexico. This laser will generate the four beams that will be used to make sheared interferograms of real satellites. In ground-based experiments, the images constructed from such interferograms have demonstrated immunity to scintillation of the intervening atmosphere. The laser is planned to be delivered in FY 1996.

Electronic Commerce

The Livermore Technology Information Systems Program supports the Government Acquisition through the Electronic Commerce project, which has resulted in significant reductions in the costs of goods procured and in the costs of the procurement process.

Veterans Administration (VA)

Electronic Commerce

The Livermore Technology Information Systems Program supports the Veterans Administration project to augment its existing procurement system with electronic commerce enhancements. This is resulting in significant reductions in the costs of goods procured.

Other Federal and State Sponsors 2.3

For a summary of the funding for programs described in this section, see Table 2.3-1.

Arms Control and Disarmament Agency (ACDA)

Defense Conversion Workshops

The U.S. Arms Control and Disarmament Agency formulates, coordinates, and implements arms control policies; conducts and coordinates research; prepares and manages U.S. participation in negotiations; and disseminates arms control information to the public. At Livermore, ACDA and DOE have cosponsored workshops on defense conversion. We are now proposing projects that will help ACDA review the results of an international seismic monitoring experiment, examine the extent to which the proposed monitoring networks will meet the U.S. monitoring goals, and demonstrate regional seismic monitoring systems as transparency measures in the Middle East.

Environmental Protection Agency (EPA)

Climate Modeling

Using our two-dimensional, troposphere/stratosphere, global-chemistry model, we are examining the effects of global warming and establishing an index of relative importance for carbon dioxide compared with methane, nitrogen oxides, and chlorofluorocarbons. We are also developing a new three-dimensional, tropospheric, atmospheric-chemistry model for studying how trace gases (such as the nitrogen oxides from fossil fuel emissions) affect ozone, an important greenhouse gas that strongly influences the ultraviolet transmission of the atmosphere. Finally, we are using our global climate models to assess how local and global changes in climate affect vegetation and the carbon dioxide balance.

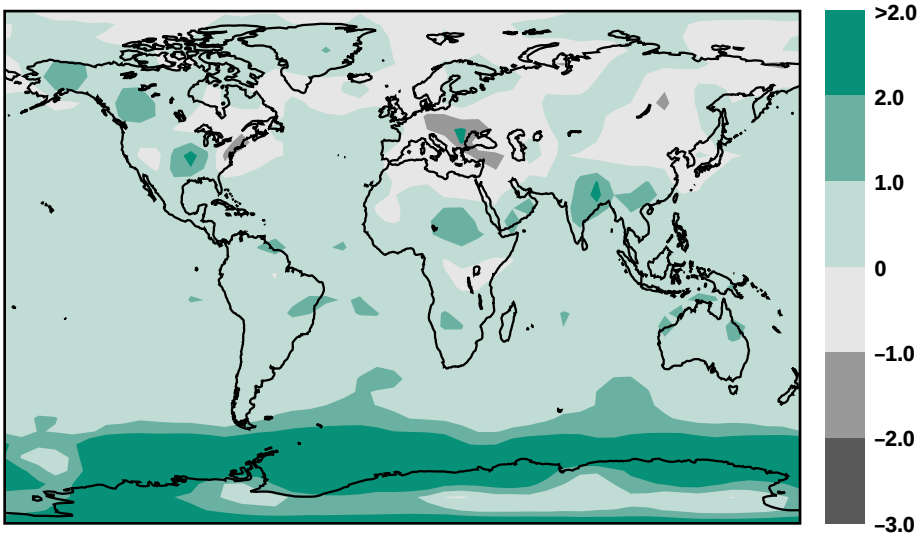
Chemical and Ecological Relations in the Earth System

This project is developing a comprehensive and flexible Earth systems modeling framework to understand how biogeochemical processes affect global climate. With a prototype framework that includes representative models of the physics and chemistry of the atmosphere, oceans, and land surfaces, we have started a series of experiments to elucidate the role of biogeochemical processes in shaping global climate conditions. The early experiments are focused on the temporal and special distributions of atmospheric carbon dioxide concentration both for preindustrial and contemporary conditions.

National Aeronautical and Space Administration (NASA)

DOE/EM Technology Development

LLNL conducts fundamental and applied research to develop,



Our new climate simulation of the direct aerosol effect and the effect of increasing greenhouse gases takes into account the nonuniform geographic distribution of aerosol sources. In response to summertime increases in aerosols and CO_2, the simulation predicts areas of cooling and other areas of warming.

demonstrate, and commercialize innovative technologies for solving environmental problems. The main sponsor for environmental restoration and waste management research and development is the DOE Office of Environmental Management. Key business areas include research and technology development for site investigation, in-situ remediation, and ex-situ waste destruction applications. Supporting technologies include groundwater modeling for contaminant fate and transport, risk assessment, waste minimization, and process automation through intelligent systems. In recent projects, we

- Completed a downhole treatability test of microbial filter technologies at Cape Canaveral, Florida. This test demonstrated the robustness of the technique in treating a broad range of VOC contaminants, and was jointly funded by DOE/EM-50 and NASA.
- Completed a revolutionary in-situ microbial filter huff-and-puff field test at the Chico, California, airport. This was the first in-situ bioremediation of TCE-contaminated ground water to single-digit ppb concentration levels known to have been successfully completed in the U.S. or internationally. It was funded by DOE/EM-50 with industrial support in kind from Brown and Caldwell Inc.
- Completed dynamic underground stripping at the Livermore site's gasoline spill. This technology successfully removed thousands of gallons of gasoline from the subsurface in less than one year of field operations, and at a normalized unit cost of approximately $60–70 per cubic yard of soil treated.
- Developed an advanced fiber-optic-based sensor system for remotely characterizing highly radioactive wastes in the storage tanks at the Hanford Reservation in Washington State.

Future environmental technology research and development efforts will meet defense complex needs for in-situ detection and monitoring of contaminants, in-situ remediation of nonaqueous phase liquid (NAPL) and metal contaminants, ex-situ low-temperature and nonthermal treatment of hazardous and mixed wastes, and integrated approaches to accelerate site cleanup design and operation.

Table 2.3-1. Non-DOE operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[a,b]
NASA	**5.1**	**3.2**	**3.3**	**2.4**
% of Total Laboratory Operating Funding	0.6%	0.4%	0.3%	0.2%
U.S. Enrichment Corporation	**38.5**	**40.0**	**50.0**	**40.0**
% of Total Laboratory Operating Funding	4.5%	4.6%	5.1%	4.1%
Other Federal Agencies	**8.1**	**26.3**	**27.1**	**28.0**
% of Total Laboratory Operating Funding	0.9%	3.1%	2.8%	2.9%
Non-Federal Agencies	**10.0**	**44.2**	**39.0**	**21.8**
% of Total Laboratory Operating Funding	1.2%	5.1%	4.0%	2.2%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

Reflection Grating Spectrometer for the X-ray Multimirror Mission

Under NASA sponsorship, Livermore is collaborating with Columbia University, the Space Research Institute of the Netherlands, the Mullard Space Sciences Laboratories in England, and the Paul Scherrer Institute in Switzerland to design and build the reflection grating spectrometer (RGS) for the European Space Agency's X-ray Multimirror Mission (XMM) to be launched in 1999. XMM/RGS will be the most sensitive x-ray spectroscopy experiment ever flown and will perform unprecedented exploration of thousands of cosmic sources. We are heavily involved in the design, fabrication, environmental testing, and scientific calibration of the RGS experiment, with specific responsibility for the optical assembly (consisting of two arrays of several hundred gratings each) of the instrument.

Stellar X-Ray Polarimeter for the Spectrum-X-Gamma Mission

Under NASA sponsorship, Livermore is collaborating with Columbia University, the Marshall Space Flight Center, Sandia National Laboratory, and the Italian Space Agency to design and build the stellar

x-ray polarimeter (SXRP) to be flown on the Russian SPECTRUM-X-Gamma x-ray astronomy mission in 1996. The scientific goal of this mission is to explore the properties of some exotic objects in the universe, such as x-ray binaries, quasars, black holes, and binary pulsars. Livermore is responsible for designing, building, and testing the graphite and lithium polarizers and for the calibration of the integrated SXRP instrument prior to flight.

Microcalorimeters for High-Resolution X-Ray Spectroscopy

Our NASA-sponsored research program on microcalorimeters has three parts. The first is the continuing development of x-ray and gamma-ray detectors. To date we have improved the energy resolution to 10 eV at an energy of 6 KeV, using a detector with 95% quantum efficiency. A similar but thicker detector achieved 50-eV resolution at 60 KeV. The second effort involves the fielding of the x-ray microcalorimeter on the Electron Beam Ion Trap (EBIT) for laboratory astrophysics experiments. Thirdly, we are focusing on the design of small, lightweight, long-lasting cryogenic instruments as payloads for future satellite missions.

Spectroscopic Imaging Detectors for the Extreme Ultraviolet

Superconducting photon detectors will provide new opportunities in ultraviolet and soft x-ray astrophysics. We are developing this new technology to produce a broadband imaging detector system that will cover a wavelength range of 50 to 500 Å with moderate spectral resolution, excellent spatial resolution, and high-quantum efficiency. The spectroscopic imaging detector will eventually be configured to study hot gas in stars, galaxies, and interstellar space.

Observation and Analysis of Accretion Powered Astrophysical Objects

In a number of closely related and synergistic studies sponsored by NASA, we are using data obtained by Earth-orbiting satellites to study accretion processes in cataclysmic variables, neutron stars, black hole binaries, and active galactic nuclei. Recently we obtained spectra of the magnetic cataclysmic variable AM Herculis in the energy range between 6 eV and 10 KeV simultaneously with the Hopkins Ultraviolet Telescope, the Extreme Ultraviolet Explorer, the German/U.K./U.S. ROSAT x-ray satellite, and the Japanese/U.S. ASCA x-ray satellite. These data-gathering activities are accompanied by strong modeling efforts in the areas of atomic processes, gas dynamics, and spectral formation.

Federal Highway Administration (FHWA)

We are working with the FHWA and the National Highway Traffic Safety Administration to improve computational tools for designing roadside safety hardware. Our approach uses the DYNA/NIKE code to model barrier crashes and post-crash vehicle motions.

Under FHWA sponsorship, we are addressing advanced traffic management systems by developing the WINTRANSYT code for traffic engineers to use on desktop computers.

We are developing new methods of ground-penetrating radar to rapidly assess earthquake damage to bridge structures and roadways. Work in this area is currently underway with FHWA, Caltrans, and the Oregon Department of Transportation.

California Department of Transportation (Caltrans)

We have assisted Caltrans in defining a communications standard for Automatic Vehicle Identification for California. This standard has now been cast into law for electronic toll collection, and the technology is being applied to toll bridges as the first application.

We are also using electrical impedance tomography in roadway inspections to detect moisture penetration.

Federal Aviation Agency (FAA)

Human Factors in Security

To enhance airport security, we are developing functional requirements and explosive simulants for the next generation of security screening devices.

Nuclear Regulatory Commission (NRC)

Support to Office of Nuclear Materials Safety and Safeguards

We are providing technical support in a number of projects:

• Working with the NRC staff to provide the nuclear regulatory authority in Ukraine with information needed to establish regulatory control over radioactive wastes and spent nuclear reactor fuel.

• Reviewing DOE Office of Civilian Radioactive Waste Management activities relative to changing the NRC's methods for evaluating the criticality safety of a spent-fuel transport cask.

• Providing expert technical assistance to resolve issues related to transporting spent nuclear fuels and other radioactive materials.

• Developing input for resolving new issues on the storage of spent nuclear fuel that arise during the review of Safety Analysis Reports.

• Developing a process to analyze the risks in the use of radiation-emitting devices and applying this process to the gamma knife, a gamma-irradiation device used for intracranial lesions.

• Assisting with the reviews of quality management plans at medical facilities.

• Providing technical assistance in the review of uranium mill tailings remediation plans, evaluation of radon barrier adequacy, and pile seismic stability.

Support to Office of Nuclear Reactor Regulation

Our technical assistance includes

• Assisting with the evaluation of civil, structural, seismic, electrical, and instrumentation and control systems of advanced light water reactors. The work includes recommending acceptance criteria for advanced design features.

• Performing sensitivity analyses for ten nuclear power plant sites, which includes deaggregating the seismic hazard results to determine the controlling earthquake's magnitude and distance from each site.

• Assembling data and developing technical positions as preparation for the revised geologic and seismic siting criteria for nuclear power plants.

• Providing data and expertise for the review of seismic design criteria for the new generation of nuclear reactors.

Support to Office of Nuclear Regulatory Research

Our work includes

• Evaluating the existing probabilistic hazard methodologies and defining a state-of-the-art methodology for future use.

• Providing technical support for the review of Individual Plant Examination of External Events submittals from utility companies.

• Providing guidance for industry standards related to the development of safety-critical software for nuclear power plants.

Information Technologies

We have established a Nuclear Systems Safety Center (NSSC) to serve as an on-line national resource for information and analysis. The NSSC is linked via communications networks to regulatory agencies (including the NRC) to national laboratories and other parts of the technical community. As part of our information security efforts, we have developed capability in implementing so-called firewalls to protect information systems from assault. Additionally, our information technology strengths contributed to bringing the Vice President's National Performance Review office on-line on the Internet.

National Institutes of Health (NIH)

Detection of Low Levels of Damage to Proteins and DNA

Many classes of chemicals that can attack the genetic material (DNA) form covalent adducts, which eventually lead to mutation and perhaps cancer or birth defects. Heterocyclic amines are a particularly potent class of carcinogen. They are formed through the heat-processing and pyrolysis of protein-rich foods, as in such standard American cooking practices as broiling, frying, and barbecuing of meats. Heterocyclic amines are also present in energy effluents and environmental wastes.

Determining whether these compounds and other mutagens and

carcinogens contribute to human cancer incidence is our goal. We are applying biological dosimetry techniques to determine the relation between low-dose exposure to potent mutagens and carcinogens and their effect on human health.

In recent research, we have

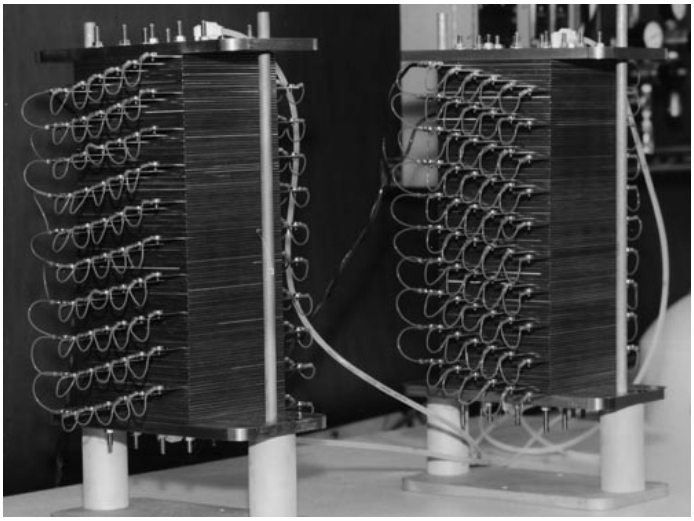
- Established that the amount of MeIQx (a dietary compound that causes liver tumors in animals) that is absorbed from the diet and the amount that damages DNA decreases linearly with decreasing dietary content to actual human exposure levels for chronic exposures.
- Determined that the ability of the body to remove the DNA damaged by MeIQx appears to depend on the starting level of damage, suggesting that short-term studies or DNA damage levels may inaccurately represent the ultimate cancer risk.
- Determined that the breast and colon carcinogen PhIP (a heterocyclic amine found in the human diet) forms five different DNA adducts. Some of these adducts appear unstable and are likely to degrade. This work will lead to understanding which adducts actually affect cancer.
- Found that benzene forms both protein and DNA damage in liver and bone marrow at doses equivalent to the benzene levels in a single cigarette. Protein damage appears to be tenfold greater than DNA damage, which suggests that protein damage may play a more significant role in the blood diseases caused by this compound.
- Demonstrated that benzene binds specifically to a 55,000 mass unit protein and a smaller 14,500 mass unit protein. Identification of these proteins should elucidate how benzene causes chromosomal damage as well as pinpoint targets for identifying individuals at risk from benzene exposure.

Chemical Carcinogens

In a study supported by the National Institutes of Health, we are examining and characterizing chemicals formed through the heat-processing of foods that might be factors in dietary carcinogenesis. Our crystallography, x-ray diffraction, and nuclear magnetic resonance capabilities will play a major role in the characterization of relevant proteins and of the interactions between proteins or small molecules and DNA. We also have developed expertise in biodosimetry with unique capabilities in the application of human biomarkers as an indicator of exposure dose and accelerator mass spectrometry as a tool to quantify DNA or protein adducts. Three of the biomarker tools that we use were developed at Livermore: the automated erythrocyte glycophorin mutation assay, accelerator mass spectrometry, and chromosome painting.

Strategic Environmental Research and Development Program (SERDP)

The Strategic Environmental Research and Development Program supports Livermore projects in capacitive deionization for purifying contaminated water and in neural-network-enhanced Raman spectroscopy for identification and



Prototype aerogel system for the deionization of aqueous solutions. It is based on multiple cells containing carbon aerogel as the active component.

measurement of chemical species. Capacitive deionization uses high-surface-area carbon aerogels in a novel energy-efficient method to remove inorganic species from water. Preliminary tests indicate that it will compare favorably with alternatives such as reverse osmosis and ion exchange resins for many applications. Neural network enhancement for Raman spectroscopy provides a means for strengthening and automating signal processing from these spectroscopic sensors, leading to more cost-effective measurement capabilities.

United States Enrichment Corporation (USEC)

Atomic Vapor Laser Isotope Separation (AVLIS)

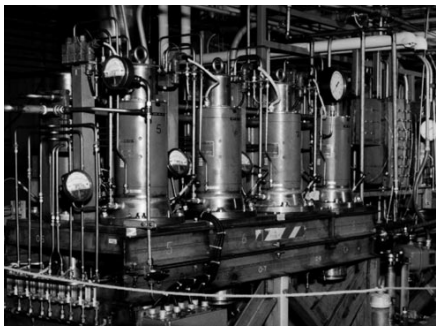
During FY 1995, the U-AVLIS (uranium-AVLIS) Program was sponsored by the United States Enrichment Corporation, which recently decided to continue with development of enrichment technologies for uranium and possibly for gadolinium-155 and -157 for use in commercial reactors. The overall goal is to construct an AVLIS enrichment facility and bring it to full production as quickly as possible. U-AVLIS technology will provide a low-cost production capability to USEC that will help assure a long-term competitive position for the U.S. enrichment business.

Recent accomplishments include

- Beginning the planning process for design, licensing, and construction of the uranium-enrichment plant.
- Reinitiating engineering design and development activities directly supporting plant construction.
- Verifying gadolinium-enrichment physics and hardware performance in a series of enrichment tests.

The objectives for the next several years will focus on the uranium-plant construction projects. Key goals include

- Completion of AVLIS hardware development and demonstration to meet goals for plant construction and operations.



One of the major components of AVLIS technology is uranium processing. Pyrochemical processing technology developed for AVLIS is also being applied to the treatment of hazardous mixed waste.

- Completion of plant engineering design to support Nuclear Regulatory Commission licensing and construction.
- Transfer of AVLIS technology to the USEC project team.

The AVLIS project has the potential to become the largest technology transfer effort to the commercial sector in the Laboratory's history.

Alternative Applications of AVLIS

The following alternative applications for AVLIS technology have been identified as having scientific and commercial value:

- Enrichment of the Tl-203 isotope to produce Tl-201 for heart imaging and enrichment of the Sr-88 isotope to produce Sr-89 for relief of pain from metastasized prostate cancer.
- Laser material processing of metals and ceramics for use in fuel-efficient jet engines and production of high-quality, diamond-like carbon films for flat panel displays, and artificial joints for human prosthesis.
- Electron-beam material processing of high-temperature alloys in the manufacturing of complex alloys and metal-matrix composite materials needed for the U.S. turbine-driven power generator and aerospace industry.
- Laser guide-star systems for U.S. observatories to improve the resolution of ground-based telescopes.

Special Programs 2.4

Industrial Partnerships and Commercialization (IPC)

The Industrial Partnerships and Commercialization (IPC) organization actively pursues dual-benefit opportunities to support DOE's programmatic goals. At the same time, we contribute to the nation's industrial competitiveness by forging partnerships and building alliances between Laboratory researchers and U.S. industry, other DOE laboratories, and government agencies. Partnering includes managing the Laboratory intellectual property in a manner that ensures cost-effective use of our R&D resources. In recognition of the institutional and national importance of these activities, we report to the Laboratory Director through the Deputy Director for Science and Technology. Table 2.4-1 shows the projected funding and staffing of the IPC organization.

We manage all collaborative research and development agreements (CRADAs), negotiate technology licensing, provide industrial outreach, and support the Small Business Initiative. The demand for CRADAs continues to increase. By the end of FY 1995, we expect to have more than 190 CRADAs in place. The ongoing CRADA efforts are worth over $500 million in total funding and represent a spectrum of technologies within the laboratory core competencies (Table 2.4-2). The number of technology licenses is also increasing, with over 150 licenses and other agreements expected to be in place by year end (Table 2.4-3). Similarly, small-value CRADAs and technical assistance are in demand. To date, we have processed over 92 technical assistance requests, with 55 more in the pipeline and 25 small-value CRADAs executed.

We have formed an internal Industrial Partnering Working Group to enhance communication and streamline management of Laboratory industrial collaborations. This group is the institutional focal point for industrial partnership activities and consists of senior representatives from each directorate. The group provides a forum for information exchange, policy formulation, and strategic planning.

Table 2.4-1. Projected funding and staffing for LLNL's technology transfer effort (in millions of dollars, personnel in full-time equivalent).

	FY 1992	FY 1993	FY 1994	FY 1995[a]	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001
Funding for management										
Program operations	2.3	3.3	4.6	6.2	5.6	5.0	5.0	5.0	5.0	5.0
Patent prosecution	0.7	0.8	0.8	1.0	1.0	1.1	1.2	1.3	1.4	1.4
Technology maturation	0.6	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**3.6**	**9.1**	**5.4**	**7.2**	**6.6**	**6.1**	**6.2**	**6.3**	**6.4**	**6.4**
Staffing										
Administration and systems	9	10	10	10	9	8	8	8	8	8
Technology licensing	5	6	6	10	10	10	10	10	10	10
Intellectual property and technical data management	11	9	7	8	7	7	7	7	7	7
Collaborative agreements	7	8	9	9	8	7	7	7	7	7
Outreach	3	3	3	4	4	3	3	3	3	3
Small Business Program	0	3	3	7	5	5	5	5	5	5
Total indirect FTEs	**35**	**39**	**38**	**48**	**43**	**40**	**40**	**40**	**40**	**40**
Funding for Collaborations	**25.0**	**45.0**	**52.0**	**76.0**	**69.0**	**45.0**	**50.0**	**50.0**	**50.0**	**50.0**
FTEs for collaborations	**106.0**	**190.0**	**196.2**	**240.3**	**251.3**	**164.0**	**182.1**	**182.1**	**182.1**	**182.1**

[a] Estimated year-end totals.

Accomplishments

Institutional accomplishments and work in progress in industrial partnering include the following:

• We are working with the Beckman Laser Institute and Medical Clinic (Irvine, CA) to design, build, and test three medical laser systems. The goal is to use Livermore-developed laser technologies to build cost-effective prototype systems that are more compact, flexible, and reliable than existing ones. These systems are applicable to future DOE Defense Program needs in areas such as remote sensing and biological research.

• We signed a three-year Industrial Computing Initiative with Cray Research Inc., Los Alamos National Laboratory, and eight other industrial partners to conduct research and develop software that will enable the use of massively parallel computers in most industry sectors. Applications include atomic-level material simulation codes, oil-well logging, and support of Defense Program needs for high-explosive and material simulations.

• We are working with Silicon Video to develop low-cost process and equipment technologies for a new class of flat panel displays, which are needed for future military aircraft, vehicles, and command centers.

• We are working with General Motors on a three-year CRADA to evaluate the flywheel battery as part of a hybrid system to power future passenger vehicles. This is part of the broad-

Table 2.4-2. Projected technology transfer agreements.

	FY 1992	FY 1993	FY 1994	FY 1995[a]	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001
New licenses	8	10	36	50	70	80	85	95	95	95
CRADAs (cumulative)	24	77	115	190	250	290	330	370	410	450
Other agreements[b]	8	10	20	35	50	70	100	100	100	100

[a] Estimated year-end totals.
[b] Other agreements include nonfederal work for others such as User Facility Agreements, Material Transfer and Consulting Research Agreements which involve intellectual property, personnel exchanges with industry, universities, and other laboratories.

Table 2.4-3. Projected licensing and other earned or retained income and uses (in thousands of dollars).

	FY 1992	FY 1993	FY 1994	FY 1995[a]	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001
Income	300	400	567	1000	1500	1800	2000	3000	5000	5000
Uses of Income[b]										
Patenting and licensing	100	36	74	75	200	200	200	200	200	200
Technology maturation[c]	100	50	0	0	1380	700	700	1500	2500	2500
Awards, inventors, authors' shares	80	150	180	333	500	550	800	1000	1500	2000
Total	**280**	**236**	**254**	**408**	**2080**	**1450**	**1700**	**2700**	**4200**	**4700**
Reserve (accumulation)	**536**	**700**	**1013**	**1605**	**1025**	**1375**	**1675**	**1975**	**2775**	**3075**

[a] Estimated year-end totals.
[b] Funds will vary from year to year as a result of possible changes in royalty sharing with employees and/or the costs associated with transferring technologies to the licensee(s).
[c] The LLNL Director has designated these funds for purposes such as education, training, R&D, and technical exchanges between the Laboratory and industry consistent with the R&D mission and objectives of the Laboratory. The income includes funds for the maturation, demonstration, and preparation of technologies to increase their potential for technology transfer.

based Partnership for a New Generation of Vehicles. This collaboration could strengthen the DOE technology base in cost-effective energy storage and also address DOE energy and environment needs.

• The Laboratory's radar-based technology continues to command high interest. In FY 1994, we granted a limited, exclusive technology license for it to two companies: Amerigon Inc., for its use on an on-board warning device, and Zircon Corp., for its use in electronic hand tools. Eight other nonexclusive licenses have been granted in FY 1995.

• We developed and tested a prototype self-feeding, zinc-particle electrode for a zinc/air battery for an electric bus. The electrode increases energy storage capability and emergency reserve for batteries by allowing external storage of the zinc reactants.

• We are developing an electro-mechanical battery based on the flywheel concept of energy storage. A working flywheel will be delivered to an industry partner in 1995.

• We have an agreement with Power One (and PolyStar) to develop and commercialize aerocapacitors based on carbon aerogels for electronic and energy-storage applications.

• We have a CRADA with Aerojet to commercialize silica aerogels for high-value insulation applications.

• We granted a limited, exclusive license to Cytomation Inc. to manufacture and sell a Livermore-developed high-speed cell sorter that can analyze cells and chromosomes at a rate of 20,000 per second and separate them at up to 2,000 per second, a rate roughly ten times faster than today's standard commercial machines.

• We formed the Center of Economics and Systems Studies to conduct economic assessments and provide analytical foundations for the Laboratory's technology and intellectual property management decisions, and to evaluate and document the Laboratory's performance in its industrial collaboration and technology commercialization efforts.

• We are exploring innovative approaches to encourage the creation of start-up companies based on Livermore-developed technologies.

All-Optical Network Testbed

We are collaborating with the National Transparent Optical Networking Consortium to deploy an optical network testbed in the Bay Area. Members of the consortium are LLNL, Northern Telecom, United Technologies, Hughes, Rockwell, Columbia University, Case Western Reserve University, Pacific Bell, and Sprint. The goal of this three-year project is to demonstrate the benefits of an all-optical network and the optoelectronic components and control strategies on which it is built.

We are responsible for integrating the network that will initially use devices provided by consortium members. We will also establish application demonstrations that load and showcase the network. The network will use wavelength division multiplexing with up to eight wavelengths (each 2.5 Gbit/s), and optical switches based on acousto-optic tunable filters that can independently switch the different wavelengths. Switches will be located at LLNL, UC Berkeley, Pacific Bell, and Sprint facilities, where other facilities will be connected as well.

Energy Materials and Transportation Technology (EMATT)

The Laboratory has initiated more than 100 partnerships with private companies—partnerships intended to benefit Laboratory programs and aid U.S. industry in enhancing global manufacturing competitiveness. The manufacturing projects can be grouped as follows: (1) design, analysis, and characterization of machine tools; (2) advanced materials and manufacturing processes; (3) computer modeling of manufacturing processes; (4) testing, inspection, and nondestructive evaluation; and (5) education and training.

Our goal is to provide manufacturing engineering support to the DOE production complex and at the same time develop manufacturing technologies critical to U.S. industrial competitiveness. Recently, we

• Coordinated one of the first efforts in the DOE complex to work on precompetitive technology with industry and successfully implemented the project called TEAM (Technologies Enabling Agile Manufacturing).

• Implemented and managed one of the largest and most successful partnerships with Cincinnati Milacron, a three-year, $8-million agreement.

• Completed the first CRADA within the DOE complex to receive an R&D 100 award.

• Finalized a significant partnership with ICON Industrial Controls Inc.
• Received designation of Building 432 (The Livermore Center for Advanced Manufacturing and Productivity) as Livermore's first Technology Deployment Center/User Facility.
• Actively participated in the effort to establish a Northern California Manufacturing Extension Center; proposal to be submitted in 1995 to the Technology Reinvestment Program.
• Worked with the National Science Foundation to establish an Engineering Research Center in precision manufacturing.
• Extended codes of fundamental importance in national security—three-dimensional codes developed in DOE's Defense Programs and applied to resin transfer, casting, and materials forming—for commercial applications in materials processing.
• Developed, in a CRADA with Kaiser Aluminum, the superplastic properties of 7000-series aluminum for aerospace applications and also for a more scientific understanding of superplastic properties.
• Used our knowledge of catalysts and aerogels to develop a new catalytic converter for the USCAR initiative, which illustrates the crosscutting nature of materials to specific programmatic objectives.

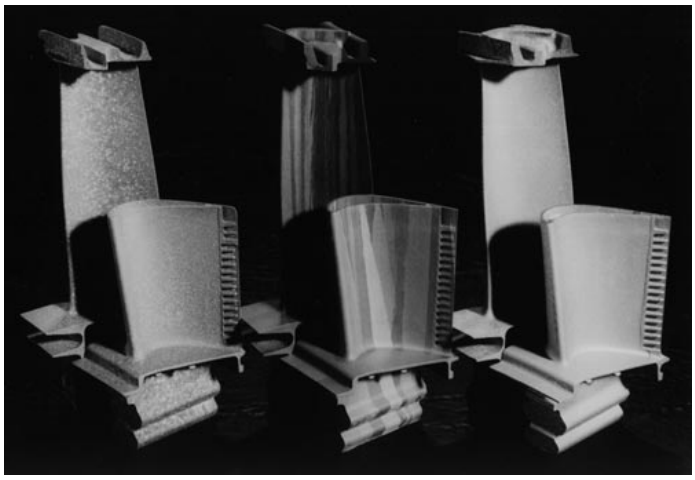
Over the next few years, we will work with DOE/DP to integrate the past manufacturing thrust of maintaining and enhancing DP manufacturing capabilities into the current Advanced Design and Production Technology (ADaPT) initiative.

Center for Microelectronics and Optoelectronics

LLNL's strengths in microelectronics and optoelectronics arise from high-speed detection, transmission, and transient recording requirements of the nuclear test program, from the specialized computing and instrument interfacing requirements of strategic defense and other satellite systems, and from diagnostic and fabrication requirements of the inertial confinement (laser) fusion program. The Center for Microelectronics and Optoelectronics (CMO) integrates our diverse activities into a single organization to encourage communication, coordination, and entrepreneurship in the pursuit of DOE/DP needs and of technology commercialization.

The CMO incorporates crosscutting capabilities in materials development, characterization, and modeling of fundamental material properties and in thin-film processing and microfabrication technology. CMO has an annual budget of about $25 million for programs in semiconductor processing and process modeling, lithography, electronic packaging, communication and computing systems, magnetic storage, and flat-panel display technologies.

Highlights of CMO:
• Initiation of a five-year collaboration with the Semiconductor Research Corporation on computer modeling and simulation of doping, etching, and chemical deposition processes in semiconductor manufacturing.
• Participation with LAM Research to develop a large-area plasma etching tool for manufacturing flat-panel displays funded by the U.S. Display Consortium.
• Collaboration with Read-Write in a $24-million development of magnetic heads for disc drives.



These turbine blades were cast using (from left) the equiax (randomly grown, equisized crystals), polycrystal (unidirectional crystals), and single-crystal (one unidirectional crystal) processes.

• Development of manufacturable field-emission, flat-panel displays with several industrial partners described in the Section 2.2 under ARPA sponsorship.
• Participation in the OETC consortium to develop parallel fiber interconnects for computer clusters.
• Development of semiconductor manufacturing process technologies, including deep submicron copper metalization with Sematech and Intel, a laser doping process for producing shallow source/drain junctions in integrated circuits with Sematech and Ultratech Stepper, and EUV lithography for the production of 0.1-µm features in future integrated circuits.
• Development with Hewlett Packard and Texas Instruments of packaging and interconnect technology for three-dimensional circuitry required to connect and cool stacked chips.

The definition of the Accelerated Supercomputing Initiative (ASCI) in DP has accelerated CMO's year-old program to enable novel massively parallel computer architectures using LLNL's advanced optical communication and packaging technologies. CMO expects to contribute to the Advanced Design and Production Technology (ADaPT) through its microelectronics programs and its associated microfabrication technologies.

Partnership for a New Generation of Vehicles

We are an active participant in President Clinton's Partnership for a New Generation of Vehicles initiative. All projects involve close collaboration with other DOE laboratories and the "Big 3" U.S. automotive manufacturers. The current technology focus is on low-emissions catalysis, NO_x sensors, and systems (engine management) for diesel engines, advanced composite material modeling, design and optimization of cast light metals, supercomputing for advanced automotive component design, computational fluid dynamics (combustion analysis, drag reduction, and under-the-hood thermal management), and superplastic forming of stainless steel. We expect future involvement to include energy storage (flywheel, fuel cells, and aerocapacitors), and hybrid vehicle development and prototype demonstration.

Laboratory Directed Research and Development Program (LDRD)

The LDRD Program funds R&D activities that provide or enhance the technologies needed to maintain our core competencies and drive the future fundamental scientific and technological vitality of the Laboratory. The program provides new capabilities that enable the Laboratory to respond to new DOE missions and national initiatives. It nurtures research that expands the scientific and technical horizons at the Laboratory and fosters scientific collaborations with industry, academia, and other government laboratories.

The LDRD Program has three components: Director's Initiatives, Exploratory Research, and the Laboratory-Wide Competition.

The Director's Initiatives are innovative R&D projects chosen by the Director to implement the Laboratory's strategic vision and plan. These projects explore new technologies that address national needs or provide new multidisciplinary capabilities for the Laboratory. Any LLNL employee may initiate a project in this category, but the proposal for LDRD funding must have the active support of at least one associate director.

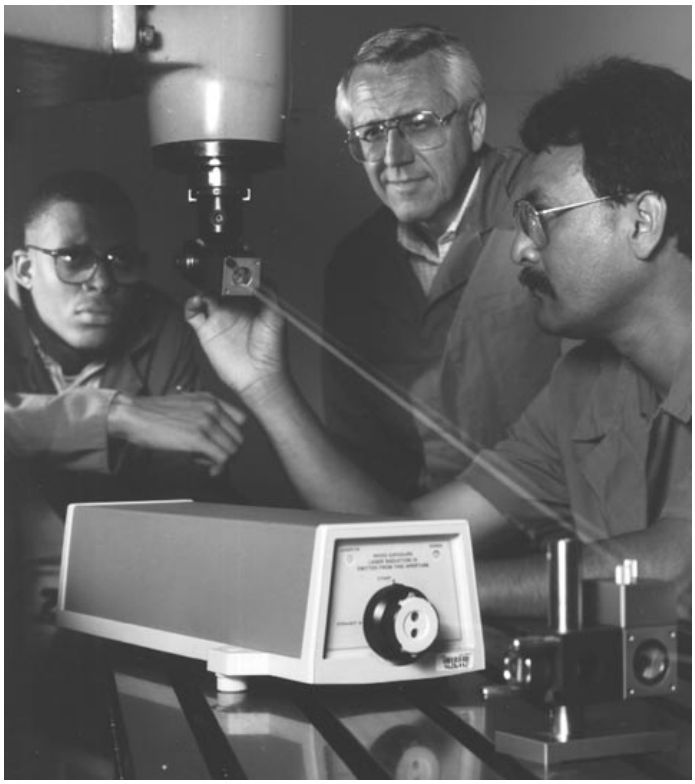
Exploratory Research proposals are submitted by the directorates and are weighted heavily by their ability to attract and develop young scientists, their effectiveness in maintaining the scientific and technological competence of the Laboratory, their effectiveness in furthering the strategic vision of the programs, and their effectiveness in intellectual outreach to the academic and industrial communities.

The Laboratory-Wide Competition provides all members of the Laboratory's staff the opportunity to pursue their own ideas for one to three years. This competition selects innovative projects that further the missions of the Laboratory but are not expected to pass a line-management filter.

In some of the major accomplishments of the program's projects, we
• Produced and trapped fully stripped uranium atoms. We measured the electron capture rate to produce

hydrogen-like uranium and found a major disagreement with theory.
• Developed a receiver that can detect echoes of rapid, wideband radar pulses (about 1 million per second) reflected from objects at distances from 0 to 200 feet. Data about objects or vehicles near a car can be sent to a cruise control system, a beeping alarm, or a system to inflate a side air bag prior to a side-impact crash.
• Developed and demonstrated a system that can track bullets and mortar shells and locate their source so weapons can be neutralized.
• Observed evidence of large amounts of dark matter toward the center of the Milky Way. We observed by far the largest astronomical microlensing event, with an increase in brightness by a factor of 17.
• Demonstrated a technology using capacitive deionization that will enable the cleanup of radioactive liquid waste streams and potentially provide an economical technology for desalinization of sea water.
• Demonstrated that a plume of bacteria can be established in a heterogeneous underground environment to remove chlorinated hydrocarbons from groundwater.
• Successfully used carbon "buckyballs" in the first practical application to manufacture silicon carbide microchips, electromechanical devices, and sensors.
• Demonstrated that laboratory rats having osteoporosis can be treated with a naturally occurring hormone and completely regain their bone mass. The technology may lead to a dramatic new treatment for this debilitating bone disease afflicting millions of older Americans.

Many of the technologies that form the Laboratory's most successful industrial partnerships have their origins in the LDRD Program. Nearly 75% of our current CRADAs derive from LDRD-supported projects. The LDRD Program will continue to foster excellence in science and technology in order to drive the technical vitality of the Laboratory and meet the challenges of changing national needs. This work is described in much greater detail in *Laboratory Directed Research and Development FY 1994* (UCRL-53689-94).



College-level students reap collaborative research opportunities in our laser program as part of our work to shape the future scientific work force.

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 science. Our applied-science expertise at the Laboratory can often instigate experimental approaches in basic research. Simultaneously, advances in basic research facilitate new applications and broaden the skills of LLNL scientists. Collaborations with university and industrial researchers provide effective ways for unique Laboratory facilities and expertise to be made available and address problems of interest to the broad U.S. research community.

During the past decade, several Institutes and Centers have been founded at Livermore, with the goal of facilitating collaborations in specific topic areas and providing a hospitable environment for visiting students and faculty. Our long-term strategy is to advance the strategic goals of the Laboratory, the Department of Energy, and the University of California. To accomplish this, over the coming five years we plan to realign our Institutes and Centers in areas that support the National Ignition Facility and Science-Based Stockpile Stewardship, as well as in areas selected jointly with the University of California to be of particularly strong synergy for collaborative research with university faculty and students.

Participation in LLNL institutes and centers has grown to an annual level of more than 600 researchers from the University of California and other universities, together with their Livermore collaborators. A recent call for proposals from the University of California's Office of the President produced more than 100 new proposals. Clearly there is strong interest in collaborative research on the parts of both the university and Laboratory communities. The challenge over the coming years will be to find new ways to accommodate this strong interest within the budgetary constraints that we all face.

Institute of Geophysics and Planetary Physics (IGPP)

The Institute of Geophysics and Planetary Physics is one of seven branches of a University of California-wide multicampus research unit. Through this institute, some of the Laboratory's unique facilities and expertise (e.g., computer codes, experimental facilities) are made available to the University of California and other universities. At the core of this institute are collaborative research projects in geophysics, geochemistry, high-pressure physics, and astrophysics.

In FY 1994, 42 faculty and students, 6 research staff, and 39 LLNL scientists participated in projects. These projects are often used as "seeds" for larger endeavors and external funding opportunities.

This institute has a strong and active postdoctoral program. Currently, 10 postdoctoral fellows are working in this institute. Each year, this institute also sponsors more than 50 seminars, and usually at least one workshop is conducted on site.

Laboratory for Experimental Astrophysics (LEA)

The Laboratory for Experimental Astrophysics (LEA) supports research in astrophysics as well as projects to develop advanced scientific instruments for remote sensing and for space- and land-based observation of astrophysical phenomena. At the core of the LEA are collaborative projects with University of California faculty, research staff, and students, including those from the Space Sciences Laboratory in Berkeley. Major activities include the development of

- Reflection-grating spectrograph for the X-Ray Multimirror Mission.
- The Gamma-Ray Arc-Minute Telescope Imaging System.
- The Automated Multi-object Spectrograph for the Lick Observatory.
- Novel cryogenic x-ray detectors.

During the past six years, more than 20 faculty, research staff, and graduate students have participated in interactions with LEA scientists.

A Search for Dark-Matter Axions

Livermore is a partner with Massachusetts Institute of Technology, the University of Florida, the University of California at Berkeley, Lawrence Berkeley Laboratory, Fermilab, and the Institute for Nuclear Research in Moscow in a search for a very light particle called the axion. The axion is a candidate for the "dark matter," the unseen mass which constitutes perhaps 90% of the mass of our universe. The experiment, to be commissioned this year, integrates a large superconducting magnet, very high-Q microwave cavities, and state-of-the-art microwave amplifiers. Ultralow-noise microwave detection efforts are synergistic with other Laboratory programs in the area of nonproliferation and national security.

Institute for Scientific Computing Research

The Institute for Scientific Computing Research (ISCR) conducts projects that advance scientific computing and strengthen the ties between computer science and scientific computing. The institute supports collaboration between scientists at the University of California campuses and those at LLNL through a program that funds research at the campuses and through a variety of informal ties. The institute sponsors on-site postdoctoral researchers and conducts seminars and workshops on neural networks, computer vision, computational physics, and applied computing.

Current research under way includes medical and industrial image processing, biomechanical simulations and code development, parallel computing, and adaptive computing methods for non-invasive patient monitoring in biomedicine. In FY 1994, 22 faculty and students and 17 LLNL scientists participated in the ISCR. The computing research group in the institute annually sponsors the International High Performance Functional Computing Conference.

Electron Beam Ion Trap (EBIT)

The EBIT Program conducts projects to develop new experimental capabilities for investigating the fundamental properties and technological applications of highly charged atomic ions. Many of these projects involve collaborations with faculty and students from universities. Major activities include

- Measurements of the fundamental properties of very highly charged ions produced by the SuperEBIT device.
- Development of a new particle trap for storing cold, highly charged ions.
- X-ray spectroscopy of species relevant to Laboratory and astrophysical plasmas.
- Experiments focusing on the interactions of very slow ions with solid-state materials.

During the past five years, more than 40 faculty, research staff, and graduate students have participated in EBIT projects at Livermore.

Plasma Physics Research Institute

The Plasma Physics Research Institute serves LLNL, the University of California, and other universities by providing opportunities for collaborative research in plasma physics. This institute gives faculty researchers access to LLNL's facilities, expertise, and ongoing projects. It also provides LLNL's staff members with a greater opportunity to collaborate with faculty and graduate students. In FY 1994, 40 University of California students and faculty and 32 LLNL scientists participated in research through this institute.

Glenn T. Seaborg Institute of Transactinium Science

The institute is named for Nobel laureate Glenn T. Seaborg, in recognition of his contributions to transactinium science and to science education. This year, for the first time, the Institute participated in the University Collaborative Research Program. There are currently eight postdocs and three graduate students with the institute, which has research affiliates at LLNL, LANL, and LBNL. This summer the institute had two high school teachers on the staff as well as four summer students from various universities. In August, the Institute hosted a four-day international workshop that included prominent scientists from the U.S. and former Soviet Union.

Energetic Materials Center

The Energetic Materials Center is a joint effort between LLNL and Sandia–California. It includes Sandia's Combustion Research Center, facilities in LLNL's High Explosives Applications Facility, and facilities at Site 300. This center was established to promote technical partnerships with U.S. industry, government laboratories and agencies, and academic institutions for long-term, high-payoff R&D of energetic materials. The center is staffed by more than 200 scientists and engineers with expertise in high explosives, propellants, and pyrotechnics. It includes some $400 million worth of modern research and testing facilities specifically designed for energetic materials work.

Optical Sciences Institute

The Optical Sciences Institute will serve as a leading-edge research organization in optics and photonics. The institute will work with Laboratory Directed Research and Development investigations and ongoing CRADAs to stimulate collaborations with university and industrial partners in laser and electro-optical technology. This institute should be fully operational in FY 1995.

Open Computing Facility

The Laboratory's Open Computing Facility has completed its conversion from a supercomputer environment to a distributed computing environment. With 18 high-performance UNIX minicomputers interconnected by a high-bandwidth shared-file system, this facility provides computing resources to Laboratory researchers and their external collaborators at an extremely low cost. It also provides a research environment for parallel computing, high-performance communications systems, and automatic file migration systems. This facility will evolve as new hardware and software become available; we

will add new computers periodically to augment the overall computing environment.

Massively Parallel Computing Initiative

The Massively Parallel Computing Initiative is a collaborative effort between LLNL and the University of California to explore ways to best use massively parallel computers—a class of computers with many hundreds or thousands of identical processors. University-based users play a significant role in this project.

Institutional Collaborative Research Program

The University of California Institutional Collaborative Research Program supports the development and testing of a coupled ocean–atmospheric global model. The partners in this collaboration are LLNL, Los Alamos, the Scripps Institute of Oceanography, and the University of California campuses at Davis, Irvine, and Los Angeles. The global model will be used to study the potential for future chemical and climatic changes from rising concentrations of greenhouse gases. The 6 graduate students and 12 postdoctoral fellows supported through this program have been assisted by 10 to 20 staff members at each institution. In addition to participating in this program, the Laboratory's Atmospheric and Geophysical Sciences Division is conducting a joint regional climate study with the University of California at Davis and Los Alamos under the sponsorship of the DOE National Institute for Global Environment Change, located at the University of California at Davis.

Program for Climate Model Diagnosis and Intercomparison (PCMDI)

PCMDI was established by the DOE/OHER Environmental Sciences Division to support the U.S. Global Change Research Program. Our mission is to carry out coordinated analysis and validation of climate models for documenting, understanding, and reducing systematic errors. A primary activity is organizing and supporting the Atmospheric Model Intercomparison Project (AMIP) in cooperation with the United Nation's World Climate Research Program. This international project diagnoses and compares under standardized conditions all atmospheric general circulation models used in global climate research, in order to identify common deficiencies and guide model improvements. Our leadership in AMIP includes developing and distributing documentation, data banks, and software in cooperation with the worldwide climate modeling and diagnostic community.

We began limited production use of the Meiko-CS2 massively parallel computer, integrated it into the classified supercomputer center supporting defense programs, and began working with users to develop a new generation of parallel-capable applications.

Science and Mathematics Education

Promoting change in science, math, engineering, and technology education is at the very heart of the Laboratory's Education Program. We are focusing our efforts on six key areas, as identified by the National Science and Technology Council:

- Curriculum improvement.
- Teacher enhancement.
- Student support.
- Systemic reform.
- Educational technology.
- Public understanding of science.
- Diversity efforts

Table 2.4-4 summarizes the Laboratory's education programs and participants. Table 2.4-5 shows FY 1994–1997 operating funds.

Curriculum Improvement

At the request of school districts and colleges, we help develop and implement custom-designed science-education programs. The curricula are developed cooperatively by teachers and Livermore scientists; we are making the curricula available electronically through our Technology Resource Center. Our

Table 2.4-4. Science and mathematics education programs.

Project	Grade	Number of FY 1995 participants[a]	NCST Set categories[b]	Description
Science Bowl and Math Challenge	9-12	300	SS	One-day competition
Access to Science Teaching Careers	UG	5	SS	Internships for minority teaching students
National Physical Science Consortium (NPSC) and National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM) Students	GRA	25	SS	Minority/women fellowships and research experience
Expanding Your Horizons (EYH) Consortium	6-12	1800	SS	Young women's conference, includes impact study
Take Our Daughters To Work and Son Day	4-11	1900	SS	One-day work experience
Undergraduate Institute on Contemporary Topics-Applied Sciences	UG	60	SS	Two-week physics institute
School-To-Work Interns	11-12, UG	100	SS/ET	Nontraditional career training, includes at-risk students
Apprenticeship and Pre-Apprenticeship	UG	40	SS/ET	Year-round program
Explorers Post	9-12	10	SS	Research projects with scientists
Science and Engineering Research Semester	UG	52	SS	Cooperative research program
Lab Technology Resource Center (TOWER)	K-12	2500	ET/CI	Electronic curriculum resources, electronic server, bulletin board, technology training and desktop video conferencing
National Energy Supercomputer Program	4-12	10,000	ET/TE	Week-long workshops for teachers
Science Appreciation	9-12, UG	150	PU/CI	Development of course and curriculum materials and classroom evaluation
Fun With Science	K-12	30,000	PU	Science and technology demonstrations
Speakers Bureau	All	5000	PU/SS	Presentations to school and community groups and tours
Historically Black Colleges & Universities (HBCU) Projects	UG	60	II/SS	Collaborative research and internships for faculty and students
Science and Technology Inquiry Partnerships	K-12	1500	TE	Integration of introductory-level material
Summer Research Internship	K-12	60	TE	Research opportunities
Global Concerns Thematic Immersion Curricula			CI/TE	Multidisciplinary curricula threaded with technology, includes issues of risk assessment
Biotechnology Education Project	9-12	20,000		
Global Security Curriculum	9-12	500		Immersion of entire school in biotechnology
Environmental Monitoring (formerly Global Climate Change)	6-12	200		Centered around nuclear security and nonproliferation (under development)
QUAKES	6-12	100		Immersion in issues of the environment (under revision) Examine issues in seismology (under development)
Student Science Research Associates	K-12	3000	CI/SS	Facilitated student research on issues of water monitoring. Includes international and multi-Lab collaboration

[a] FY 1995 numbers are year-end estimates based in part on FY 1994 experience.
[b] NCST (National Council on Science and Technology) Set Categories: CI = curriculum improvement, ET = educational technology; II = institutional improvement; PU = public understanding of science; SS = student support; TE = teacher enhancement.

current thrust is to move away from providing prepackaged science education courses (although they are still widely requested and presented) toward collaborations with schools and school districts. To ensure that all our materials have sound technical content and educational value, they are evaluated and assessed both by the research staff and by educators.

Global Concerns

The Global Concerns projects reflect a spectrum of issues, such as space exploration, global warming, nuclear proliferation, earthquakes, and genetic engineering. These projects directly reflect LLNL Defense Program core competencies and provide opportunities for teachers and students to study complex global issues through participation in ongoing Laboratory research efforts. All efforts incorporate risk assessment, scientific, and technological solutions to these issues. Solutions are implemented in multidisciplinary themes with participation by the classroom and entire school. In addition to established themes on Biotechnology and Clementine, new topics include the Global Earth, focusing on nuclear security and earthquake studies, and Environmental Monitoring, which incorporates our current global climate change models.

The Clementine project makes available to the public a scientific database containing pictures of the Moon and Earth taken by the deep space Clementine satellite. Several thousand of these images, along with information regarding the Clementine deep space mission, are available over the Internet through a Mosaic interface from the Laboratory. Teachers have developed thematic curricula and classroom resources (a CD-ROM) that will assist teachers and students in learning about lunar geology, remote sensing, and the origins of the universe.

Biotechnology is a two-week integrated, multidisciplinary thematic immersion curriculum that deals with topics brought about by advances in biotechnology. The curriculum includes equipment and materials to conduct hands-on experiments in the classrooms and schedules for school-wide activities.

Environmental Monitoring is a multidisciplinary curriculum in which elementary- and high-school teachers and students explore the physical aspects of the Earth's climatic variations.

Quakes is an interdisciplinary project that will teach middle- and high-school students about seismology. Students will use a computer program to examine soil types throughout the San Francisco Bay Area, pick a site to build on, design and construct virtual buildings, simulate earthquakes, and analyze the results.

The Global Security project consists of a team of Livermore physicists and local high school teachers who are designing an education module that focuses on the worldwide proliferation of nuclear weapons.

Partnerships for Environmental Technology Education

In 1991, in an effort to improve environmental science and technology teaching at the junior college level, we established Partnerships for Environmental Technology Education. This program provides community colleges with the resources they need to develop training programs or college-prep curricula that will increase the number of qualified environmental scientists and technicians, and promote environmental technology transfer. Currently, 40 community colleges in

Table 2.4-5. Science Education and Technical Information operating funds (in millions of dollars).

Reporting category	FY 1994 BO	FY 1995 BA	FY 1996 BA[a]	FY 1997 BA[a,b]
KT University & Science Education	1.0	1.3	2.4	2.7
KV University & Science Education	0.0	0.0	0.0	0.0
Total	**1.0**	**1.3**	**2.4**	**2.7**
% of Total Laboratory Operating Funding	0.1%	0.2%	0.2%	0.3%

[a] 3% Escalation FY 1996 and FY 1997.
[b] Guidance case.

the five-state western region are participating in the program.

Teacher Enhancement

Student Science Research Associates

This project helps K–12 students, their teachers, and Livermore researchers explore science through cooperative research teams that use computers as well as data recording and analysis tools to study complex global issues. They also use electronic communication networks to share ideas and discoveries with their research mentors at LLNL.

Teacher Research Internship Program for Teachers

The Teacher Research Internship Program provides opportunities for elementary-, middle-, and high-school teachers to participate in up to three summers of ongoing research at the Laboratory from which they develop new curricula for their classes. In 1994, 45 teachers participated in the program.

Science and Technology Inquiry Partnerships

In a series of workshops, the Science and Technology Inquiry Partnerships prepare teachers as partners in the systemic change process and allows them to develop and implement inquiry-based curricula for science and technology.

Student Support

Science and Engineering Research Semester

The Laboratory is one of nine DOE sites that sponsors students in semester research opportunities. The intent is to encourage them to pursue advanced degrees and, ultimately, careers in science and engineering. At LLNL, the students spend 80% of their time on a Laboratory project and 20% of their time in seminars, workshops, and courses. Since the program began in the fall of 1992, we have sponsored more than 60 students from all over the nation.

Two students from nearby Foothill High School observe water sampling techniques at the Laboratory's water retention basin.

Partnerships with Industry and Education

The Partnerships with Industry and Education is a program between businesses, universities, and LLNL in which students intern at a business and continue research upon returning to college.

Student Internships

Through our association with the Associated Western Universities—a consortium of universities devoted to preparing students for scientific and technical careers in government, business, and industry—we provide an on-site program in which students choose their own projects and perform research under the supervision of Laboratory scientists. Approximately 50 students enter the program each year.

School to Work Internships

The School to Work Internships provide paid and unpaid internships in careers in the trades.

Undergraduate Physics Institute

The Undergraduate Physics Institute is a two-week program offered to students in their junior year of college. The program is structured

so that the students spend their mornings at lectures and their afternoons working with researchers on projects in applied physics, chemistry, mathematics, or engineering. At the end of the two weeks, the students present the results of these projects at a poster session.

Teacher Certification Program

The Teacher Certification Program is a collaboration with San Jose State University in which Laboratory employees with advanced degrees in science or math earn a single-subject secondary teaching credential.

Systemic Reform

Partnership with the State of California

We are working with the California state systemic initiative efforts and Lawrence Berkeley National Laboratory to provide expertise for integrating technology into the state education reform initiatives.

Educational Technology

Technology Resource Center

The Technology Resource Center provides technology training for teachers, administrators, and students throughout California. We are making all of our curricula materials available electronically. We have offered this resource to the other DOE laboratories so it can be used both for information dissemination and as a portal to the Internet for their partners in the education community.

National Education Supercomputer Program

We offer a year-round supercomputing program designed specifically for teachers. Teachers from across the U.S. attend tutorials and work on projects to learn how to use the National Education Supercomputer. They work from their classrooms with Laboratory professionals to develop curricula that make use of this supercomputer. One of the most effective aspects of these workshops is the development of "master" teachers who conduct workshops for teachers in their local areas and thereby extend access to the National Education Supercomputer to more teachers and students.

Supercomputing Programs

The National Education Supercomputer Program (NESP) operates a Cray X-MP as an educational resource for elementary through community college teachers and students across the nation. In another Livermore effort, the DOE High School Science Students Honors Program brings students to the Laboratory's National Energy Research Supercomputer Center (NERSC) to spend two weeks investigating leading-edge technology and learning about how supercomputers are used in scientific research.

Our recent accomplishments:

- Maintained 10,000 active accounts on the National Education Bulletin Board System, which accesses the NESP machine.
- Held NESP training workshops for over 150 teachers.
- Completed the tenth Superkids program.
- Completed the third Southwest Indian Polytechnic College Bound Program workshop.

Our objectives:

- Planning for the return of the Superkids program to Livermore in 1996.
- Developing new applications for the NES.
- Increasing the number of teachers and students using the NESP.

About 1,000 girls participated in the Laboratory's Daughters Day this year. These girls were shown the Technical Information Department.

Public Understanding of Science

Expanding Your Horizons

Many LLNL women scientists participate in Expanding Your Horizons, a nationwide program that

encourages middle- and high-school girls to develop and maintain an interest in science. We were involved in implementing four regional conferences that reached over 1,800 young women.

Fun With Science

Fun with Sciences is a program that stimulates students' interest in science and heightens their curiosity about the physical world and the way it works. This program is coordinated with our Science and Technology Inquiry Partnership workshops so that teachers who have participated in the workshops can present the Fun With Science demonstrations to their students in tandem with LLNL scientific and technical staff. Each year, this program reaches more than 20,000 students nationwide.

Special Programs for Students

The Special Programs for Students includes the Earth Day Conference for local students, regional competitions such as Science Bowl and Math Challenge, speakers for special events, and tours for educational institutions.

Diversity Efforts

Historically Black Colleges and Universities Research Collaborations

Laboratory connections with historically black colleges and universities date back to the 1970s. We work with these institutions to enhance their science and technology capabilities and to establish collaborative research efforts through seminars, workshops, and conferences; summer employment opportunities and research projects; and loans or donations of computer, engineering, and laboratory equipment.

Post-Secondary Initiatives

Research internships are provided for underrepresented students to expose them to the scientific process and further their pursuit of teaching credentials in science and mathematics. Graduate fellowships and research opportunities are provided through the National Physical Science Consortium for underrepresented students pursuing Ph.D.s in science and engineering.

American Indian Program

We are offering teaching enhancement courses for elementary school teachers on the Navajo Reservation in partnership with the Navaho Community College.

User Facilities

Center for Advanced Manufacturing and Productivity

The Livermore facility in which we are concentrating our activities in advanced manufacturing and precision machining has now been designated the Livermore Center for Advanced Manufacturing and Productivity as our first Technology Deployment Center/ User Facility. The facility currently houses CRADA activity in manufacturing processes and is developing administration functions needed to accept users early in FY 1996.

Center for Accelerator Mass Spectrometry

The Center for Accelerator Mass Spectrometry is the world's most versatile and productive accelerator mass spectrometry facility, providing some 14,000 measurements of isotopic ratios in the past year. In 1995, we provided routine and reliable unattended operation of the spectrometer and achieved 1-μm resolution with the microprobe beamline for spatial analysis of materials at atomic scales.

This center serves Laboratory programs in toxicology and genotoxicity, carbon-cycle paleoclimate records and geologic and hydrologic processes, radiation dosimetry, and nonproliferation. External users and collaborators, numbering some 500 in the past year, include investigators from the nine University of California campuses, a broad distribution of university and government scientists, private companies, and researchers funded by the governments of Canada, Mexico, Australia, Denmark, Sweden, Italy, and the United Kingdom. The center serves external programs in archaeology, art history, clinical and nutritional medicine, and geoscience.

National Energy Research Supercomputer Center (NERSC)

NERSC is a national scientific supercomputing resource managed by Livermore for the DOE. This Center serves about 2000 DOE accounts, about 2000 university accounts, and many industrial accounts at about 130 sites in the U.S., Asia, and Europe.

Section 3

Institutional Infrastructure

Communication and Information 3.1

This section covers the operational aspects of the Laboratory. These activities are organized in accordance with the DOE's critical success factors, including communication and information; human resources; environment, health, and safety; management practices; and the site and facilities.

Scientific and Technical Information

To make Laboratory-generated scientific and technical information more quickly and easily available to internal researchers and to an ever-widening national and international audience, our Technical Information Department is organizing and managing what we call "The Library of the Future."

The Library of the Future has two significant goals:

• Make Laboratory and archival documents available as they are produced.

• Provide information-retrieval tools that are progressively more sophisticated but remain consistent with formal industry standards.

Thus far, the Library of the Future

• Identified and implemented sophisticated text-search technologies.

• Developed and implemented a process for providing current documents electronically to Laboratory researchers while ensuring adequate review for classification and intellectual property considerations.

• Began scanning the archival document collection (about 77,000 documents) for gradual inclusion in the electronic collection.

• Began efforts to identify more sophisticated text-search technologies.

At present, Livermore documents are not made available via the Internet because of overarching security concerns. Efforts are proceeding to resolve these issues. In the meantime, the Library of the Future home page is the second most frequently accessed of the internal home pages, a clear indication of interest and acceptance.

In addition, our Technical Information Representative works actively with DOE/OAK to establish effective and reasonable measures of successful management of scientific and technical information. The Technical Information Representative also teams with the Office of Scientific and Technical Information, DOE/OAK, and counterparts at the other national laboratories in developing scientific and technical information policies and procedures.

Administrative Information

Computer-based financial and administrative information management services are provided to all segments of the Laboratory by our Administrative Information Systems team. Services include analysis, design, and implementation of business information systems that are designed to meet the legal, fiscal, and operational information-processing requirements of the Laboratory.

Planned retirement of older computer systems and implementation of a new computing environment, coupled with a significant effort to modernize business systems at the Laboratory, is a major effort. It includes migrating and re-engineering administrative applications software to a UNIX-based, distributed-workstation architecture, which consists of a multivendor set of workstations in an open computing environment. The Laboratory has licensed Oracle software to provide a comprehensive database-management system that can operate in this environment, and we continuously evaluate other products that can improve our administrative systems.

Institutional oversight and direction for business information systems is the responsibility of the Institutional Business Council. This council defines business strategies, coordinates and integrates business processes and procedures, and ensures that cost-effective business information systems support our programmatic missions.

Information Archive

The Laboratory Historian heads the Office of History and Historical Records and reports to the head of the Technical Information Department. This office has three major functions:

• Preparing and disseminating historical accounts of LLNL, its programs, and related topics.
• Acquiring, cataloguing, and maintaining pertinent historical records.
• Assisting historical research by others and answering questions from officials, professionals, and the public.

This office archives and indexes documents, photographs, negatives, motion pictures, video tapes, and optical disks, it publishes annually updated indices that comprise 17 volumes covering 370,000 items to date. Of these items, about 12% are classified.

Information to Employees and the Public

The Laboratory has strengthened its internal and external communication efforts in recent years through the activities of the Public Affairs Office (PAO). Projecting the Laboratory's policy of openness, Public Affairs has made concerted efforts to reach employees, the general public, local and regional leaders, and local, regional, and national news media. Following are some highlights:
• The Internal Communications Group doubled the publication frequency of the Laboratory newspaper, *Newsline*, to twice a week, arranging for direct mail delivery to all employees instead of leaving it in boxes for pickup.
• For faster-breaking news, an electronic "E-line" gets vital messages to some 6,000 on-line employees within two to three hours.
• Face-to-face communication was improved in monthly "400" Meetings with managers, Town Hall Meetings with the Deputy Director, the Director's TV talks, and Thursday Forums with presentations on research programs, administrative developments, and other events.
• 20,000 visitors toured our Visitors Center last year. We now conduct student and citizen tours, arrange public speeches and school visits, and respond to hundreds of "community hotline" calls.
• We organized hundreds of volunteers for charity events such as the Cystic Fibrosis Walk-a-thon, Hope Hospice, and March of Dimes.

PAO's responsibilities extend to the wider community, as well, by providing timely information to DOE, UC, and inquiring private companies about topics ranging from research highlights to the possibility of obtaining licenses to commercialize Laboratory inventions.
• We issued three to four news releases per week plus tip sheets, media advisories, and photos for current news stories. We also hosted three to five media visits per week, while beginning to make extensive use of the electronic distribution systems.
• We offered special services such as placements for editorial articles, comprehensive planning, public opinion survey capability, media training, and tours for editorial boards.
• Laboratory articles appeared frequently in major national daily newspapers like *The New York Times* and *The Los Angeles Times*, in business publications like *Business Week* and *Financial World*, and in the major science publications like *Scientific American*, *Science*, and *New Scientist*. In the past year, Livermore research programs have been highlighted on all the major broadcast networks, both radio and TV.

The Public Affairs Office is also responsible for providing timely, accurate information to the media on matters concerning health and safety during and following an operational emergency at the Laboratory, and it coordinates communication with the FBI and DOE through the Laboratory's Emergency Management Center.

Congressional Support

This 104th Congress in particular has shown great interest in understanding the missions, programs, and benefits to the taxpayers of the DOE national laboratories. The DOE has encouraged us to provide this information and to support the Congressional legislative and budget processes. To this end, our Director and Executive Officer have given formal testimony before House and Senate Committees, our legislative analyst and technical staff respond to several dozen Congressional requests for information each month, an administrator in the University of California office in Washington provides a ready point of access and

information, senators and congressmen have visited Livermore, and a newsletter and technical journal, which receive wide general distribution, are also sent to the California delegation and to other Congressional personnel who have expressed an interest. In addition, our local congressman, Bill Baker, has been very helpful in providing information to his colleagues regarding future benefits of Laboratory science and technology. In this era of rethinking the purposes and proper functions of national laboratories, it is critical for us to be accessible and open to the public and to our government leaders.

Community Involvement

The Laboratory has been active in service to our local communities and has been a founding member and active participant in several important Bay Area economic development efforts, including the Alameda County Economic Development Advisory Board (EDAB); Bay Area Regional Technology Alliance (BARTA), now directed by a former Laboratory Associate Director; and Alameda Center for Environmental Technology (ACET), of which we are a founding partner. We are also active with the Bay Area Economic Forum in promoting the laboratory–university–industry knowledge-based economy and with the East Bay Conversion and Reinvestment Commission, a Congressionally funded project that assists communities with military base closures (eight in our area) and defense downsizing.

We are currently working with the City of Livermore to plan a civic center that will include educational, conferencing, and display facilities—useful to the Laboratory and beneficial to the City. While the Laboratory cannot participate in the capital support of these facilities, we expect that our outreach, partnering, and educational activities will mutually serve the city and the Laboratory.

Laboratory employees contributed about $600,000 to local and national charities, principally through our HOME campaign. In addition, approximately 2,500 employees volunteered for all types of community activities that help students, seniors, and the needy of all ages.

Human Resources 3.2

LLNL's Human Resources organization provides services and programs to help achieve workforce excellence. One of the goals of Human Resources is to recruit, hire, and retain the most outstanding, diverse workforce possible. Recruitment, reward, and advancement decisions are based on merit, with successful employees being those whose performance contributes to the objectives of the Laboratory. To accomplish this, Human Resources staff members work in partnership with Laboratory managers to help them meet their programmatic mission and goals and to define workforce planning priorities and solutions. In addition to the two ongoing activities described in this section, this year the Laboratory embarked on four new initiatives: a new workforce planning model, a career center, a formal brokering process, and the use of Resumix.

New Workforce Planning Model

A new workforce planning model was adopted with the goal of determining the workforce needs and skills mix requirements for both the near-term and long-range time spans. The process includes developing a fiscal year staffing plan for each directorate and a discussion among the top Laboratory managers of the workforce needs for the next three to five years. When the workforce planning process is completed, skill needs will be communicated to Laboratory employees so they can shape their own development plans in accordance with the Laboratory's needs. Staffing composition as of March 31, 1995, is given in Table 3.2-1.

Career Center

As the Laboratory redirects its programs, work assignments, and skills needed for them will change. A Career Center was opened to help facilitate the changes by providing resources for employees to help them understand options, set goals, and form career development plans. This facility offers ongoing workshops on career development, one-on-one sessions with a skilled counselor, a resource library, and assistance in identifying available assignments.

Formal Brokering

A brokering process was initiated in which representatives from each directorate identify potential jobs and existing vacancies. These representatives match employees who are between assignments with employment opportunities in other parts of the Laboratory.

Resumix

Our new applicant tracking system, RESUMIX, which combines optical scanning and artificial intelligence technology, was fully implemented in July 1994. With it, we created an ongoing inventory of skilled personnel available both inside and outside the Laboratory. Our active database contains 15,000 resumes that Laboratory managers can access to identify appropriate candidates for available positions.

Compensation

Even while the Laboratory reviews and reconfigures its mix of workforce skills, salary programs must remain competitive with the external salary markets in which we compete. Our compensation program

Table 3.2-1. Laboratory staff composition as of March 31, 1995.[a]

	Ph.D.	M.S./M.A.	B.S./B.A.	Other	Total
Scientists	887	381	371	15	1654
Engineers	257	442	252	32	983
Managers and administrators	34	206	310	462	1012
Technicians	1	31	325	1614	1971
All others	1	6	94	1520	1621
Total	**1180**	**1066**	**1352**	**3643**	**7241**

[a]Excludes summer hires and temporary program participants.

provides Laboratory management with in-depth assessments of external salary markets and develops appropriate salary-increase proposals to the Department of Energy. Internally, we implemented a salary-management program that recognizes and rewards performance, productivity, and contribution to Laboratory programs. In addition, compensation policy options are provided for managing reconfigurations of the workforce skill mix.

Diversity and Affirmative Action

Our goal is to make the Laboratory an employer of choice for all who can contribute to the Laboratory's missions. To reach this goal, we focus on building a world-class workforce that is reflective of the rich diversity of California and our nation, improving communication, and fostering work environments that build strength for diversity and provide opportunity and encouragement to excel. We aim to become the model for diversity among the national laboratories, accomplishing this with leadership through the Director's Office (see Figure 3.2-1).

The Laboratory's Executive Officer is the Laboratory's Equal Employment Opportunity Officer and is responsible for overseeing and directing our diversity and affirmative action activities and for ensuring effective institutional support for affirmative action and diversity objectives. This responsibility is delegated from the Director, who is strongly committed to these programs. Responsibility for developing and maintaining a diverse workforce and a discrimination-free work environment is shared by all Laboratory managers. Line managers are responsible for setting and achieving goals, on the basis of hiring requirements, that will increase the representation of minorities and women at all levels and in all job groups in the organization. The managers are assisted by the Deputy Associate Director for Affirmative Action and Diversity.

The Laboratory has just received the results from its first-ever, all-employee survey focused on diversity, the results of which were reviewed with employees on August 16, 1995. These results along with other information will serve as a baseline for the newly underway diversity planning process, which will be used to identify the key strategic and operational diversity issues and to organize diversity action teams. Our intention is to develop solid, enduring responses to these issues and, over the next three to five years, evolve effective policies, procedures, and practices that facilitate inclusion, equality, and the productivity achievable by a world-class workforce. We expect this initial planning process to be completed during FY 1996.

In addition to the diversity plan currently in progress, our annual *Affirmative Action Plan* documents the goals and efforts of each Laboratory organization and the Laboratory-wide activities that go far beyond compliance with Executive Order 11246, Rehabilitation Act of 1973 (Section 503), the Vietnam Era Veterans Readjustment Assistance Act of 1974, and the 1990 Americans with Disabilities Act. The document is approved by the University of California and is submitted to the Department of Labor, Office of Federal Contract Compliance Programs.

Ongoing goals described in the plan are to

- Recruit and hire outstanding performers from diverse backgrounds.
- Design and implement leading educational and community outreach programs.
- Increase the employment of qualified individuals with disabilities, Vietnam-era veterans, and special disabled veterans in all job classifications and at all levels at the Laboratory.
- Communicate technical and human resource achievements.
- Provide technical expertise in diversity, employment law, and affirmative action to organizations within LLNL.

A variety of programs are effective across the Laboratory in working to improve opportunities for minorities, covered veterans, individuals with disabilities, and women within the Laboratory and at the local community, state, and national levels. The objectives of these programs are to

- Help women and minorities develop the skills for future employment needs.
- Maintain liaisons with and provide support for programs that assist in the skill development of women, minorities, covered veterans, and individuals with disabilities to meet utilization goals.
- Assure the continued excellence and diversity of our current work population.

Employee associations contribute significantly to making the Laboratory the institution of choice for all employees. These on-site groups

- Work with existing Director-appointed committees and task forces to communicate interests, issues, and concerns.

• Offer Laboratory-wide celebrations and speakers to promote greater cultural understanding.
• Offer scholarships to assist in the advancement of qualified applicants.

With the addition of new and expanded activities over the last year, the Laboratory's focus is shifting from promoting diversity training among managers and supervisors to greater inclusion of the entire workforce in Laboratory diversity activities. Examples of accomplishments include
• Participation of over 400 managers and employees in diversity dialogue group training and focus groups that identify diversity-related topics and strategic issues.
• Increased participation in the cross-cultural mentoring program from 23 pairs to 32 pairs.

The central theme of the Laboratory's compliance efforts is greater utilization of minorities, women, covered veterans, and people with disabilities within the workforce. This means increasing the representation of these groups in new hires and in their upward mobility within the institution. Programs and activities to support these goals include Equal Employment Opportunity Programs, Disabilities Services program, complaint resolution, and workforce demographic trending and analysis efforts.

Examples of accomplishments during the past year include
• Revision of the *Affirmative Action Plan* to facilitate tracking and accountability for achieving affirmative action hiring goals.
• Placement of over 63 women or minority candidates in various employment programs (e.g., summer, Science and Engineering Alliance programs) for periods ranging from two months to three years with positions ranging from clerk-typist trainees to post-doctorate physicists.
• Transferal of costs for interpreting services for deaf employees from Laboratory departments to the Affirmative Action and Diversity Programs (AADP) office, resulting in an increased use of interpreters by as much as 30% in some departments.
• Implementation of a database for tracking participants in AADP-sponsored programs and activities.
• Collaboration with a consortium of four HBCUs (historically black colleges and universities, in this case, Alabama A&M University, Jackson State University, Prairie View A&M University, and Southern University) and LLNL to focus on scientific research of mutual interest.

Over the next several years, compliance activities will focus increasingly on relating compliance activities to affirmative action performance. Through increased statistical monitoring and tracking of workforce representation of minorities and women, we will know which areas are most under-used with respect to these two groups. Similar analyses performed on the effectiveness of our various outreach efforts and employment programs will then allow for a more surgical application of these programs to the areas that need them most. This more quantitative approach to compliance should result in increased yet more cost-effective use of limited fiscal resources.

Tables 3.2-2 through 3.2-4 and Figure 3.2-1 show statistics related to affirmative action for Laboratory career employees.

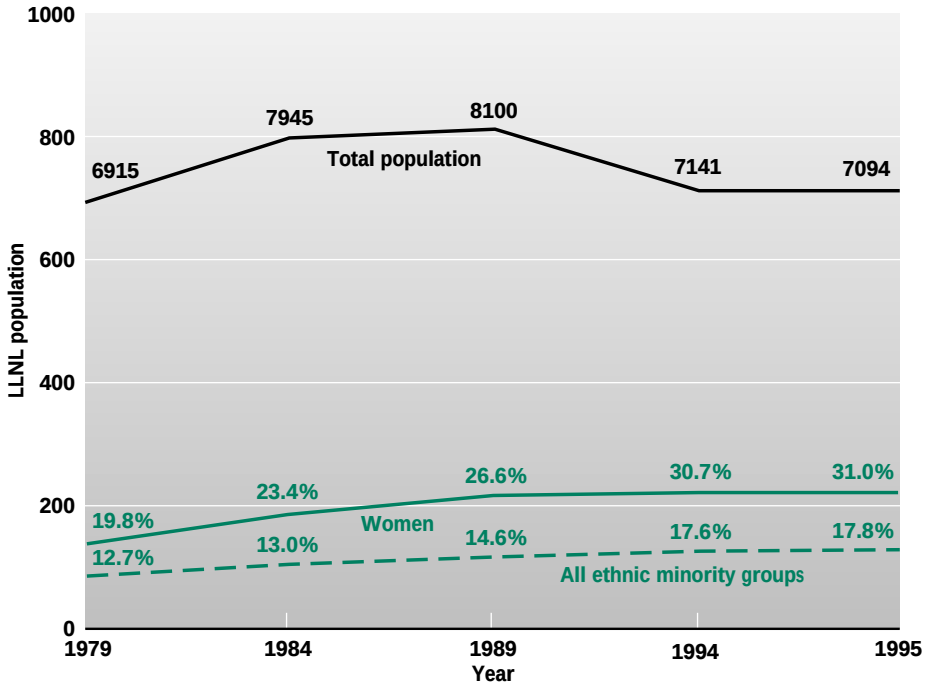


Figure 3.2-1. Increase in minorities and women employees at the Laboratory from 1979 to 1995, during declining overall population.

Table 3.2-2. Population of Laboratory career employees as of March 31, 1990 (by number and percentage).

		Officials & Managers		Scientists & Engineers		Administrative		Technicians		All Others		Totals	
White	M	1037	76.0%	1873	76.6%	188	33.2%	1504	71.9%	655	36.1%	5257	63.5%
	F	201	14.7%	275	11.3%	303	53.4%	266	12.7%	770	42.4%	1815	21.9%
Black	M	20	1.5%	23	0.9%	10	1.8%	57	2.7%	58	3.2%	168	2.0%
	F	5	0.4%	7	0.3%	14	2.5%	21	1.0	49	2.7%	96	1.2%
Hispanic	M	35	2.6%	45	1.8%	11	1.9%	107	5.1%	88	4.9%	286	3.5%
	F	15	1.1%	8	0.3%	12	2.1%	17	0.8%	95	5.2%	147	1.8%
Native American	M	7	0.5%	8	0.3%	1	0.2%	19	0.9%	12	0.7%	47	0.6%
	F	1	0.1%	1	0.0%	4	0.7%	4	0.2%	19	1.0%	29	0.4%
Asian	M	36	2.6%	159	6.5%	8	1.4%	79	3.8%	30	1.7%	312	3.8%
	F	8	0.6%	45	1.8%	16	2.8%	17	0.8%	38	2.1%	124	1.5%
Total Minorities	M	98	7.2%	235	9.6%	30	5.3%	262	12.5%	188	10.4%	813	9.8%
	F	29	2.1%	61	2.5%	46	8.1%	59	2.8	201	11.1%	396	4.8%
Totals	**M**	**1135**	**83.2%**	**2108**	**86.3%**	**218**	**38.4%**	**1766**	**84.5%**	**843**	**46.5%**	**6070**	**73.3%**
	F	**230**	**16.8%**	**336**	**13.7%**	**349**	**61.6%**	**325**	**15.5%**	**971**	**53.5%**	**2211**	**26.7%**

Table 3.2-3. Population of Laboratory career employees as of March 31, 1995 (by number and percentage).

		Officials & Managers		Scientists & Engineers		Administrative		Technicians		All Others		Totals	
White	M	891	67.7%	1410	72.2%	181	27.2%	1135	67.9%	489	32.9%	4106	57.9%
	F	250	19.0%	261	13.4%	354	53.2	248	14.8%	609	40.9%	1722	24.3%
Black	M	33	2.5%	29	1.5%	11	1.7%	52	3.1%	57	3.8%	182	2.6%
	F	8	0.6%	12	0.6%	25	3.8%	19	1.1%	46	3.1%	110	1.6%
Hispanic	M	44	3.3%	37	1.9%	13	2.0%	94	5.6%	79	5.3%	267	3.8%
	F	22	1.7%	8	0.4%	30	4.5%	15	0.9%	103	6.9%	178	2.5%
Native American	M	14	1.1%	9	0.5%	3	0.5%	21	1.3%	13	0.9%	60	0.8%
	F	5	0.4%	0	0.0%	10	1.5%	7	0.4%	19	1.3%	41	0.6%
Asian	M	28	2.1%	148	7.6%	16	2.4%	61	3.7%	28	1.9%	281	4.0%
	F	21	1.6%	40	2.0%	22	3.3%	19	1.1%	45	3.0%	147	2.1%
Total Minorities	M	119	9.0%	223	11.4%	43	6.5%	228	13.6%	177	11.9%	790	11.1%
	F	56	4.3%	60	3.1	87	13.1%	60	3.6%	213	14.3%	476	6.7%
Totals	**M**	**1010**	**76.7%**	**1633**	**83.6%**	**224**	**33.7%**	**1363**	**81.6%**	**666**	**44.8%**	**4896**	**69.0%**
	F	**306**	**23.3%**	**321**	**16.4%**	**441**	**66.3%**	**308**	**18.4%**	**822**	**55.2%**	**2198**	**31.0%**

Table 3.2-4. Minority and women diversity statistics as of March 31, 1995 (by number and percent utilization).

Job group	Job title	Total LLNL representation	Women			Composite of Minorities		
			Population	Target population[a]	Utilization[b]	Population	Target population[a]	Utilization[b]
AA	Management Scientific	245	19	26	73.1%	12	28	42.9%
AB	Management Administrative	105	39	39	100.0%	16	16	100.0%
AC	Supervisor Technical	594	63	69	91.3%	75	70	107.1%
AD	Supervisor Clerical	161	149	137	108.8%	31	33	93.9%
AE	Supervisor Non-clerical	78	27	53	50.9%	19	13	146.2%
AF	Supervisor Blue Collar	84	2	4	50.0%	12	22	54.5%
AG	Supervisor Service	49	7	7	100.0%	10	17	58.8%
Total Officials & Managers		**1316**	**306**	**335**	**91.3%**	**175**	**199**	**87.9%**
BA	Administrator	613	412	351	117.4%	124	138	89.9%
BB	Physicist	535	39	59	66.1%	51	59	86.4%
BC	Chemist/Metallurgist	181	48	48	100.0%	26	37	70.3%
BD	Life Scientist	34	20	14	142.9%	7	7	100.0%
BE	Computer Scientist	417	127	123	103.3%	59	84	70.2%
BG	Engineer Mechanical	242	23	14	164.3%	46	39	117.9%
BH	Engineer Electronics	251	19	25	76.0%	36	45	80.0%
BJ	Engineer Miscellaneous	236	22	20	110.0%	52	44	118.2%
BK	Tech. Info. Editor	52	29	21	138.1%	6	5	120.0%
BZ	Environmental Scientist	58	23	10	230.0%	6	5	120.0%
Total Professionals		**2619**	**762**	**685**	**111.2%**	**413**	**463**	**89.2%**
Total Scientific Professionals[c]		**1954**	**321**	**313**	**102.6%**	**283**	**320**	**88.4%**
CA	Mechanical Technician	51	8	5	160.0%	11	12	91.7%
CB	Mechanical Tech. Specialist	257	15	33	45.5%	37	61	60.7%
CC	Electronics Technician	45	8	7	114.3%	12	14	85.7%
CD	Electronics Tech. Specialist	157	3	29	10.3%	25	57	43.9%
CE	Electronic Fabrication Technician	36	13	3	433.3%	9	10	90.0%
CI	Chemical Technician	69	15	15	100.0%	17	30	56.7%
CJ	Engineering & Science Technician	109	36	61	59.0%	17	39	43.6%
CL	Assistant Technical Coordinator	90	29	42	69.0%	15	17	88.2%
CM	Tech-Scientific Coordinator	83	6	26	23.1%	12	16	75.0%
CN	Technical Associate/Non-Engineering	157	44	56	78.6%	22	33	66.7%
CO	Drafter/Designer	133	15	54	27.8%	30	36	83.3%
CP	Technical Associate/Engineering	275	6	11	54.5%	23	36	63.9%
CQ	Computer Programming Technician	153	85	48	177.1%	42	41	102.4%
CS	Medical Technologist	5	4	4	100.0%	2	2	100.0%
CT	Technical Illustrator	51	21	18	116.7%	14	17	82.4%
Total Technicians		**1671**	**308**	**412**	**74.8%**	**288**	**421**	**68.4%**

[a] Target populations indicate what the Laboratory population mix would be if it reflected the ethnic and gender mixes of available job pool populations within a profession or skill category. The estimate is based on national, regional, and internal statistics depending on the geographic recruitment area and on OFCCP estimating procedures. For example, clerical employees are recruited locally and physicists nationally. Specific minority and women hiring goals are set annually and monitored quarterly for each job group.
[b] Utilization indicates the achieved percentage of the target.
[c] Includes B job groups, except BA and BK.

Table 3.2-4, continued. Minority and women diversity statistics as of March 31, 1995 (by number and percent utilization).

Job group	Job title	Total LLNL representation	Women			Composite of Minorities		
			Population	Target population[a]	Utilization[b]	Population	Target population[a]	Utilization[b]
DA	Administrative Support I	89	89	83	107.2%	30	26	115.4%
DB	Administrative Support II	516	516	501	103.0%	129	124	104.0%
DC	Resource Management Support	45	42	39	107.7%	12	12	100.0%
DD	Info./Computer Service Support	97	89	65	136.9%	3	34	91.2%
Total Office & Clerical		**747**	**736**	**688**	**107.0%**	**202**	**196**	**103.1%**
EA	Miscellaneous Crafts	164	4	7	57.1%	29	48	60.4%
EC	Maintenance Mechanic	44	0	2	0.0%	15	15	100.0%
EJ	Machinist	110	5	4	125.0%	16	38	42.1%
EK	Assembly Specialist	27	0	2	0.0%	5	3	166.7%
Total Crafts		**345**	**9**	**15**	**60.0%**	**65**	**104**	**62.5%**
FD	Printer	5	5	1	500.0%	0	2	0.0%
FF	Warehouse Worker	56	12	20	60.0%	15	21	71.4%
FG	Photographic Specialist	32	10	12	83.3%	12	9	133.3%
FH	Vehicle Driver	27	1	2	50.0%	9	9	100.0%
Total Operators		120	28	35	80.0%	36	41	87.8%
GA	Laborer Gardener	37	2	8	25.0%	9	15	60.0%
Total Laborers		**37**	**2**	**8**	**25.0%**	**9**	**15**	**60.0%**
HA	Firefighters	31	3	3	100.0%	9	8	112.5%
HB	Protective Service Officers	134	14	22	63.6%	42	57	73.7%
HC	Custodian	74	30	25	120.0%	27	35	77.1%
Total Services		**239**	**47**	**50**	**94.0%**	**78**	**100**	**78.0%**
Laboratory Total Population		**7094**	**2198**	**2228**	**98.7%**	**1266**	**1539**	**82.3%**

[a] Target populations indicate what the Laboratory population mix would be if it reflected the ethnic and gender mixes of available job pool populations within a profession or skill category. The estimate is based on national, regional, and internal statistics depending on the geographic recruitment area and on Office of Federal Contract Compliance Program (OFCCP) estimating procedures. For example, clerical employees are recruited locally and physicists nationally. Specific minority and women hiring goals are set annually and monitored quarterly for each job group.
[b] Utilization indicates the achieved percentage of the target.
[c] Includes B job groups, except BA and BK.

Environmental, Safety, and Health Management 3.3

LLNL environmental policy requires that all Laboratory operations be conducted in a manner that preserves the quality of the environment and complies with the letter and the spirit of all applicable governmental regulations and orders. Similarly, LLNL safety and health policy requires that all operations be conducted in a manner that is safe, healthful, environmentally sound, and consistent with all regulations and DOE orders. These operations are supported by staff with environmental, safety, and health (ES&H) expertise who reside primarily in LLNL's Environmental Protection, Hazards Control, and Health Services Departments, respectively.

Our goals and objectives are to

- Continue to reduce occupational exposure to ionizing radiation to levels as low as reasonably achievable.
- Continuously decrease exposure relative to our benchmark levels of regulated toxic chemicals and physical hazards.
- Develop waste-minimization plans and goals consistent with state and DOE performance goals.
- Ensure proactive compliance with applicable laws and regulations.
- Implement continuous quality improvement and quality assurance programs integrated with training and performance evaluations.
- Keep fire-loss rate and workday accident incidence rate below the DOE and industrial averages and on a downward trend.
- Implement site-wide environmental impact statement/environmental impact report (EIS/EIR) mitigation measures to manage and protect natural and cultural resources at Site 300.

In support of the DOE's compliance with the National Environmental Policy Act (NEPA), the Laboratory has made extensive use of information contained in its site-wide EIS and has worked with the DOE to ensure that Laboratory ES&H documents are suitable in format and content for incorporation either completely or by reference into DOE's NEPA documents. This has resulted in significant reductions in administrative effort and cost, for which the DOE has expressed appreciation.

Indirect costs for ES&H, paid through overhead, are shown in Table 3.3-1. These costs include Tiger Team and DOE order compliance self-assessment activities. Table 3.3-2 shows direct funding levels.

Current Conditions

Our laboratory is now subject to the Superfund Amendments and Reauthorization Act 313 Toxic Release Inventory Program, Federal Clean Air Act Title III and Title V permitting, requirements for offsetting air emissions, regulation of

Table 3.3-1. Indirect costs for environment, safety, and health per the *ES&H Management Plan* (in millions of dollars; personnel in FTEs).

	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001 and beyond
ES&H	50.0	49.1	49.2	50.0	48.7	49.8	51.3	53.9
FTEs	420	440	435	430	425	422	421	422

Table 3.3-2. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives (in millions of dollars), including capital funding.

	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001 and beyond
Waste Minimization	0.5	0.9	0.9	1.1	1.1	1.1	1.1	1.1
Environmental Restoration	28.6	26.0	25.5	21.2	16.5	16.5	16.5	16.5
Waste Management	35.7	35.5	33.8	35.0	32.6	27.2	26.4	21.3

storm-water discharges from industrial operations and construction activities, and increased scrutiny of radionuclide emissions. Other factors influencing Laboratory operations and environmental activities are

• The UC–DOE contract and related commitments that implement measures to mitigate potential environmental effects resulting from our operations.

• The changing world order, which has increased the need to provide environmental support for nuclear weapon dismantlement and the disposition of plutonium from the dismantled weapons.

Air Emission Standards

A change in the California Clean Air Act of 1987 required that geographical areas not meeting ambient air-emission standards implement strategies to reach these standards. Although the San Francisco Bay Area was declared an "attainment" area in 1995 due to improved air quality conditions, both the San Francisco Bay and San Joaquin Valley areas were nonattainment areas, and therefore the local air-quality management districts adopted rules to implement strategies for meeting the air-emission standards. The new rules became effective July 11, 1991.

These rules require that a new source of emissions or precursor organic compounds must be offset by a reduction in existing emissions to achieve a no-net increase. We have continually improved our emission-control practices and have been in compliance with the emission reduction and offset rules since the enactment of the 1987 Clean Air Act.

The San Francisco Bay Area and San Joaquin Valley air-quality management districts are implementing similar rules for oxides of nitrogen and sulfur and for particulate emissions. In addition, both air districts are implementing Federal Clean Air Title III and Title V permitting programs. Both programs have significant potential to affect our air-emission permitting and compliance efforts. We are monitoring developments and assessing possible options.

Our ideal tank-system model facilitated the design of this upgraded retention-tank system.

Storm Water Discharges

The Environmental Protection Agency issued a rule in October 1990 requiring National Pollutant Discharge Elimination System permits for storm-water discharges from industrial activities. In California, the State Water Resources Control Board adopted two general permits that will cover the majority of facilities. The regional water-quality control boards implement the general permits.

The Laboratory is currently covered under general permits for both the Livermore site and Site 300. Applications have been submitted for each site for permits specifically tailored to the operations at that site. These permits should authorize certain discharges of nonstormwater to the surface and storm drains that will have no environmental impact, such as irrigation water, emergency shower and eyewash test water, and air conditioner condensate. Nonpermitted discharges, identified in an earlier investigation, are being repaired or rerouted. LLNL's Stormwater Pollution Prevention Plans identify practices to assure that nonpermitted discharges are controlled and to assure the quality of stormwater runoff.

Oil Pollution Prevention

The Environmental Protection Agency Oil Pollution Prevention Regulation (40 CFR 112), promulgated under the Clean Water Act and amended by the Oil Pollution Act of 1990, establishes requirements for spill prevention, control, and countermeasure plans. We have issued plans for the Livermore and Site 300 facilities and are implementing line-item funded improvements.

Hazardous Waste Operations

In 1994, many facets of LLNL's hazardous waste management operations will participate in permit activities.

• The Resource Conservation and Recovery Act Main Site draft permit will be issued for public comment by

the California Department of Toxic Substances Control; the final permit will likely be issued in mid-1995.
• Permit applications for the Site 300 explosives waste storage and treatment facilities will be under active review by the California Department of Toxic Substances Control, and a draft permit for each may be issued for comment before the end of 1995. We expect the permit to be granted in 1995 or early 1996, at which time construction of the facilities will begin. Although current methods for heating explosive waste by burning are permitted, future regulations may require advanced handling and treatment technology and facilities.
• The Site 300 Building 883 storage facility permit renewal was initiated in 1994, and a Notice of Deficiency (NOD) was issued in 1995. We are responding to the NOD, and permit renewal should follow shortly.

We are also developing methods to remove one hazardous characteristic of low-level radioactive mixed waste through stabilizing one hazardous component. If this method is successful, we could then ship this waste to the Nevada Test Site for disposal as low-level waste.

Assessing the Impact of LLNL Operations

In August 1992, we completed the EIS/EIR for continued operation of LLNL and Sandia–California (DOE/EIS-0157; UC/EIR, SCH 90030847). This document assured the Regents of the University of California that potential environmental impacts of LLNL operations will be avoided or mitigated whenever feasible. These measures are outlined in the January 21, 1993, DOE Record of Decision on the EIS (58 FR 6268), the August 1992 UC Mitigation Monitoring and Reporting Program, and the October 1993 DOE Mitigation Action Plan for the continued operation of LLNL.

Mitigation measures and recommendations include
• Reporting cultural resources unearthed during excavation activities.
• Preparing a comprehensive cultural resource management plan.
• Conducting surveys for the San Joaquin kit fox, American badger, and burrowing owl before starting ground-disturbing projects at Site 300.
• Establishing marked protective exclusion zones around any known San Joaquin kit fox dens.
• Replacing wetland acreage lost because of utility improvements.
• Providing an annual report to the Regents of the University of California on the progress of implementing these mitigation measures.

LLNL is implementing the Mitigation Monitoring and Reporting Program and the Mitigation Action Plan requirements.

Radionuclide Emission Sources

In April 1991, the Environmental Protection Agency issued an order requiring LLNL to comply with 40 CFR Part 61, Subparts A and H (National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities). This order required the Laboratory to evaluate all potential sources of radionuclide emissions.

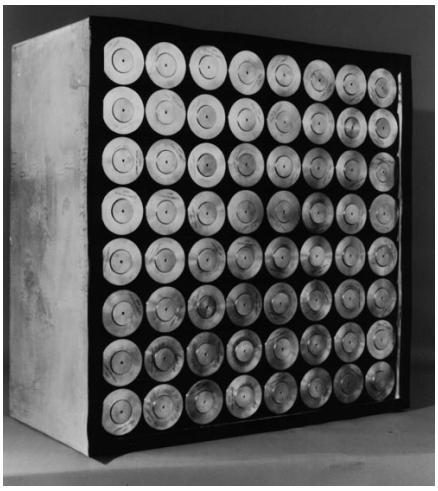
We evaluated potential sources and determined the Laboratory is in compliance with the radionuclide National Emissions Standards for Hazardous Air Pollutants. We instituted a system of inventory updates that streamlines the process of source term gathering. Based on a conservative model, as required by the Environmental Protection Agency, the 1994 effective dose equivalent to the hypothetical site-wide maximally exposed individuals are 0.65% and 0.81% of the 10 mrem/yr standard for the Livermore site and Site 300, respectively.

Regulatory Compliance

Environmental activities at the Laboratory focus on regulatory compliance and good management practices from the point of waste generation to waste disposal. Our Environmental Protection Department assists Laboratory programs and organizations in meeting these objectives.

The activities in the Environmental Protection Department are as follows. The Operations and Regulatory Affairs Division
• Provides Laboratory organizations with guidance and expertise regarding regulatory compliance.
• Assists programs in obtaining necessary permits.
• Prepares environmental documentation.
• Ensures that waste minimization is taken into account in program and project planning.
• Responds to environmental emergencies.

• Conducts environmental sampling to support construction activities.
• Oversees tank testing.
• Acts as the primary interface with regulatory agencies.
• Advises Laboratory management on environmental issues.
• Performs environmental monitoring to determine the impact of LLNL's operations and to assure compliance with permits and environmental standards.
• Performs dispersion and transport modeling to evaluate the risks of LLNL operations.
• Prepares LLNL's comprehensive Site Annual Environmental Report.
The Hazardous Waste Management Division provides/operates
• Services and support for the handling, storage, treatment, disposal, and minimization of hazardous wastes.
• Treatment and Storage Facility at the main site and a storage facility at Site 300 in accordance with state and federal requirements.



This prototype HEPA filter contains 64 cartridges of stainless-steel fiber media, making it more reliable and environmentally safe than previous paper filters. It can be cleaned in place, saving workers from exposure and eliminating the need for and cost of processing radioactive particulate waste.

Waste Minimization

The Laboratory has established and is implementing a waste-minimization program. During FY 1995 a Quarterly Waste Generation Report will be written in order to identify and increase awareness of the waste sources. As a follow-up, cost estimates for waste management will be made, and methods will be proposed for generating funding through taxes or recharges levied on programs. However, the current Congressionally mandated fencing of waste management funds impedes development of cost-based incentives for waste management.

Waste-minimization program activities include working with Laboratory programs to evaluate waste-generating processes, to identify and prioritize pollution-prevention measures, and to provide guidance in their implementation. During the past five years, we have decreased our waste streams by more than a factor of 2 and increased our salvage and recycle products by a factor of about 10.

Chemical Tracking

LLNL's a computerized chemical inventory system, ChemTrack, greatly enhances the Laboratory's ability to track chemicals and improve its chemical management practices. This system uses a barcode scanner and customized software to enter and track chemical inventory information; it is uniquely designed to provide portability and local control over chemical inventories. ChemTrack provides chemical inventory data for emergency planning purposes and for preparing chemical inventory reports for regulatory agencies. ChemTrack expands our ability to identify and exchange excess chemicals internally, thereby reducing the need to procure and store additional chemicals and minimizing the generation and disposal of hazardous waste.

Waste Certification Program

The Waste Certification Program is developing the necessary documents and characterization systems to allow the shipment of low-level radioactive waste to the Nevada Test Site and transuranic waste to the Waste Isolation Pilot Plant in New Mexico.

LLNL currently has 18 low-level radioactive waste streams certified and approved for disposal at the Nevada Test Site. An additional five waste streams are conditionally approved, waiting for review of analytical data. We will continue this process until all newly generated radioactive waste is certified for disposal at a DOE or commercial disposal facility.

In addition, LLNL is using its waste certification and waste management expertise to assist the DOE in managing waste generated from the shutdown of other DOE facilities.

Corrective Actions

Corrective actions include a variety of activities that help ensure

compliance with federal, state, and local regulations. Activities in the five-year plan include obtaining tank permits, upgrading wastewater and petroleum underground tanks and aboveground petroleum tanks, installing secondary containment for transformers whose capacity exceeds 660 gallons on those deemed necessary through risk analysis, rehabilitating and reconstructing sewer laterals, and correcting nonstandard building sewer lines.

We continue to upgrade our on-line sewer monitoring system. This system has enabled us to identify and eliminate inappropriately sewered waste sources.

Environmental Training

The training section of Livermore's Environmental Protection Department is primarily responsible for providing all environment-related training and education at the Laboratory. This responsibility includes three major activities:

- Providing environmental and waste management training as required by federal and state laws, DOE orders, and operational agreements.
- Providing environmental and waste management training and education to increase regulatory knowledge and environmental management capabilities.
- Assisting LLNL programs and the DOE with environmental training and training policies, plus technology transfers to foreign countries.

Environmental and Waste Management Training

Training in this area addresses the Resource Conservation and Recovery Act (RCRA), the Superfund Amendments and Reauthorization Act, the Occupational Safety and Health Act, the Department of Transportation requirements, radioactive waste certification, and state-certified waste management apprenticing.

Resource Conservation and Recovery Act Training

We have trained approximately 2,000 Laboratory employees in the proper characterization and management of hazardous wastes. This training includes four to eight hours of classroom instruction as well as on-the-job training.

The Laboratory received funding from DOE's Assistant Secretary for Defense Programs to develop RCRA Hazardous Waste Management Training Guidance and associated training to be used throughout the DOE complex. The RCRA Hazardous Waste Management Guidance has been completed, and training is under development. After the our RCRA Hazardous Waste Management Training Program was reviewed by DOE, it was cited as one of the most comprehensive and well-run programs in the complex.

Superfund Amendments and Reauthorization Act / Occupational Safety and Health Act Training

All personnel performing site remediation or managing hazardous waste in permitted waste-management units receive health and safety training. We work with the University of California to provide training for approximately 300 personnel on site.

Department of Transportation Training

Personnel involved with the shipment of hazardous materials are required to take Department of Transportation training. We provided classroom and on-the-job training for approximately 75 personnel, which took about 40 hours for each person to complete.

Radioactive Waste Certification Program

Approximately 225 waste-generator and support personnel were trained in the requirements for the certification of low-level radioactive waste. As a result of this effort, the Laboratory has been able to ship low-level radioactive waste to the Nevada Test Site.

Waste Management Apprenticeship Program

This two-year, state-certified apprenticeship program leads to journey-level status as a hazardous waste-management technician. The program consists of almost 600 hours of classroom and on-the-job training and approximately 1,400 hours of on-the-job experience.

Environmental and Waste Management Education

The Laboratory offers three courses—Air Source Management, National Environmental Policy Act Compliance, and Spill Prevention Control and Countermeasures—to

assist personnel with environmental management. These courses provide regulatory and policy guidance for compliance with the Clean Air Act, the National Environmental Policy Act, and the management of petroleum products.

We collaborated with the University of California to provide courses for environmental professionals on advanced topics, such as environmental laws and regulations, environmental auditing, and underground storage tank management.

We also sponsored the broadcasting of two courses, one on pollution prevention and one on decommissioning, which were provided by the University of New Mexico in conjunction with the Waste Management Education and Research Consortium.

We received funding from DOE's Assistant Secretary for Defense Programs to assist in training for low-level-waste certification for a production-related facility in Michigan. We provided certification procedures and training for low-level waste generated as part of a facility decontamination effort.

Safety and Health

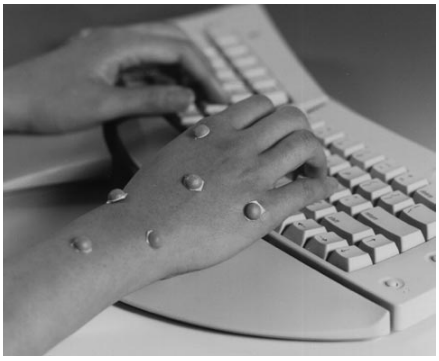
Our safety and health efforts address the industrial, chemical, radiological, and biological hazards posed by Laboratory activities. We also address issues involving workplace-related injuries and illnesses, including repetitive motion injuries. In addition, the Laboratory has a number of employee wellness programs.

Industrial Hygiene

LLNL operates DOE's Industrial Hygiene Technical Center of Excellence for Assessment of Biological and Chemical Hazards. This center is intended to focus the technical resources necessary for DOE to implement and maintain an expanded worker exposure assessment program.

Case Management

Health Services, in collaboration with Risk Management and Applied Risk Management, provides an on-site case management program for employees who become ill or injured as a result of workplace activities. Early return to work of ill or injured employees has resulted in a decrease of lost and restricted work days, from 5,601 in 1992 to 3,131 in 1994.



Ergonomics research is conducted is a joint project of LLNL's Health Services and Hazards Control and consultants from UC San Francisco. Here, buttons attached to the operators hand allow a video camera to record hand and wrist motion for analysis of keyboard design variations intended to minimize repetitive motion injuries.

Ergonomics Program

The Ergonomics Program is a joint effort of the Health Services and Hazards Control departments, Laboratory programs, and consultants from University of California at San Francisco. This program emphasizes ergonomic awareness for Laboratory employees as well as prevention of and early intervention to correct repetitive motion injuries and other health problems related to the work routine.

Employee Assistance and Other Health Programs

We are continuing to increase the visibility, and therefore the utilization, of the Laboratory's Employee Assistance Program (EAP), Alcohol Substance Abuse Prevention Program (ASAP), and Recovery Assistance Program (RAP). The EAP brochure was updated this year, and ASAP training was provided to all Laboratory managers and supervisors. Annual employee health events include the "Health Fair" and "To Your Health Month." We have added a series of monthly noontime health lectures for employees and their families. The Laboratory also observes the national "Red Ribbon Week" to support drug-use prevention. The 24-hour Helpline continues to supplement the EAP's on-site services.

Health Promotion

The newly formed Health Services Wellness Partnership Program provides custom wellness packages for groups of Livermore employees. A multidisciplinary team coordinates projects with the Livermore recreation association and Human Resources.

Management Practices 3.4

Audit and Oversight

The Audit & Oversight Department reports to the Director and has primary responsibility for maintaining an internal audit program consistent with contractual requirements and professional standards and for coordinating, tracking, and preparing the official response to external audit activities. We consult with and perform special studies for senior management on policy and procedural issues relating to internal controls. We facilitate external reviews; report on fraud, waste, or misuse of government assets; provide guidance for the University of California/Department of Energy contract Self-Assessment evaluation process; and facilitate the Director's Annual Assurance Letter to the DOE. We function as a management resource to the Laboratory in policy and procedure matters.

Contract Administration

Contract Administration at Livermore focuses on the prime contract between DOE and UC (for Livermore). This contract is the defining legal document governing the roles and responsibilities between the University of California and the Department of Energy.

In 1992, this contract relationship entered a new era with the signing and implementation of a "performance-based contract." The new contract, for the first time, included specific measurable performance requirements designed to promote and encourage continuous quality improvements.

The performance measures show we have made positive improvements in both administrative and scientific areas. At the end of the FY 1994 evaluation period, the DOE/OAK rated our overall performance in both areas as "excellent" or "exceeds expectations."

The Laboratory and the UC are committed to strengthening the working partnership with DOE and to continuing to improve the performance-based contract administration and management approach. This proactive, innovative approach has placed UC and Livermore in a leadership role within the DOE community.

Budget, Finance, and Resource Information and Analysis

Reporting to the Laboratory Controller, who serves as the Laboratory's financial advisor, the Budget Office and Finance Department provide sound financial management in support of Laboratory programs.

The Budget Office provides resource information and services to support the Controller and contributes to Laboratory missions, management decisions, and the promotion of good business practices. The Budget Office and Finance Department interpret, analyze, and implement DOE and Laboratory resource management policies and guidelines. They help ensure compliance with the DOE and University of California through close working relationships with LLNL programs and departments and by providing formal training for all Laboratory personnel who have financial management responsibilities. The Budget Office and Resource Information and Analysis group have automated many of their activities, including the annual DOE Field Budget Submission and internal program planning, to provide more efficient and effective budget information processing.

The Finance Department's responsibilities include

- Assuring the integrity and accountability of operations.
- Offering financial advice about the UC–DOE contract.
- Administering Laboratory disbursements, collections, and financial reporting.
- Ensuring that Laboratory financial operations are conducted according to generally accepted accounting practices, cost accounting standards, and sound business practices.

Reviews by the DOE—including the Contractor Business Systems Review, the Oakland Operations Office performance appraisals, and the DOE Headquarters Controller's Compliance Review—have given high ratings to the department's operations, which validate the integrity of its systems. Extensive

audits by the DOE, University of California, and other audit agencies have found no materials weaknesses, significant findings, or significant unallowable costs.

The Controller's staff makes changes to meet Laboratory business management needs. Many modern business systems are in place to ensure accurate and timely financial information, and work continues on additional applications, including

- Institutional project management system for on-line budget execution plans.
- Project accounting capability, which will be the core of a fully integrated business management system.
- Payroll/human resources.
- Revenue management system.
- DOE management analysis and reporting system/government standard general ledger.
- Electronic invoicing through electronic data interchange and electronic commerce.
- Document imaging.
- Global funding database.
- Uncosted obligations balance projections.

Procurement and Contracting

The Business Operations organization supports all Laboratory programs and departments by procuring, supplying, and distributing materials and services. Through acquisition planning, we obtain and analyze data on anticipated procurements, involve appropriate procurement staff, and execute and document our specific planning activities so that we can respond to the demands of our customers and stakeholders. We are committed to a customer-oriented process to ensure continuous quality improvement. In some of our recent accomplishments, we

- Established an efficient and effective milestone-driven closeout tracking system.
- Implemented a comprehensive procurement-related training program.
- Implemented a self-assessment program to review compliance with documented procedures.
- Participated with the three UC laboratories to develop a Laboratory Procurement Policy and Standard Practices Manual.
- Received for FY 1994 an "exceeds expectations" rating from both the DOE and UC for the procurement self-assessment in the performance measures of the UC–DOE contract.
- Received an "Approved" outcome for 1995 Contractor Personal Property System Review conducted by DOE Headquarters.
- Received an "Approved" outcome of 1995 Contractor Purchasing System Review conducted by DOE Headquarters; LLNL purchasing authority was increased to $25 M without DOE review and approval.

In the next few years, our goals are to

- Develop and implement a decentralized procurement system for low-value purchases. The goal is to eliminate non-value-added activity and thus reduce procurement costs and acquisition cycle time.
- Improve the efficiency and effectiveness of the purchasing process by adopting, where possible, the best practices of commercial organizations consistent with the objectives of the National Performance Review and the Secretary of Energy's Contract Reform Team Report.
- Establish integrated, flexible teams with the capability to provide a broad range of service for programs that require a significant subcontracting effort.

Affirmative Action in Subcontracting and Procurement

In accordance with Contract 48, the DOE, the University of California, and the Laboratory jointly determine annual socioeconomic goals for the dollar value of subcontracts as a management-performance measure. These goals have called for the Laboratory to continually increase procurement and contracting activities related to small businesses, small disadvantaged businesses and small women-owned businesses. For the past two fiscal years (FY 1993 and FY 1994), the Laboratory has exceeded its goals in all areas.

The Business Affirmative Action Office of the Procurement Department works closely with Laboratory programs and Plant Engineering on larger and/or more technical

procurements. This office is also increasing its involvement with contracting and procurement groups in setting affirmative action goals in these areas. See Table 3.4.-1.

In the next few years, our goals are to

• Diligently pursue our socioeconomic goals and satisfy the respective performance measures.
• Make the socioeconomic efforts an integral and routine part of Laboratory procurement activities.
• Establish LLNL, through continuous performance, as a leader among its peers in providing procurement opportunities to small businesses (including small disadvantaged and small women-owned businesses).

Property Management

Property at LLNL is owned by the U. S. Government, and we, as a contractor, are accountable to the government for that property. The Property Management Division, in partnership with Laboratory programs and departments, is responsible for maintaining an effective property management system. Property is managed by assigning employee responsibility and accountability when the property is first acquired and then maintaining a trail of accountability at each step in its life cycle. We adopted a graded approach to property management in which high-value and high-risk property is subject to more stringent controls than low-value and low-risk property. Through rigorous inventory control of 20% of the items (all capital and attractive), we efficiently manage 80% of our billion-dollar investment in personal property. The remaining low-value and low-risk items are managed using less-expensive administrative and physical controls.

When a property item is no longer needed, it is made available to other programs here or at the DOE through the excess process. If a property item is not needed elsewhere at LLNL or the DOE, it is made available for reissue to other government agencies and programs, or for sale to the general public. As a result of recent legislation, the property item can also be made available for donation to schools and nonprofit organizations involved in science education.

The Laboratory has made particular efforts in recent years to improve property management functions, and these efforts are succeeding. Our recent accomplishments include the following:

• In 1994, we successfully inventoried 100% of capital and attractive equipment at the Livermore site, Site 300, and the Nevada Test Site as well as equipment at employee residences and other off-site locations. We accounted for 99.8% (dollar value) of attractive property and 99.6% (dollar value) of capital property.
• For the second year, we received an "exceeds expectations" rating from both the DOE and the University of California for the property management self-assessment performed in response to the performance measures in the UC–DOE contract.
• We achieved a positive outcome to the Contractor Personal Property System Review conducted by DOE Headquarters.
• Our Property Information System (PRISM) automated database was recognized as "best in class" by DOE; it is now available to other DOE facilities.

In the next few years, our goals are to

• Maintain the current high level of accountability for LLNL property but reduce the impact of the property management system on the programs by developing more cost-effective ways to achieve the same results.
• Continue to work with DOE to develop an oversight approach based on program performance as opposed to one based solely on compliance with regulations and individual transactions.

Safeguards and Security

The Safeguards and Security Department provides guidance and expertise to support the Laboratory's mission. We create and maintain a secure environment that protects personnel, information, property, and nuclear material, and complies with laws, policies, and procedures in a cost-effective manner.

We are changing from strict DOE order compliance to a cost–risk security program. A strategic security-planning initiative, known as Saving Money and Resources Through Technology, has enabled us to

successfully reduce the cost of administering security by applying technological means to meet security objectives whenever possible.

In addition, we implemented graded electronic-access control systems and introduced the vouching concept for access to Controlled and Limited Areas. Vouching allows a vehicle driver who has an authorized badge for the area being entered to confirm to security officers at staffed security posts that all passengers within the driver's vehicle are also authorized badge holders.

To increase the area designated for unclassified activities, the Classified Core Contraction Plan minimizes the number of physical barriers by moving security fence lines and using building walls for Classified Area perimeters. Physical security surveys of all facilities within the Limited Area core are underway to estimate the cost to complete the contraction in the next four to five years.

We will develop a management structure and the tools necessary to efficiently integrate Safeguards and Security's daily operational activities with UC contract performance measures, while accommodating the changing missions and needs of the Laboratory.

Electronic Data Interchange

The need for Electronic Data Interchange (EDI) became apparent when President Clinton noted in a memorandum published on October 26, 1993, that strongly encourages moving to an electronic commerce system to simplify and streamline the acquisition process. The Laboratory has successfully demonstrated a pilot EDI gateway to a large electronic supplier.

We will use electronic commerce, where possible, in lieu of paper-driven, wage-intensive processes to improve communications with our primary vendors, reduce acquisition cycle times, and significantly reduce costs associated with acquiring a wide variety of commercially available commodities.

Travel Service

The need for improvements to travel services was identified in February 1994. This project was a response to concerns about the quality of service, efficiency issues, customer dissatisfaction, and convoluted policies and procedures. In addition, the project was designed so the Laboratory would have flexibility to take advantage of the dynamic changes in the travel industry.

A working group—with representatives from each directorate, Travel Services, and Finance—designed the travel model. Representatives from the travel organizations at LBNL and LANL also participated. The group held a series of workshops to formalize service requirements and establish deliverables; benchmarked travel practices at Sandia, Hewlett Packard, LANL, LBNL, Grumman, Hazeltine, and General Services Administration; consulted industry experts; and reviewed available technology. Early in the process, the group decided to contract out the travel reservation function to an outside agency no later than December 1995.

The following were established as project deliverables:

- A business model that defines roles and responsibilities for the Laboratory travel organization, directorates, travelers, and the travel vendor.
- Simplified travel policies and procedures that are consistent with UC travel reimbursement policies.
- Initiatives to build awareness and contain travel costs.
- Outsourcing of travel reservation function by December 1995.
- A communication strategy for the new policy.
- A training program for LLNL personnel.

Site and Facilities 3.5

LLNL comprises two sites: the main Livermore site, on the eastern border of the City of Livermore, and Site 300, a 28-km^2 remote explosives test facility located about 25 km southeast of Livermore (operated by LLNL since 1955). The replacement plant value, including both the main Livermore site and Site 300, is estimated to be $3.2 billion, which does not include some $2.4 billion in personal property and land value (see Table 3.5-1).

The Livermore Site

The main LLNL site is located on 332 hectares (about one mile square) approximately 80 km southeast of San Francisco. In January 1995, the Laboratory population numbered 10,089, including 268 at off-site leased facilities and 244 at Site 300. The Livermore site has 173 permanent and 331 temporary structures, housing a population of 9610 in a total (gross) of 532,000 m^2 of offices, laboratories, and support facilities (see Tables 3.5-2 and 3.5-3). Figures 3.5-1, 3.5-2, and 3.5-3 illustrate the condition of existing facilities in total, by age and by use. Approximately 41% of the facilities are rated substandard, yet these structures house more than one-half of the LLNL population. Substandard facilities include all temporary structures and those facilities possessing extensive maintenance deficiencies.

The physical development of the Livermore site has evolved greatly in the 50 years since it was a naval air station. In the Laboratory's early years, development was concentrated in the site's southwest quadrant. In the late 1960s, a system of loop roads was constructed, and development spread to the central area of the site. Major growth occurred, together with the construction of new facilities, mainly in the north and central areas in the 1970s and 1980s. Upgrades to the site infrastructure have been ongoing since 1988.

Site 300

At Site 300, there are 66 permanent buildings and 10 temporary structures, for a total (gross) of 32,227 m^2 of facilities. The site consists of two remote firing areas, supported by a chemistry and mechanical processing area, and an administrative complex at the main entrance. The general condition of the Site 300 facilities is good except for some overcrowded, undersized, and ill-equipped facilities in the administrative complex. Three buildings have been identified for seismic upgrading because a fault zone was discovered close to the main gate. A poor traffic circulation system remains as the most significant infrastructure problem. Revitalization

Table 3.5-1. Replacement value of facilities (in billions of dollars).

Facility type	Replacement value[a]
Buildings and structures	2.3
Utilities	0.9
Total[b]	**3.2**

[a] Cost in today's dollars for in-kind replacement.
[b] The additional value of installed equipment brings the total replacement value to about $5 billion.

Table 3.5-2. Space, facilities, and population figures.

	Main Site	Site 300	Off-Site Lease
Gross square meters	532,045	32,228	13,955
Net square meters	354,072	24,026	11,039
Number of permanent buildings	173	66	8
Number of trailers	239 (1075 units)	7 (21 units)	1 (7 units)
Number of modulars	77	3	0
Number of utility facilities	33	22	0
Number of WWII buildings	15	0	0
LLNL population	8114	228	60
Other population	1293	16	208
DOE and other federal employees	140	0	0
DOE support contractors	30	0	0

Table 3.5-3. Facilities owned/leased (in gross square meters).

Livermore Main Site	
Owned	529,072
Leased	2,973
Total	**532,045**
Site 300	
Owned	32,228
Leased	0
Total	**32,228**
Off-site	
Owned	0
Leased	13,955
Total	**13,955**

projects to correct facility and infrastructure deficiencies are in progress, as is a groundwater cleanup project. To date we have completed the traffic safety improvements to the main site entry, the widening and better alignment of Do-All Road, and the grade decrease and truck escape ramp for Route 3.

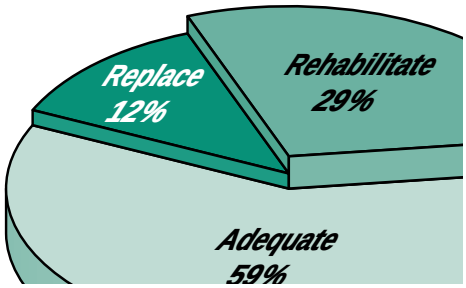


Figure 3.5-1. The condition of building structures.

Site 300 contains several sites of historical or ecological significance. The Laboratory's archeologist oversees their management, which includes working with the DOE to review the requirements of the federal Historical Preservation Act, interacting with the California State Historic Preservation Officer, and developing a cultural resources management plan. In addition, opportunities for university research in the fields of biology, zoology, ecology, archeology, and geology are being explored.

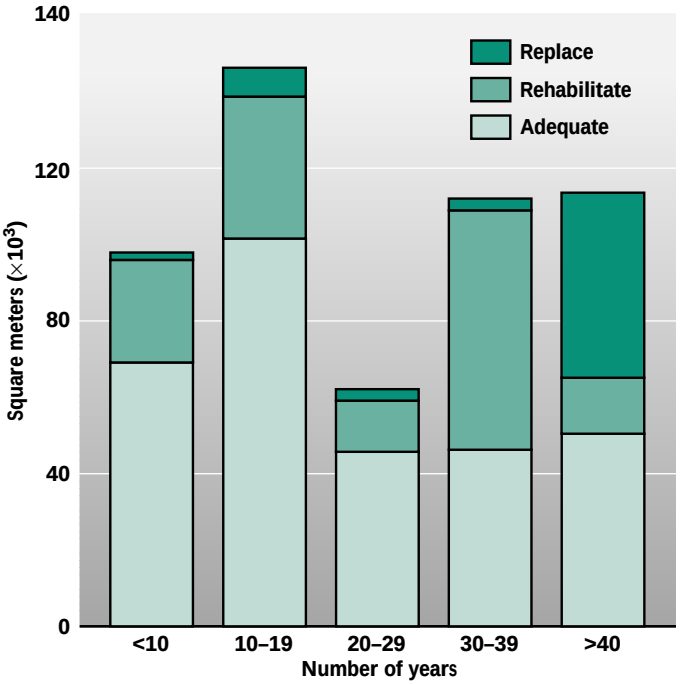


Figure 3.5-2. The age distribution of buildings.

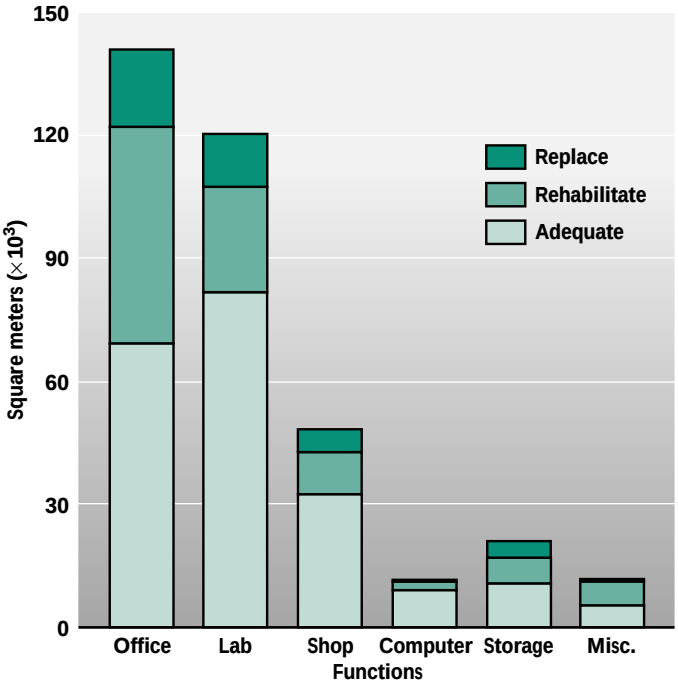


Figure 3.5-3. The appropriateness of facilities for their current uses.

Facilities Maintenance

The Laboratory's maintenance management program has four major objectives:

• Provide a physically safe environment.
• Maintain and operate the facilities, infrastructure, and utilities in a manner that enhances R&D and supports the Laboratory's mission while observing appropriate ES&H guidelines and rules.
• Optimize the effectiveness of the preventive maintenance program, operations, inspection, and quality control.
• Maximize and, if possible, extend the life cycle of facilities, infrastructure, and utilities.

Plant Engineering uses a combination of operating funds and capital investment to achieve these objectives. Additionally, Plant Engineering has implemented a program in continuous quality improvement to reach these objectives.

The Maintenance and Operations Department participates in several benchmarking groups to track various maintenance indices, including work control, maintenance work ratios, and maintenance cost ratios. The maintenance management program is subject to periodic reviews of current business practices and procedures, ES&H compliance actions, and compliance with regulatory requirements.

Facilities Plans and Options

A variety of planning issues are being explored in an effort to strengthen the stewardship of DOE lands and facilities. Primary planning considerations at LLNL include economic impact, ecosystem management, site accessibility, lease arrangements, facilities management, and redevelopment. Efforts are being pursued to ensure public stakeholder participation in the planning process. For example, under development is a process for the generation and review of a comprehensive land-use and facility plan for the Laboratory. It involves community members, elected officials, and planning and engineering experts from local jurisdictions.

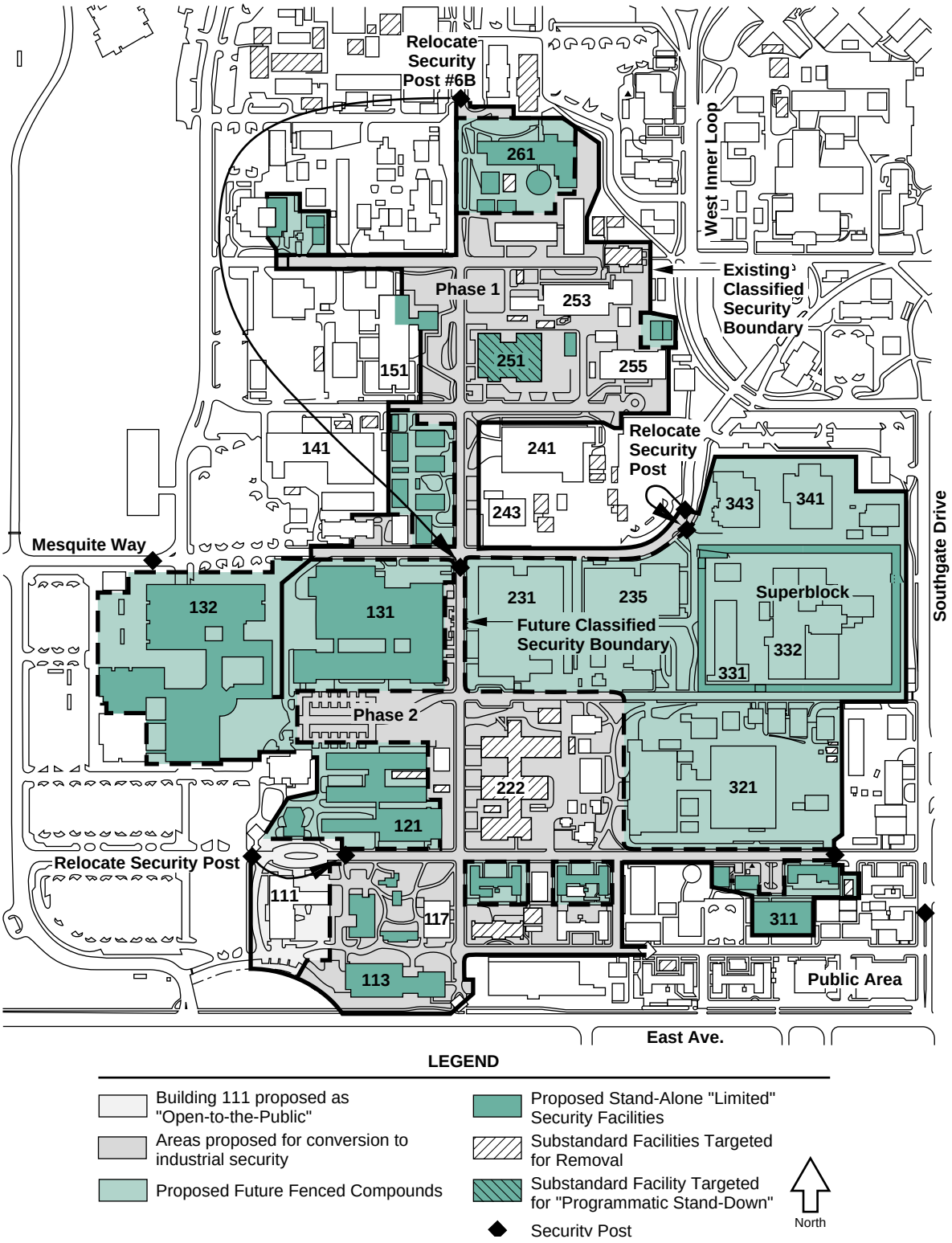
LLNL's Mike Holda (left) received a DOE Individual Achievement Award from Bill White, Deputy Secretary of Energy, for his contributions to energy efficiency.

The continuing long-range planning process at LLNL is coordinated through the Site Planning–Capital Assets Management (SP–CAM) Working Group. The annual Capital Assets Management Process (CAMP) document describes the Laboratory's assets and facility requirements for the next 20 years. The Site Development Plan (SDP) updates trends and land-use options in response to CAMP's projections and is supported by the comprehensive Technical Site Information (TSI) document.

Site development goals have been set to direct the planning effort. These goals and the basis for them can be found in the SDP. Additionally, the SDP outlines future land-use plans for both the Livermore site and Site 300, and presents implementation strategies for striving toward the stated goals.

Workforce migrations are significant in shaping the future of the site. Due primarily to the nominal amount of new facility construction that is anticipated, current planning relies heavily on personnel migrations from substandard to adequate facilities as space becomes available. Personnel migrations are carefully determined by functional compatibility and consistency with the security recommendations in the Classified Core Contraction Plan (Figure 3.5-4). Once a migration is completed, the substandard facilities may be demolished. The vacated sites then become prime candidates for future development or site improvements.

Figure 3.5-4. Classified Core Contraction Plan.



Completion of the Weapons Program's Nuclear Test Technology Complex and the Defense Program Research Facility (both housed in Building 132) is providing an exciting opportunity to dispose of temporary and substandard facilities. To assist in this effort, a Facility Assessment and Ranking System (FAaRS) has been developed to allow LLNL planners to identify and rank substandard facilities. FAaRS is coordinated with CAMP; the ranking results help justify facility removal, mothballing, continued maintenance, and renewal investment proposals. Facility decisions are coordinated with land-use planning to shape the direction of the physical site.

Additional analyses are being conducted to determine the best secondary and tertiary moves into the vacated spaces. Ensuing decisions will be aided immeasurably by continued application of the FAaRS and consistent pursuit of the site development goals.

Facilities Resource Requirements

The following construction project summaries represent proposed facilities for FY 1996 through 1998. The fiscal year shown represents the date construction begins. Tables 3.5-4 and 3.5-5 present the requirements for funded and proposed construction, respectively. Summarized descriptions for projects scheduled for FY 1999 and beyond are not included here but can be found in LLNL's FY 1997 *Capital Assets Management Process Report* (UCRL-AR-110100-95). A prioritization system is being used to determine which facilities will be requested in light of declining budgets. Overseen by the Deputy Director of Operations, planners and facility managers work together to prioritize and resolve facility issues within each program area and across organizational lines. Additionally, FAaRS is being used to identify facilities that may be vacated and "mothballed" in an effort to reduce maintenance and repair expenses.

Assistant Secretary for Defense Programs

FY 1996

National Ignition Facility ($842.6 million)

The National Ignition Facility (NIF) is a critical component of the national Stockpile Stewardship Program. This facility will satisfy the following missions of the Inertial Confinement Fusion Program by

- Making it possible to access experimentally some of the physics regimes relevant to nuclear weapon physics.
- Providing an aboveground simulation capability for nuclear weapon effects on strategic, tactical, and space assets (including sensors and command-and-control instrumentation).
- Providing essential data for developing inertial fusion energy for civilian power production.
- Providing basic experimental capability in thermonuclear physics for sciences such as astrophysics.

These applications require a facility in which thermonuclear ignition and fusion burn are achieved.

Site 300 Contained Firing Facility ($49.7 million)

This facility will occupy approximately 2,700 m^2, consisting of four related areas for increasing the safety and environmental compliance of testing explosive charges (up to 60 kg). This project will build on the existing Building 801 bunker by adding a reinforced firing chamber, a support facility, and a diagnostic equipment facility.

FY 1997

Protection of Real Property—Roof Replacement ($33.3 million)

In this project, the roofs of 17 buildings will be replaced. Each roof in this project has severe problems, including membrane failure and possible structural damage. The deterioration is such that repairs will neither stop leaks nor be cost-effective. The project is planned in four phases: Phase I in FY 1997 at $7.8 million; Phase II in FY 1998 at $8.9 million; Phase III in FY 1999 at $8.3 million; and Phase IV in FY 2000 at $8.3 million.

ICF Advanced Optical Technology Facility ($5.2 million)

The ICF Program has an ongoing research and development effort to develop high-damage fluence KDP and KD*P crystals and optical coating for future lasers. In order to continue these important efforts, thermal and vibrationally stable laboratory space is required for optical processing, finishing, optical measurements, and inspections; and high-bay clean room areas are required for handling and

(Continued on page 143)

Table 3.5-4. Funded construction (in millions of dollars).

Sponsor	Type of Facility[a]	Total Estimated Cost[b]	Prior Years Total	FY 1994 BO	FY 1995 BA	FY 1996 BA	FY 1997 BA	FY 1998 BA[c]	FY 1999 BA[c]	FY 2000 BA[c]	FY 2001 BA[c,d]
Defense Programs											
GB-01 Stockpile Stewardship											
Site 300 Contained Firing Facilities	PR	49.7	0.0	0.0	0.0	6.6	17.1	19.3	6.7	0.0	0.0
Defense Programs Research Facility	PR	72.7	47.3	19.9	4.0	1.5	0.0	0.0	0.0	0.0	0.0
Site 300 Facilities Revitalization – Part 1	PR	27.4	17.8	3.4	0.9	3.7	1.6	0.0	0.0	0.0	0.0
Electrical Power System Upgrade	GPF	31.0	22.8	5.4	0.0	2.8	0.0	0.0	0.0	0.0	0.0
Fiber Optics Communication	GPF	1.8	1.1	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Infrastructure Modernization	GPF	10.9	10.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atmospheric Emergency Response Facility	PR	11.3	4.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GB-01 Total		**204.8**	**103.3**	**36.6**	**4.9**	**14.6**	**19.4**	**19.3**	**6.7**	**0.0**	**0.0**
Total Defense Programs		**204.8**	**103.3**	**36.6**	**4.9**	**14.6**	**19.4**	**19.3**	**6.7**	**0.0**	**0.0**
Energy Research											
KA-00 High Energy Physics											
B-Factory	PR	16.8	2.5	0.0	9.3	4.0	1.0	0.0	0.0	0.0	0.0
KA Total		**16.8**	**2.5**	**0.0**	**9.3**	**4.0**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total Energy Research		**16.8**	**2.5**	**0.0**	**9.3**	**4.0**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**
Environmental Restoration and Waste Management											
EW-11 Corrective Activities											
Sanitary Sewer System Upgrades	GPF	7.1	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tank Upgrades Project	GPF	18.5	13.6	3.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0
EW-11 Total		**25.6**	**20.7**	**3.9**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EW-31 Waste Management											
Decontamination/Waste Treatment Facility	GPF	68.1	18.8	2.3	5.0	8.9	11.0	11.1	5.9	5.1	0.0
EW-31 Total		**68.1**	**18.8**	**2.3**	**5.0**	**8.9**	**11.0**	**11.1**	**5.9**	**5.1**	**0.0**
Total Environmental Restoration and Waste Management		**93.7**	**39.5**	**6.2**	**6.0**	**8.9**	**11.0**	**11.1**	**5.9**	**5.1**	**0.0**
Field Management											
WB In-House Energy Management											
Energy Conservation Retrofits	GPF	23.4	15.0	5.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0
WB Total		**23.4**	**15.0**	**5.4**	**3.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total Field Management		**23.4**	**15.0**	**5.4**	**3.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total Funded Projects		**338.7**	**160.3**	**48.2**	**23.2**	**27.5**	**31.4**	**30.4**	**12.6**	**5.1**	**0.0**

[a] PR = program related; GPF = general purpose facility/utility.
[b] Includes escalation incorporated at various rates.
[c] FY 1998–2001 in constant FY 1997 dollars.
[d] BA includes projected construction beyond FY 2001.

Table 3.5-5. Proposed construction (requirement case; in millions of dollars).

Sponsor	Type of Facility[a]	Total Estimated Cost[b]	FY 1994 BO	FY 1995 BA	FY 1996 BA	FY 1997 BA	FY 1998 BA	FY 1999 BA	FY 2000 BA	FY 2001 BA[c]
Defense Program										
GB-01 Stockpile Stewardship										
Protection of Real Property (roofs) Phase 1	GPF	7.8	0.0	0.0	0.0	3.0	4.8	0.0	0.0	0.0
Advanced Optical Technology Facility	PR	5.2	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0
Site 300 Fire Station and Medical Facility	GPF	5.2	0.0	0.0	0.0	0.9	4.3	0.0	0.0	0.0
Sanitary Sewer System Rehabilitation Phase 2	GPF	4.6	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0
B-151 Plant and Seismic Upgrade	PR	11.5	0.0	0.0	0.0	0.0	2.9	7.0	1.6	0.0
Chlorofluorocarbons (CFC) Chiller Conversion	GPF	9.3	0.0	0.0	0.0	0.0	3.0	3.1	3.2	0.0
Road Reconstruction	GPF	7.8	0.0	0.0	0.0	0.0	1.4	5.3	1.1	0.0
NW LCW Station	GPF	6.5	0.0	0.0	0.0	0.0	2.1	4.4	0.0	0.0
Protection of Real Property (roofs) Phase 2	GPF	8.9	0.0	0.0	0.0	0.0	4.0	4.9	0.0	0.0
Building Renovation Project	GPF	20.0	0.0	0.0	0.0	0.0	4.0	4.0	4.0	8.0
Public Affairs Center	GPF	6.2	0.0	0.0	0.0	0.0	0.0	3.1	3.1	0.0
Central Cafeteria & Conference Center	GPF	9.3	0.0	0.0	0.0	0.0	0.0	1.9	7.4	0.0
B-123 General Upgrade (Conference Center Upgrade)	GPF	5.4	0.0	0.0	0.0	0.0	0.0	3.2	2.2	0.0
Tank Upgrades Project Phase 2	GPF	5.1	0.0	0.0	0.0	0.0	0.0	2.0	3.1	0.0
Protection of Real Property (roofs) Phase 3	GPF	8.3	0.0	0.0	0.0	0.0	0.0	4.0	4.3	0.0
Earth Science Building	PR	12.0	0.0	0.0	0.0	0.0	0.0	2.4	7.0	2.6
ES&H Facility	GPF	41.6	0.0	0.0	0.0	0.0	0.0	8.4	12.0	21.2
Site 300 HE Machining Facility	PR	23.5	0.0	0.0	0.0	0.0	0.0	4.3	19.2	0.0
Refurbish Hazard Control Facility	GPF	21.0	0.0	0.0	0.0	0.0	0.0	3.0	15.0	3.0
Fire Safety Training Facility	GPF	7.5	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.5
Hazards Control Fire Science Facility	GPF	7.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	6.0
Projected Utility Projects	GPF	29.8	0.0	0.0	0.0	0.0	0.0	0.0	8.3	21.5
Protection of Real Property (roofs) Phase 4	GPF	8.3	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.3
Technology Transfer Complex	PR	21.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	16.5
Backlog Reduction - Building Utilities	GPF	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0
Backlog Reduction - Roofing	GPF	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3
Electric Power System Replacement Upgrade 2	GPF	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0
Replace Deteriorating Offices	PR	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5
Site 300 SFR Phase 2	PR	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0
Laboratory Administration Center	GPF	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Plutonium Facility Upgrade	PR	28.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.2
Laboratory Business Center	GPF	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0
B-151 Effluent Systems Upgrade	PR	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4
B-321 General Upgrade	PR	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0
B-231 General Upgrade	PR	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5
B-141 General Upgrade	PR	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7

[a] PR = program related; GPF = general purpose facility/utility.
[b] Includes escalation incorporated at various rates.
[c] BA includes projected construction beyond FY 2001.

Table 3.5-5, continued. Proposed construction (requirement case; in millions of dollars).

Sponsor	Type of Facility[a]	Total Estimated Cost[b]	FY 1994 BO	FY 1995 BA	FY 1996 BA	FY 1997 BA	FY 1998 BA	FY 1999 BA	FY 2000 BA	FY 2001 BA[c]
B241 Renovation/Replacement	PR	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.4
Building Electrical Systems Code Upgrade	GPF	31.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.3
B-181 Addition	GPF	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1
Building Envelope Repair	GPF	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6
Civil Maintenance - Sitewide	GPF	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3
Generic Office Building #1	GPF	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8
Backlog Reduction - Flooring	GPF	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8
Upgrade Smoke Detection	GPF	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
B-235 Upgrade	PR	30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.5
Generic Office Building #2	GPF	21.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.3
GB Total[d]		**726.8**	**0.0**	**0.0**	**0.0**	**9.1**	**31.1**	**61.0**	**103.5**	**522.1**
GC Verification and Control Technology										
SCIF Area for NAI	PR	7.5	0.0	0.0	0.0	0.0	1.5	6.0	0.0	0.0
GC Total		**7.5**	**0.0**	**0.0**	**0.0**	**0.0**	**1.5**	**6.0**	**0.0**	**0.0**
Energy Research										
AT Magnetic Fusion										
B-543 Addition	PR	17.7	0.0	0.0	0.0	0.0	3.4	10.4	3.9	0.0
Energy Program Office Building	PR1	9.2	0.0	0.0	0.0	0.0	0.0	5.2	8.5	5.5
AT Total		**36.9**	**0.0**	**0.0**	**0.0**	**0.0**	**3.4**	**15.6**	**12.4**	**5.5**
KP-04 General Life Sciences										
Genomics and Structural Biology	PR	37.0	0.0	0.0	0.0	6.0	22.0	9.0	0.0	0.0
KP Total		**37.0**	**0.0**	**0.0**	**0.0**	**6.0**	**22.0**	**9.0**	**0.0**	**0.0**
Total Energy Research		**73.9**	**0.0**	**0.0**	**0.0**	**6.0**	**25.4**	**24.6**	**12.4**	**5.5**
Environmental Restoration and Waste Management										
EW-31 Waste Management										
B-222 Chemistry Building Decontamination/ Demolition	PR	23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2
EW Total		**23.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**23.2**
Total Proposed Projects[d]		**831.4**	**0.0**	**0.0**	**0.0**	**15.1**	**58.0**	**91.6**	**115.9**	**550.8**

[a] PR = program related; GPF = general purpose facility/utility.
[b] Includes escalation incorporated at various rates.
[c] BA includes projected construction beyond FY 2001.
[d] Does not include the National Ignition Facility funding.

assembling these large optical components. Areas to be built include approximately 667 m^2 of thermal and vibrationally stable laboratory space, including 446 m^2 of Class 10,000 to Class 100 clean room with 5.5-m clear-height high-bay space.

Site 300 Fire Station/Medical Facility ($5.2 million)

The proposed new fire station and medical facility for Site 300 will replace the existing 30-year-old facility. This 700-m^2 facility will include three apparatus bays for an ambulance, a pumper, and a patrol vehicle; living quarters for firefighters; a dayroom; exam rooms; a laboratory; advanced care rooms; offices; and an equipment decontamination area.

FY 1998

Chlorofluorocarbon Chiller Conversion ($9.3 million)

This project will replace or convert approximately 50 chillers serving 29 buildings around the Livermore Site to support programmatic missions. The approach will be to modify or replace the chiller machinery and reactivate it with as little disturbance to the facilities as possible.

Road Reconstruction ($7.8 million)

This project will address the required rehabilitation of paved roads on the Livermore site that are reaching critical points in their usual life spans. This includes reconstructing approximately 7.9 km of roadway, safety upgrades to align one roadway, improvements to two intersections, and curb and gutter corrections in four areas. With the completion of this work, the transportation and service road system will meet current safety standards.

Sanitary Sewer Rehabilitation II ($4.6 million)

This new project will provide investigation, rehabilitation, proper reconnection, and other infrastructure improvements to water drain and sewer lines in the 50-year-old system. The proposed project will correct old and deteriorated sanitary sewer lines throughout the site to keep the sanitary sewer system in compliance with California's Porter-Cologne Water Quality Control Act.

Building Renovation Project ($20.0 million)

The proposed project is to renovate eight World War II-vintage buildings for adaptive reuse (approximately 18,000 m^2) instead of demolition and replacement. The structural integrity of these buildings offers a cost-effective opportunity for renewal. The renovation will include upgrades to seismic standards, office modernization, enhanced exterior appearance, hazardous material removal, accessibility, and energy-efficient central HVAC systems.

Northwest LCW System Upgrade ($6.5 million)

This project will increase the thermal capacity of the Northwest Low-Conductivity Water (LCW) Station at Building 291 to accommodate important ICF and NIF programmatic growth in the area. This station supplies LCW in a closed-loop system to facilities in the northwest and north central areas of the Livermore site. LCW is used for cooling experimental apparatus, laboratory devices, and shop equipment and is used as a condenser cooling medium for air conditioning and refrigeration equipment.

Building 151 Plant and Seismic Upgrade ($11.5 million)

This project will remove the two chillers and two boilers, which provide temperature control for Buildings 151 and 154, and replace them with new, more energy-efficient units. The project will also upgrade the building for seismic safety.

Office of Energy Research

FY 1997

Genomics and Structural Biology Research Facility ($37.0 million)

This project is essential for the continued success of our rapidly growing human genome research program and initiatives. The 6,500-m^2 Genomics and Structural Biology

Research Facility will provide modern facilities for physical mapping, gene discovery, and DNA sequencing of the human genome and the genomes of organisms critical to bioremediation of toxic hazards. The facility will also support research with university, laboratory, and industrial colleagues and collaborators.

FY 1998

Building 543 Addition ($17.7 million)

A west wing will be added to Building 543, with approximately 4,650 m^2 of office and support space. This facility will house about 140 occupants. With the consolidation of our energy programs and the inclusion of transportation and manufacturing technology programs into this directorate, we have immediate needs for offices to house 120 people. During the next two years, we anticipate the programs to grow by 160 people. This addition meets part of the space needs for this program.

Office of Nonproliferation and National Security

FY 1998

SCI Facility ($7.5 million)

This project supports the Nonproliferation, Arms Control, and International Security (NAI) Directorate, which is responsible for handling all work at the sensitive compartmented information (SCI) level. The new SCI Facility (approximately 3,000 m^2) would be located within the classified core area, near other national security programs in the directorate. It would also be built to meet security accreditation requirements and accommodate new computers. Work in the SCI area has been expanding with the increased national security focus on nuclear nonproliferation, counterproliferation, and antiterrorism. Further expansion in these programs, strongly endorsed by the Galvin Report, are planned by DOE.

Section 4

Appendices

Program Resource Requirement Projections 4.1

Data for FY 1994 is taken from the FY 1994 *LLNL Budget Office Annual Report.* Data for FY 1995 through FY 1997 represent a combination of the FY 1997 Field Budget Submission and the FY 1997–1998 Defense Programs Field Budget Estimates (April 1995). The requirements case is used for all programs except for Defense Programs (GB), which uses the guidance case. The resource data for FY 1994 through 2001 are based on the following:

- FY 1994 through 1995, actual budget obligations and authority.
- FY 1996 through 2001, Program Managers' estimates of resource requirements.
- Inflation factor: from FY 1995 through 1997, inflation is 3.0%; from FY 1997 through 2001, inflation is expressed in constant FY 1997 dollars, except where a project budget plan extends into this period, in which case the project numbers are used.

The program resource projections are shown as follows:

- Table 4.1-1. Laboratory funding summary.
- Table 4.1-2. Laboratory personnel summary.
- Table 4.1-3. Resources by major DOE program.
- Table 4.1-4. Resource projections by sponsor for non-DOE reimbursable programs.
- Table 4.1-5 through 4.1-19. Detailed resource breakouts by DOE sponsors.

Table 4.1-1. Laboratory funding summary (in millions of dollars).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Sponsor-Funded Operating								
DOE Direct	617.1	596.3	669.6	684.1	697.6	697.6	697.6	697.6
DOE Other	75.6	79.2	89.9	103.2	103.2	103.2	103.2	103.2
Non-DOE	164.8	186.6	213.4	181.9	181.9	181.9	181.9	181.9
Total Operating	**857.5**	**862.1**	**972.9**	**969.2**	**982.7**	**982.7**	**982.7**	**982.7**
DOE Capital								
Capital Equipment	83.8	20.8	77.3	97.2	103.7	103.7	103.7	103.7
Facility Construction	48.2	23.2	27.5	31.4	30.4	12.6	5.1	0.0
General Plant Projects	1.3	0.0	2.5	5.0	5.0	5.0	5.0	5.0
Total Capital	**133.3**	**44.0**	**107.3**	**133.6**	**139.1**	**121.3**	**113.8**	**108.7**
Total Laboratory	**990.8**	**906.1**	**1080.2**	**1102.8**	**1121.8**	**1104.0**	**1096.5**	**1091.4**
Proposed Construction	0.0	0.0	0.0	15.1	58.0	91.6	115.9	550.8
NIF-PACE[d]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[d]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] National Ignition Facility; site determination pending.

Table 4.1-2. Laboratory personnel summary (in full-time employee equivalent).

	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001
Sponsor Funded Operating								
DOE	2782	2617	2820	2708	2708	2708	2708	2708
Non-DOE	649	652	783	628	628	628	628	628
Total Operating	**3431**	**3269**	**3603**	**3336**	**3336**	**3336**	**3336**	**3336**
DOE Capital	**136**	**156**	**144**	**92**	**92**	**92**	**92**	**92**
Total Sponsor Funded	**3567**	**3425**	**3747**	**3428**	**3428**	**3428**	**3428**	**3428**
Distributed	3754	3901	3607	3600	3600	3600	3600	3600
Total Laboratory	**7321**	**7326**	**7354**	**7028**	**7028**	**7028**	**7028**	**7028**

Table 4.1-3. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Defense Programs								
Operating Cost	349.7	336.8	364.3	366.9	380.4	380.4	380.4	380.4
Capital Equipment	31.9	12.1	19.0	21.1	27.6	27.6	27.6	27.6
Construction[d]	36.6	4.9	14.6	19.4	19.3	6.7	0.0	0.0
Total Cost/Funding	**418.2**	**353.8**	**397.9**	**407.4**	**427.3**	**414.7**	**408.0**	**408.0**
Proposed Construction	0.0	0.0	0.0	9.1	31.1	61.0	103.5	522.1
Direct Personnel	1470	1361	1415	1329	1329	1329	1329	1329
NIF-PACE[e]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[e]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8
Nonproliferation & National Security								
Operating Cost	73.6	64.9	86.7	84.7	84.7	84.7	84.7	84.7
Capital Equipment	4.9	4.2	4.8	4.9	4.9	4.9	4.9	4.9
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**78.5**	**69.7**	**92.1**	**90.4**	**90.4**	**90.4**	**90.4**	**90.4**
Proposed Construction	0.0	0.0	0.0	0.0	1.5	6.0	0.0	0.0
Direct Personnel	247	301	361	355	355	355	355	355
Fissile Materials Disposition								
Operating Cost	0.0	7.8	12.5	13.4	13.4	13.4	13.4	13.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**0.0**	**7.8**	**12.5**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	34	51	55	55	55	55	55

Table 4.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Energy Research								
Operating Cost	81.8	89.1	101.4	117.0	117.0	117.0	117.0	117.0
Capital Equipment	3.4	2.4	8.5	7.6	7.6	7.6	7.6	7.6
Construction	0.0	9.3	4.0	1.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**85.2**	**100.8**	**113.9**	**125.6**	**124.6**	**124.6**	**124.6**	**124.6**
Proposed Construction	0.0	0.0	0.0	6.0	25.4	24.6	12.4	5.5
Direct Personnel	334	309	367	373	373	373	373	373
Environmental Restoration & Waste Management								
Operating Cost	70.6	61.1	66.1	60.4	60.4	60.4	60.4	60.4
Capital Equipment	6.1	1.4	1.2	0.3	0.3	0.3	0.3	0.3
Construction[d]	6.2	6.0	8.9	11.0	11.1	5.9	5.1	0.0
Total Cost/Funding	**82.9**	**68.5**	**76.2**	**71.7**	**71.8**	**66.7**	**65.9**	**60.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2
Direct Personnel	270	250	251	225	225	225	225	225
Environment, Safety & Health								
Operating Cost	9.8	8.5	14.4	15.3	15.3	15.3	15.3	15.3
Capital Equipment	0.3	0.1	0.2	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	0.0
Total Cost/Funding	**10.1**	**8.6**	**14.6**	**15.4**	**15.4**	**15.4**	**15.4**	**15.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	36	35	50	51	51	51	51	51
Nuclear Energy								
Operating Cost	9.9	8.4	9.1	10.3	10.3	10.3	10.3	10.3
Capital Equipment	0.1	0.4	0.0	1.7	1.7	1.7	1.7	1.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**10.0**	**8.8**	**9.1**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	22	45	32	28	28	28	28	28
Civilian Radioactive Waste Management								
Operating Cost	15.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.3	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	0.0
Total Cost/Funding	**15.8**	**12.9**	**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	0.0
Direct Personnel	60	34	0	0	0	0	0	0

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] National Ignition Facility; site determination pending.

Table 4.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Fossil Energy								
Operating Cost	2.5	2.5	3.7	3.4	3.4	3.4	3.4	3.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**2.5**	**2.5**	**3.7**	**3.4**	**3.4**	**3.4**	**3.4**	**3.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	14	18	19	19	19	19	19
Energy Efficiency & Renewable Energy								
Operating Cost	1.5	2.0	7.2	8.2	8.2	8.2	8.2	8.2
Capital Equipment	0.0	0.1	0.3	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	0.0
Total Cost/Funding	**1.5**	**2.1**	**7.5**	**8.6**	**8.6**	**8.6**	**8.6**	**8.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	9	20	22	22	22	22	22
Human Resources & Administration								
WM General Administration-Contractual Services								
Operating Cost	0.6	0.6	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.6**	**0.6**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	3	3	5	5	5	5	5	5
Policy, Planning, & Program Evaluation								
PE-01 Analysis & Systems Studies								
Operating Cost	0.1	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
Science Education & Technical Information								
Operating Cost	1.0	1.3	2.4	2.7	2.7	2.7	2.7	2.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.0**	**1.3**	**2.4**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	4	7	10	10	10	10	10

Table 4.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Field Management								
WB In-House Energy Management								
Operating Cost	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction[d]	5.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**5.9**	**3.5**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	3	3	3	3	3	3	3
Total DOE Direct								
Operating Cost	617.1	596.3	669.6	684.1	697.6	697.6	697.6	697.6
Capital Equipment	47.0	20.8	34.0	36.1	42.6	42.6	42.6	42.6
Construction	48.2	23.2	27.5	31.4	30.4	12.6	5.1	0.0
Total Cost/Funding	**712.3**	**640.9**	**731.7**	**752.4**	**771.4**	**753.7**	**746.2**	**741.0**
Proposed Construction	0.0	0.0	0.0	15.1	58.0	91.6	115.9	550.8
Direct Personnel	2458	2402	2580	2475	2475	2475	2475	2475
NIF-PACE[e]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[e]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8
Total DOE Other								
Operating Cost	75.6	79.2	89.9	103.2	103.2	103.2	103.2	103.2
Capital Equipment	36.8	0.0	43.3	61.1	61.1	61.1	61.1	61.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**112.4**	**79.2**	**133.2**	**164.3**	**164.3**	**164.3**	**164.3**	**164.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	324	215	240	233	233	233	233	233
Total All DOE								
Operating Cost	692.7	675.5	759.5	787.3	800.8	800.8	800.8	800.8
Capital Equipment	83.8	20.8	77.3	97.2	103.7	103.7	103.7	103.7
Construction	48.2	23.2	27.5	31.4	30.4	12.6	5.1	0.0
Total Cost/Funding	**824.7**	**720.1**	**864.9**	**916.7**	**935.7**	**918.0**	**910.5**	**905.3**
Proposed Construction	0.0	0.0	0.0	15.1	58.0	91.6	115.9	550.8
Direct Personnel	2782	2617	2820	2708	2708	2708	2708	2708
NIF-PACE[e]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[e]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] Does not include General Plant Projects.
[e] Construction dollars only; site determination is pending.

Table 4.1-4. Resource projections by sponsor for non-DOE reimbursable programs (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Department of Defense								
Operating Cost	103.1	72.9	94.0	89.7	89.7	89.7	89.7	89.7
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**103.1**	**72.9**	**94.0**	**89.7**	**89.7**	**89.7**	**89.7**	**89.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	393	230	299	246	246	246	246	246
NASA								
Operating Cost	5.1	3.2	3.3	2.4	2.4	2.4	2.4	2.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**5.1**	**3.2**	**3.3**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	19	19	18	11	11	11	11	11
U.S. Enrichment Corporation								
Operating Cost	38.5	40.0	50.0	40.0	40.0	40.0	40.0	40.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**38.5**	**40.0**	**50.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	170	175	250	200	200	200	200	200
Other Federal Agencies								
Operating Cost	8.1	26.3	27.1	28.0	28.0	28.0	28.0	28.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**8.1**	**26.3**	**27.1**	**28.0**	**28.0**	**28.0**	**28.0**	**28.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	29	102	97	96	96	96	96	96
Non-Federal Agencies								
Operating Cost	10.0	44.2	39.0	21.8	21.8	21.8	21.8	21.8
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**10.0**	**44.2**	**39.0**	**21.8**	**21.8**	**21.8**	**21.8**	**21.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	38	126	119	75	75	75	75	75

Table 4.1-4, continued. Resource projections by sponsor for non-DOE reimbursable programs (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Total Non-DOE								
Operating Cost	164.8	186.6	213.4	181.9	181.9	181.9	181.9	181.9
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**164.8**	**186.6**	**213.4**	**181.9**	**181.9**	**181.9**	**181.9**	**181.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	649	652	783	628	628	628	628	628

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-5. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
GB-01 Stockpile Stewardship[d]								
Operating Cost	211.8	178.6	198.3	246.4	246.4	246.4	246.4	246.4
Capital Equipment	26.3	8.1	16.7	17.6	17.6	17.6	17.6	17.6
Construction[e]	36.6	4.9	14.6	19.4	19.3	6.7	0.0	0.0
Total Cost/Funding	**274.7**	**191.6**	**229.6**	**283.4**	**283.3**	**270.7**	**264.0**	**264.0**
Proposed Construction	0.0	0.0	0.0	9.1	31.1	61.0	103.5	522.1
Direct Personnel	910	731	758	879	879	879	879	879
GB-01-06 Technology Transfer								
Operating Cost[f]	45.0	55.5	55.4	6.8	6.8	6.8	6.8	6.8
Capital Equipment	1.8	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	0.0
Total Cost/Funding	**46.8**	**55.5**	**55.4**	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	182	218	230	21	21	21	21	21
GB-02 Inertial Confinement Fusion								
Operating Cost	77.6	77.0	85.1	86.5	100.0	100.0	100.0	100.0
Capital Equipment	3.8	4.0	2.3	3.5	10.0	10.0	10.0	10.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**81.4**	**81.0**	**87.4**	**90.0**	**110.0**	**110.0**	**110.0**	**110.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	331	297	318	319	319	319	319	319
NIF-PACE[g]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[g]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8

Table 4.1-5, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
GB-03 Stockpile Management								
Operating Cost	0.4	11.5	13.7	15.7	15.7	15.7	15.7	15.7
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**0.4**	**11.5**	**13.7**	**15.7**	**15.7**	**15.7**	**15.7**	**15.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	66	76	78	78	78	78	78
GB-05 Program Direction								
Operating Cost	6.5	5.8	5.0	4.8	4.8	4.8	4.8	4.8
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**6.5**	**5.8**	**5.0**	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	15	11	11	12	12	12	12	12
GB-05-06 Emergency Management								
Operating Cost	0.0	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.6**	**0.7**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
GB-06 Complex Reconfiguration								
Operating Cost	6.4	3.4	2.2	1.9	1.9	1.9	1.9	1.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**6.4**	**3.4**	**2.2**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	25	20	9	7	7	7	7	7
GB Total								
Operating Cost	347.7	332.4	360.4	362.9	376.4	376.4	376.4	376.4
Capital Equipment	31.9	12.1	19.0	21.1	27.6	27.6	27.6	27.6
Construction[e]	36.6	4.9	14.6	19.4	19.3	6.7	0.0	0.0
Total Cost/Funding	**416.2**	**349.4**	**394.0**	**403.4**	**423.3**	**410.7**	**404.0**	**404.0**
Proposed Construction	0.0	0.0	0.0	9.1	31.1	61.0	103.5	522.1
Direct Personnel	1463	1343	1402	1316	1316	1316	1316	1316
GE-03 Supporting Service								
Operating Cost	2.0	4.4	3.9	4.0	4.0	4.0	4.0	4.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**2.0**	**4.4**	**3.9**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	7	18	13	13	13	13	13	13

Table 4.1-5, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Total Defense Programs								
Operating Cost	349.7	336.8	364.3	366.9	380.4	380.4	380.4	380.4
Capital Equipment	31.9	12.1	19.0	21.1	27.6	27.6	27.6	27.6
Construction[e]	36.6	4.9	14.6	19.4	19.3	6.7	0.0	0.0
Total Cost/Funding	**418.2**	**353.8**	**397.9**	**407.4**	**427.3**	**414.7**	**408.0**	**408.0**
Proposed Construction	0.0	0.0	0.0	9.1	31.1	61.0	103.5	522.1
Direct Personnel	1470	1361	1415	1329	1329	1329	1329	1329
NIF-PACE[g]	0.0	0.0	37.4	131.9	197.8	198.8	191.3	85.4
NIF-OPEX[g]	6.0	6.0	23.6	59.2	31.3	15.4	31.7	51.8

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] Guidance case.
[e] Does not include General Plant Projects.
[f] Assumes all CRADAS except ICF are integrated into the GB-01 Stockpile Stewardship Operating Cost.
[g] National Ignition Facility - pending site determination.

Table 4.1-6. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
GC Verification and Control Technology								
Operating Cost	50.1	36.2	42.0	44.0	44.0	44.0	44.0	44.0
Capital Equipment	4.5	4.0	4.0	4.2	4.2	4.2	4.2	4.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**54.6**	**40.2**	**46.0**	**48.2**	**48.2**	**48.2**	**48.2**	**48.2**
Proposed Construction	0.0	0.0	0.0	0.0	1.5	6.0	0.0	0.0
Direct Personnel	186	196	212	222	222	222	222	222
Nuclear Safeguards & Security								
GD-03 Classification Resources								
Operating Cost	0.0	0.8	1.2	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.4	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	0.0
Total Cost/Funding	**0.4**	**0.8**	**1.2**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	2	3	3	3	3	3	3

Table 4.1-6, continued. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Nuclear Safeguards & Security								
GD-05 Operational Support								
Operational Cost	0.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	2	1	1	1	1	1	1
Nuclear Safeguards & Security								
GD-06 Technology & Systems Development								
Operating Cost	3.8	5.0	11.0	9.0	9.0	9.0	9.0	9.0
Capital Equipment	0.0	0.0	0.5	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	0.0
Total Cost/Funding	**3.8**	**5.0**	**11.5**	**9.4**	**9.4**	**9.4**	**9.4**	**9.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	20	23	50	41	41	41	41	41
GD Total								
Operating Cost	3.8	6.1	12.5	10.3	10.3	10.3	10.3	10.3
Capital Equipment	0.4	0.0	0.5	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	0.0
Total Cost/Funding	**4.2**	**6.1**	**13.0**	**10.7**	**10.7**	**10.7**	**10.7**	**10.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	20	27	54	45	45	45	45	45
GH Security Investigation								
Operating Cost	3.2	5.2	4.5	1.6	1.6	1.6	1.6	1.6
Capital Equipment	0.0	0.1	0.1	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	0.0
Total Cost/Funding	**3.2**	**5.3**	**4.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	4	17	15	5	5	5	5	5
GJ Arms Control								
Operating Cost	9.3	11.4	20.0	21.0	21.0	21.0	21.0	21.0
Capital Equipment	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**9.3**	**11.5**	**20.2**	**21.2**	**21.2**	**21.2**	**21.2**	**21.2**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	11	35	55	58	58	58	58	58
NB-04 Emergency Preparedness								
Operating Cost	0.3	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0

Table 4.1-6, continued. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Intelligence								
NT-01 Analytical Support								
Operating Cost	6.5	5.8	7.5	7.6	7.6	7.6	7.6	7.6
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**6.5**	**5.8**	**7.5**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	24	23	24	24	24	24	24	24
Intelligence								
NT-03 Counterintelligence								
Operating Cost	0.0	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	0	0	0	0	0	0
Intelligence								
NT-04 Technical Support								
Operating Cost	0.4	0.2	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	2	1	1	1	1	1	1
NT Total								
Operating Cost	6.9	6.0	7.7	7.8	7.8	7.8	7.8	7.8
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**6.9**	**6.0**	**7.7**	**7.8**	**7.8**	**7.8**	**7.8**	**7.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	26	26	25	25	25	25	25	25
Total Nonproliferation & National Security								
Operating Cost	73.6	64.9	86.7	84.7	84.7	84.7	84.7	84.7
Capital Equipment	4.9	4.2	4.8	4.9	4.9	4.9	4.9	4.9
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**78.5**	**69.7**	**92.1**	**90.4**	**90.4**	**90.4**	**90.4**	**90.4**
Proposed Construction	0.0	0.0	0.0	0.0	1.5	6.0	0.0	0.0
Direct Personnel	247	301	361	355	355	355	355	355

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-7. Fissile Materials Disposition detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Fissile Materials Disposition								
Operating Cost	0.0	7.8	12.5	13.4	13.4	13.4	13.4	13.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**0.0**	**7.8**	**12.5**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	34	51	55	55	55	55	55

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-8. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
AT-00 Magnetic Fusion								
Operating Cost	0.1	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Magnetic Fusion								
AT-05 Applied Plasma Physics								
Operating Cost	13.4	12.0	16.1	17.4	17.4	17.4	17.4	17.4
Capital Equipment	0.2	0.1	0.2	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	0.0
Total Cost/Funding	**13.6**	**12.1**	**16.3**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**
Proposed Construction	0.0	0.0	0.0	0.0	3.4	15.6	12.4	5.5
Direct Personnel	29	33	53	57	57	57	57	57
Magnetic Fusion								
AT-10 Confinement Systems								
Operating Cost	4.6	4.9	6.6	14.5	14.5	14.5	14.5	14.5
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**4.6**	**5.0**	**6.6**	**14.5**	**14.5**	**14.5**	**14.5**	**14.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	27	21	25	25	25	25	25	25

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Magnetic Fusion								
AT-15 Development and Technology								
Operating Cost	7.2	7.1	8.5	9.0	9.0	9.0	9.0	9.0
Capital Equipment	1.0	0.1	0.3	0.5	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**8.2**	**7.2**	**8.8**	**9.5**	**9.5**	**9.5**	**9.5**	**9.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	43	15	18	18	18	18	18	18
Magnetic Fusion								
AT-25 Planning and Projects								
Operating Cost	0.8	1.6	2.3	5.0	5.0	5.0	5.0	5.0
Capital Equipment	0.0	0.1	0.2	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	0.0
Total Cost/Funding	**0.8**	**1.7**	**2.5**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	4	7	10	18	18	18	18	18
AT Total								
Operating Cost	26.1	25.6	33.5	45.9	45.9	45.9	45.9	45.9
Capital Equipment	1.2	0.4	0.7	0.9	0.9	0.9	0.9	0.9
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**27.3**	**26.0**	**34.2**	**46.8**	**46.8**	**46.8**	**46.8**	**46.8**
Proposed Construction	0.0	0.0	0.0	0.0	3.4	15.6	12.4	5.5
Direct Personnel	103	76	106	118	118	118	118	118
High Energy Physics								
KA-00 High Energy Physics								
Operating Cost	0.0	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	0.0
Construction	0.0	9.3	4.0	1.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**9.3**	**4.0**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
High Energy Physics								
KA-02 Facility Operations								
Operating Cost	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.1	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	0.0
Total Cost/Funding	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998-2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
High Energy Physics								
KA-03 High Energy Technology								
Operating Cost	1.1	1.1	0.7	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.1**	**1.1**	**0.7**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	6	4	2	2	2	2	2
KA Total								
Operating Cost	1.1	1.2	0.8	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	9.3	4.0	1.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.2**	**10.5**	**4.8**	**1.6**	**0.6**	**0.6**	**0.6**	**0.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	6	4	2	2	2	2	2
Nuclear Physics								
KB-01 Medium Energy Physics								
Operating Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.1	0.1	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	0.0
Total Cost/Funding	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Nuclear Physics								
KB-02 Heavy Ion Physics								
Operating Cost	0.2	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.2**	**0.3**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	3	5	5	5	5	5	5
Nuclear Physics								
KB-03 Nuclear Theory								
Operating Cost	0.1	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.1**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	2	1	1	1	1	1

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Nuclear Physics								
KB-04 Low Energy Physics								
Operating Cost	0.4	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.4**	**0.3**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	2	2	2	2	2	2
KB Total								
Operating Cost	0.7	0.7	1.5	1.5	1.5	1.5	1.5	1.5
Capital Equipment	0.0	0.1	0.1	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	0.0
Total Cost/Funding	**0.7**	**0.8**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	5	9	8	8	8	8	8
Basic Energy Sciences								
KC-02 Materials Science								
Operating Cost	2.1	2.8	3.4	4.2	4.2	4.2	4.2	4.2
Capital Equipment	0.7	0.3	0.2	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	0.0
Total Cost/Funding	**2.8**	**3.1**	**3.6**	**4.6**	**4.6**	**4.6**	**4.6**	**4.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	14	16	18	21	21	21	21	21
Basic Energy Sciences								
KC-03 Chemical Sciences								
Operating Cost	0.2	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.2**	**0.5**	**0.5**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	3	3	4	4	4	4	4
Basic Energy Sciences								
KC-04 Engineering & Geoscience								
Operating Cost	1.6	1.8	2.4	2.5	2.5	2.5	2.5	2.5
Capital Equipment	0.1	0.1	0.1	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	0.0
Total Cost/Funding	**1.7**	**1.9**	**2.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	11	8	10	10	10	10	10	10

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Basic Energy Sciences								
KC-05 Advanced Energy Projects								
Operating Cost	1.0	1.3	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.0**	**1.3**	**0.7**	**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	0.0
Direct Personnel	6	7	3	0	0	0	0	0
Basic Energy Sciences								
KC-07 Applied Mathematical Sciences								
Operating Cost	29.5	35.8	35.1	37.5	37.5	37.5	37.5	37.5
Capital Equipment	0.4	1.0	4.9	3.4	3.4	3.4	3.4	3.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**29.9**	**36.8**	**40.0**	**40.9**	**40.9**	**40.9**	**40.9**	**40.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	66	83	90	88	88	88	88	88
KC Total								
Operating Cost	34.4	42.2	42.1	45.0	45.0	45.0	45.0	45.0
Capital Equipment	1.2	1.4	5.2	3.9	3.9	3.9	3.9	3.9
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**35.6**	**43.6**	**47.3**	**48.9**	**48.9**	**48.9**	**48.9**	**48.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	98	117	124	123	123	123	123	123
KP-00 Biological & Environmental								
Operating Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.9	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	0.0
Total Cost/Funding	**0.9**	**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	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Biological & Environmental								
KP-01 Analytical Technology								
Operating Cost	0.1	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.1**	**0.1**	**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	0.0
Direct Personnel	0	1	1	0	0	0	0	0

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Biological & Environmental								
KP-02 Environmental Research								
Operating Cost	1.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**1.2**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	3	2	2	2	2	2	2
Biological & Environmental								
KP-03 Health Effects								
Operating Cost	0.9	0.9	1.8	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.2	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	0.0
Total Cost/Funding	**0.9**	**0.9**	**2.0**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	7	3	6	6	6	6	6	6
Biological & Environmental								
KP-04 General Life Sciences								
Operating Cost	11.4	11.8	14.5	15.1	15.1	15.1	15.1	15.1
Capital Equipment	0.0	0.4	1.9	2.3	2.3	2.3	2.3	2.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**11.4**	**12.2**	**16.4**	**17.4**	**17.4**	**17.4**	**17.4**	**17.4**
Proposed Construction	0.0	0.0	0.0	6.0	22.0	9.0	0.0	0.0
Direct Personnel	76	67	82	82	82	82	82	82
Biological & Environmental								
KP-05 Carbon Dioxide Research								
Operating Cost	5.9	6.2	6.7	6.7	6.7	6.7	6.7	6.7
Capital Equipment	0.0	0.1	0.4	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	0.0
Total Cost/Funding	**5.9**	**6.3**	**7.1**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	41	31	33	32	32	32	32	32
KP Total								
Operating Cost	19.5	19.4	23.5	24.0	24.0	24.0	24.0	24.0
Capital Equipment	0.9	0.5	2.5	2.7	2.7	2.7	2.7	2.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**20.4**	**19.9**	**26.0**	**26.7**	**26.7**	**26.7**	**26.7**	**26.7**
Proposed Construction	0.0	0.0	0.0	6.0	22.0	9.0	0.0	0.0
Direct Personnel	130	105	124	122	122	122	122	122

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Total Energy Research								
Operating Cost	81.8	89.1	101.4	117.0	117.0	117.0	117.0	117.0
Capital Equipment	3.4	2.4	8.5	7.6	7.6	7.6	7.6	7.6
Construction	0.0	9.3	4.0	1.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**85.2**	**100.8**	**113.9**	**125.6**	**124.6**	**124.6**	**124.6**	**124.6**
Proposed Construction	0.0	0.0	0.0	6.0	25.4	24.6	12.4	5.5
Direct Personnel	334	309	367	373	373	373	373	373

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-9. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
EW-11 Corrective Actions								
Operating Cost	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	3.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**4.7**	**1.0**	**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	0.0
Direct Personnel	0	3	0	0	0	0	0	0
EW-20 Environmental Restoration								
Operating Cost	28.8	26.0	29.7	29.8	29.8	29.8	29.8	29.8
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**28.8**	**26.0**	**29.7**	**29.8**	**29.8**	**29.8**	**29.8**	**29.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	112	86	96	98	98	98	98	98
EW-31 Waste Management								
Operating Cost	30.7	29.8	30.8	24.9	24.9	24.9	24.9	24.9
Capital Equipment	4.4	1.1	0.9	0.0	0.0	0.0	0.0	0.0
Construction[d]	2.3	5.0	8.9	11.0	11.1	5.9	5.1	0.0
Total Cost/Funding	**37.4**	**35.9**	**40.6**	**35.9**	**36.0**	**30.8**	**30.0**	**24.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2
Direct Personnel	117	136	131	103	103	103	103	103

Table 4.1-9, continued. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
EW-40 Technology Development								
Operating Cost	10.9	5.3	5.3	5.4	5.4	5.4	5.4	5.4
Capital Equipment	1.1	0.3	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	0.0
Total Cost/Funding	**12.0**	**5.6**	**5.6**	**5.7**	**5.7**	**5.7**	**5.7**	**5.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	41	24	23	23	23	23	23	23
EW-60 Program Direction								
Operating Cost	0.0	0.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.0**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	1	1	1	1	1	1
Total Environmental Restoration & Waste Management								
Operating Cost	70.6	61.1	66.1	60.4	60.4	60.4	60.4	60.4
Capital Equipment	6.1	1.4	1.2	0.3	0.3	0.3	0.3	0.3
Construction[d]	6.2	6.0	8.9	11.0	11.1	5.9	5.1	0.0
Total Cost/Funding	**82.9**	**68.5**	**76.2**	**71.7**	**71.8**	**66.7**	**65.9**	**60.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2
Direct Personnel	270	250	251	225	225	225	225	225

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] Does not include General Plant Projects.

Table 4.1-10. Environment, Safety, and Health detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
HA-01 Environment, Safety, & Health								
Operating Cost	5.6	4.6	8.7	9.0	9.0	9.0	9.0	9.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**5.6**	**4.6**	**8.8**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	15	16	29	30	30	30	30	30
HP-01 Nuclear Safety Policy								
Operating Cost	0.9	0.7	1.2	1.4	1.4	1.4	1.4	1.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.9**	**0.7**	**1.2**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	3	4	4	4	4	4	4
HR Epidemiologic Activities								
Operating Cost	1.8	1.9	2.5	2.8	2.8	2.8	2.8	2.8
Capital Equipment	0.3	0.1	0.1	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	0.0
Total Cost/Funding	**2.1**	**2.0**	**2.6**	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	12	10	10	10	10	10	10	10
HS Security Evaluation								
Operating Cost	1.3	1.2	1.5	1.5	1.5	1.5	1.5	1.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.3**	**1.2**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	5	5	5	5	5	5	5
NR-00 Radiological Oversight								
Operating Cost	0.0	0.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0

Table 4.1-10, continued. Environment, Safety, and Health detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Nuclear Safety Oversight								
NS-01 Standards Oversight								
Operating Cost	0.1	0.1	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	1	1	1	1	1	1
Nuclear Safety Oversight								
NS-06 Secretarial Initiatives								
Operating Cost	0.1	0.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.0**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	1	1	1	1	1	1
NS Total								
Operating Cost	0.2	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.2**	**0.1**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	2	2	2	2	2	2
Total Environment, Safety, & Health								
Operating Cost	9.8	8.5	14.4	15.3	15.3	15.3	15.3	15.3
Capital Equipment	0.3	0.1	0.2	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	0.0
Total Cost/Funding	**10.1**	**8.6**	**14.6**	**15.4**	**15.4**	**15.4**	**15.4**	**15.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	36	35	50	51	51	51	51	51

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-11. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
AF-12-10 Light Water Reactors								
Operating Cost	1.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.0**	**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	0.0
Direct Personnel	4	0	0	0	0	0	0	0
AF-20 Advanced Reactor Reasearch & Development								
Operating Cost	0.1	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
AF Total								
Operating Cost	1.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.1**	**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	0.0
Direct Personnel	4	0	0	0	0	0	0	0
AJ-05 Naval Reactors								
Operating Cost	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Uranium Programs								
CD-10-04 Highly Enriched Uranium Equipment Shutdown & Inventory Disposition								
Operating Cost	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.2**	**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	0.0
Direct Personnel	0	1	0	0	0	0	0	0

Table 4.1-11, continued. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Uranium Programs								
CD-10-06 Nuclear Safety								
Operating Cost	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**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	0.0
Direct Personnel	0	1	0	0	0	0	0	0
Uranium Programs								
CD-10-07 Maintenance of Leased and Non-Leased								
Operating Cost	0.2	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	0	0	0	0	0	0
Uranium Programs								
CD-10-08 AVLIS								
Operating Cost	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**4.0**	**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	0.0
Direct Personnel	12	10	0	0	0	0	0	0
Uranium Programs								
CD-10-09 Technology Partnerships								
Operating Cost	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	1	1	1	1	1	1
Uranium Programs								
CD-10-12 Program Management Services								
Operating Cost	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	7	5	5	5	5	5	5

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-11, continued. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Uranium Programs								
CD-10-13 Transparency Measures								
Operating Cost	0.8	5.2	5.5	6.8	6.8	6.8	6.8	6.8
Capital Equipment	0.0	0.4	0.0	1.7	1.7	1.7	1.7	1.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.8**	**5.6**	**5.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	19	23	20	20	20	20	20
Uranium Programs								
CD-10-15 Depleted Uranium Hexafluoride								
Operating Cost	0.0	0.0	1.0	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.0**	**1.0**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	5	3	2	2	2	2	2
CD Total								
Operating Cost	8.3	7.9	8.8	9.9	9.9	9.9	9.9	9.9
Capital Equipment	0.1	0.4	0.0	1.7	1.7	1.7	1.7	1.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**8.4**	**8.3**	**8.8**	**11.6**	**11.6**	**11.6**	**11.6**	**11.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	18	44	32	28	28	28	28	28
KK-05 Policy and Management								
Operating Cost	0.2	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.2**	**0.2**	**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	0.0
Direct Personnel	0	1	0	0	0	0	0	0
Total Nuclear Energy								
Operating Cost	9.9	8.4	9.1	10.3	10.3	10.3	10.3	10.3
Capital Equipment	0.1	0.4	0.0	1.7	1.7	1.7	1.7	1.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**10.0**	**8.8**	**9.1**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	22	45	32	28	28	28	28	28

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-12. Civilian Radioactive Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Waste Management System								
DB-01 First Repository								
Operating Cost	13.9	11.8	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.3	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	0.0
Total Cost/Funding	**14.2**	**11.9**	**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	0.0
Direct Personnel	53	30	0	0	0	0	0	0
Nuclear Waste Fund								
DB-09 Program Support								
Operating Cost	1.6	1.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.6**	**1.0**	**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	0.0
Direct Personnel	7	4	0	0	0	0	0	0
Total Civilian Radioactive Waste Management								
Operating Cost	15.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.3	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	0.0
Total Cost/Funding	**15.8**	**12.9**	**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	0.0
Direct Personnel	60	34	0	0	0	0	0	0

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-13. Fossil Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Coal								
AA-15 Advanced Research and Technology								
Operating Cost	0.3	0.1	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.3**	**0.1**	**0.1**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	1	2	2	2	2	2
Gas								
AB-05 Natural Gas Research								
Operating Cost	0.3	0.2	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	1	1	1	1	1	1
Petroleum								
AC-10 Petroleum								
Operating Cost	1.9	2.2	3.5	3.0	3.0	3.0	3.0	3.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**1.9**	**2.2**	**3.5**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	4	13	16	16	16	16	16	16
Naval Petroleum & Oil Shale								
CB-01 Naval Petroleum Reserve								
Operating Cost	0.0	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Total Fossil Energy								
Operating Cost	2.5	2.5	3.7	3.4	3.4	3.4	3.4	3.4
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**2.5**	**2.5**	**3.7**	**3.4**	**3.4**	**3.4**	**3.4**	**3.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	14	18	19	19	19	19	19

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-14. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
AK - Electric Energy Systems								
Operating Cost	0.1	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.1**	**0.1**	**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	0.0
Direct Personnel	1	1	0	0	0	0	0	0
Hydrogen Research								
AR Energy Storage Systems								
Operating Cost	0.6	1.2	5.0	6.0	6.0	6.0	6.0	6.0
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**0.6**	**1.2**	**5.0**	**6.1**	**6.1**	**6.1**	**6.1**	**6.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	5	12	14	14	14	14	14
Industrial Sector								
ED-21 Process Heating and Cooling								
Operating Cost	0.0	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.0**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	1	1	1	1	1	1
Industrial Sector								
ED-38 Materials & Metals Processing								
Operating Cost	0.2	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
Industrial Sector								
ED-39 Materials & Metals Processing								
Operating Cost	0.2	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0

Table 4.1-14, continued. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Industrial Sector								
ED-51 Materials & Metals Processing								
Operating Cost	0.1	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
ED Total								
Operating Cost	0.5	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	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.5**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	1	1	1	1	1	1
Transportation Sector								
EE-51 Materials Technology								
Operating Cost	0.0	0.3	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.1	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	0.0
Total Cost/Funding	**0.0**	**0.4**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	3	3	3	3	3	3
Transportation Sector								
EE-53 Electric & Hybrid Propulsion								
Operating Cost	0.3	0.1	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.3**	**0.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	1	4	4	4	4	4	4
EE Total								
Operating Cost	0.3	0.4	1.9	1.9	1.9	1.9	1.9	1.9
Capital Equipment	0.0	0.1	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	0.0
Total Cost/Funding	**0.3**	**0.5**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	2	7	7	7	7	7	7

Table 4.1-14, continued. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Total Energy Efficiency & Renewable Energy								
Operating Cost	1.5	2.0	7.2	8.2	8.2	8.2	8.2	8.2
Capital Equipment	0.0	0.1	0.3	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	0.0
Total Cost/Funding	**1.5**	**2.1**	**7.5**	**8.6**	**8.6**	**8.6**	**8.6**	**8.6**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	6	9	20	22	22	22	22	22

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-15. Human Resources and Administration detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
WM General Administration Contractual Services								
Operating Cost	0.6	0.6	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**0.6**	**0.6**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	3	3	5	5	5	5	5	5

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-16. Policy, Planning, and Program Evaluation detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
PE-01 Analysis & Systems Studies								
Operating Cost	0.1	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	0.0
Construction	0.0	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**	**0.0**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-17. Science Education and Technical Information detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
KT University & Science Education								
Operating Cost	1.0	1.3	2.4	2.7	2.7	2.7	2.7	2.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**1.0**	**1.3**	**2.4**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	4	7	10	10	10	10	10

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

Table 4.1-18. Field Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
WB In-House Energy Management								
Operating Cost	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction[d]	5.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**5.9**	**3.5**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	3	3	3	3	3	3	3

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.
[d] Does not include General Plant Projects.

Table 4.1-19. Other DOE detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1994 BO	FY 1995 BA	FY 1996[a] BA	FY 1997[a] BA	FY 1998[b] BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b,c] BA
Work for DOE Integrated Contractors								
Operating Cost	28.3	44.0	65.5	83.3	83.3	83.3	83.3	83.3
Capital Equipment	36.8	0.0	43.3	61.1	61.1	61.1	61.1	61.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**65.1**	**44.0**	**108.8**	**144.4**	**144.4**	**144.4**	**144.4**	**144.4**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	120	101	142	145	145	145	145	145
Work for Other DOE Installations								
Operating Cost	47.3	35.2	24.4	19.9	19.9	19.9	19.9	19.9
Capital Equipment	0.0	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	0.0
Total Cost/Funding	**47.3**	**35.2**	**24.4**	**19.9**	**19.9**	**19.9**	**19.9**	**19.9**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	204	114	98	88	88	88	88	88
Total Other DOE								
Operating Cost	75.6	79.2	89.9	103.2	103.2	103.2	103.2	103.2
Capital Equipment	36.8	0.0	43.3	61.1	61.1	61.1	61.1	61.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	**112.4**	**79.2**	**133.2**	**164.3**	**164.3**	**164.3**	**164.3**	**164.3**
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	324	215	240	233	233	233	233	233

[a] 3% Escalation FY 1996 and FY 1997.
[b] FY 1998–2001 in constant FY 1997 dollars.
[c] BA includes projected construction beyond FY 2001.

References 4.2

The following list of Laboratory publications and internet addresses is a new feature intended to improve the *Institutional Plan's* usefulness in accessing information about our plans and programs.

Area of Laboratory	Publication title or type of information; publication number and/or internet address
Institution	*Framing the Laboratory's Future: A Vision for Lawrence Livermore National Laboratory*, UCRL-AR-117362 *Report for the Regents*, UCAR-10223 "State of the Laboratory," UCRL-52000, Jan.–Feb. 1995 issue of *Energy and Technology Review*
Global Security	Advanced Technology Program (ATP), http://www-atp.llnl.gov/atp *Computer Incident Advisory Capability*, UCRL-TB-116243 *Computer Security Technology Center*, UCRL-TB-116242 *Director's Series on Proliferation*, UCRL-LR-114070 *Inertial Confinement Fusion Annual Report*, UCRL-LR-105820 *Inertial Confinement Fusion Quarterly Report*, UCRL-LR-105821 *LLNL High Explosives Accomplishments: 38 Years of Contributing to the Nuclear Weapons Program*, UCRL-TB-114198 Nonproliferation, Arms Control, and International Security, http://www.llnl.gov/nai/NAI.HTML UCRL-MI-118282 *Secure Systems Services*, www:http://ciac.llnl.gov/cstc/CSTCServices.html *Stockpile Stewardship Program Strategy*, UCRL-LR-117676
Global Ecology	*AVLIS Commercialization Plan*, UCRL-LR-113986 *Energy Research at Lawrence Livermore National Laboratory*, UCRL-MI-115471 *40 Years of Magnetic Fusion at LLNL*, UCRL-TB-111247 *Inertial Confinement Fusion Annual Report*, UCRL-LR-105820 *Inertial Confinement Fusion Quarterly Report*, UCRL-LR-105821 *Innovations in Applied Technology: Recent Activities of the Environmental Protection Program*, UCRL-TB-115976 *Isotope Separation and Advanced Manufacturing Technology Semiannual Report*, UCRL-LR-111984 *Mixed Waste Focus Area Technology Profile*, UCRL-TB-120448 *Regional Atmospheric Sciences Division, Environmental Programs Directorate, Lawrence Livermore National Laboratory*, UCRL-TB-118028
Bioscience	*Biology & Biotechnology Research Program Overview Report and Research Highlights*, UCRL-AR-117208 *OHER Program Director's Overview Report and Research Highlights*, UCAR-10317 *Technologies in the National Interest*, UCRL-AR-119000, October 1994.

4.2 References

Science & Technology

Center for AMS (Accelerator Mass Spectrometry), UCRL-TB-107087
Center for Computational Sciences and Engineering, UCRL-TB-118576; URL:http://www.nersc.gov/doc/Comp_Research/CCSE/ccse.html
Computing at the Leading Edge, National Energy Research in the Energy Sciences, UCRL-TB-111084
Computer Security Technology Center (CSTC), http://ciac.llnl.gov/cstc/CSTCHome.html
Electron Beam Ion Trap Annual Report, UCRL-ID-118274
Energy and Technology Review, UCRL-52000, monthly technical publication
Engineering Research Development and Technology Thrust Area Report, UCRL-53868
ESNet The Energy Sciences Network Overview, UCRL-TB-104203
ESNet The Energy Sciences Network Services, UCRL-TB-115841
FAST The Facility for Advanced Scalable Computing Technology, UCRL-TB-118573, URL:http://www.llnl.gov/liv_comp/fast.html
High-bandwidth Photonics, UCRL-TB-117513
High-Energy Physics, http://:www-phys. llnl.gov
Institute of Geophysics and Planetary Physics Annual Report, UCRL-53809
Laboratory Directed Research and Development Annual Report, UCRL-LR-113717
Laser Programs Highlights, UCRL-ID-109089
Livermore Computing (LC), http://www.llnl.gov/liv_comp/lc.html
National Education Supercomputer Program, UCRL-TB-118582; URL:http://nebbs.nersc.gov
National Energy Research Super Computer Center (NERSC), http://www.nersc.gov/
National Storage Laboratory (NSL), http://www.llnl.gov/liv_comp/nsl/nsl.html
National Storage Laboratory: A Collaboration for Exploring High-Performance Architectures, UCRL-TB-118927
Physics and Space Technology, http://:www-phys.llnl.gov
Physics Department: Summaries of Published Papers and Titles of Meeting Abstracts, UCRL-AR-112942
Software Technology Center, UCRL-TB-115070
Technologies in the National Interest, UCRL-AR-119000
Theory, Modeling, and Computation in Materials Science, UCRL-TB-115735

Industrial Partnership

Defense Conversion, Economic Security, and Technology Policy: A Strategy for Partnerships and Success, UCRL-AR-116223
Industrial Partnerships & Commercialization, 510-423-5660, http://www.llnl.gov
Mechanisms for Industrial Partnerships at LLNL, UCRL-MI-120270
Opportunities for Partnership, UCRL-TB-110794
Partnering with Industry, UCRL-MI-120352
Small Business Program Office, 1-800-LLNL-SBI, http://www.llnl.gov/IPandC/sbi/sbi-home.shtml

Human Resources

Affirmative Action Plan for Women and Minorities, UCRL-AR-111638

Environment, Safety, & Health

Environmental Management: Site Specific Strategic Plan, UCRL-AR-115878
Environmental Protection Implementation Plan, UCAR-10307-94
Environmental Report, UCRL-50027
Environmental Restoration and Waste Management–Applied Technology Semiannual Report, UCRL-LR-112400
Environmental, Safety, and Health Five-Year Plan, UCRL-AR-113539
Environmental, Safety, and Health Management Plan, UCRL-AR-117042
Environmental, Safety, and Health Program at LLNL, UCRL-AR-119618
Livermore Site and Site 300 Ground Water Protection Management Program, UCRL-AR-118435
LLNL NESHAPs Annual Report, UCRL-ID-113867
Remedial Action Implementation Plan for the LLNL Livermore Site, UCRL-AR-110532
Revised Community Relations Plan for the LLNL Livermore Site, June 1993, UCAR-10249-rev.1
Waste Management Plan Update, UCRL-AR-111731

Business & Operations

Budget Office Annual Report, UCAR-10185
LLNL Financial Statements, UCAR-10287
Safeguards and Security Management at LLNL, UCRL-AR-115271

Facilities

Capital Assets Management Process (CAMP) Report, UCRL-AR-110100
LLNL Technical Site Information (2 volumes), UCRL-AR-118365
LLNL Site Development Plan, UCRL-LR-110253
Maintenance Implementation Plan for Nuclear Facilities, UCRL-AR-116710

Acronyms 4.3

AADP	Affirmative Action and Diversity Programs
ACDA	U.S. Arms Control and Disarmament Agency
ACET	Alameda Center for Environmental Technology
ADaPT	Advanced Design and Production Technology
AMIP	Atmospheric Model Intercomparison Project
ARAC	Atmospheric Release Advisory Capability
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ASAP	Alcohol Substance Abuse Prevention
ASCI	Accelerated Strategic Computing Initiative
AVLIS	atomic vapor laser isotope separation
BA	budget authority
BARTA	Bay Area Regional Technology Alliance
BES	Basic Energy Sciences
BMDO	Ballistic Missile Defense Organization
BNL	Brookhaven National Laboratory
BWC	Biological Weapons Convention
Caltrans	California Department of Transportation
CAMP	Capital Assets Management Process
CAT	computer-aided tomography
CCSE	Center for Computational Sciences and Engineering
CDR	conceptual design report
CEA	Commissariat a l'Energie Atomique
CEL-V	Centre d'Etudes de Limeil-Valenton
CIAC	Computer Incident Advisory Capability
CMO	Center for Microelectronics and Optoelectronics
CRADA	cooperative research and development agreement
DNA	deoxyribonucleic acid
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOE/EM	Environmental Restoration and Waste Management
DOE/OAK	Oakland Operations Office
DOE/DP	Defense Programs
DOE/NE	Nuclear Energy
DOE/DP	Defense Programs
DOE/HQ	Headquarters
DWPF	Decontamination and Waste Process Facility
DWTF	Decontamination and Waste Treatment Facility
EAP	Employee Assistance Program
EBIT	Electron Beam Ion Trap
EDAB	Economic Development Advisory Board (Alameda County)
EDI	Electronic Data Interchange
EEO	Equal Employment Opportunity
EIS	environmental impact statement (U.S.)
EIR	environmental impact report (California)
EPA	Environmental Protection Agency
EMATT	Energy, Manufacturing, and Transportation Technologies
ES&H	environment, safety, and health
ESNet	Energy Sciences Network
EW	explosive waste
FAA	Federal Aviation Administration
FAaRS	Facility Assessment and Ranking System
FAST	Facility for Advanced Scalable Computing Technology
FESSP	Fission Energy and System Safety Program
FHWA	Federal Highway Administration
FSU	former Soviet Union
FTE	full-time equivalent (personnel)
FY	fiscal year
FXR	flash x ray
GRATIS	Gamma-Ray Arcminute Telescope Imaging System
HIF	heavy ion fusion
HIPPI	high-performance parallel interface
HRA	Health Risk Assessment
IAEA	International Atomic Energy Agency
ICF	inertial confinement fusion
IFE	inertial fusion energy
IGPP	Institute of Geophysics and Planetary Physics
IP&C	Industrial Partnerships and Commercialization
ISCR	Institute for Scientific Computing Research
ITER	International Thermonuclear Experimental Reactor
KD0,1	Key Decision Zero, One, etc.
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LDRD	Laboratory Directed Research and Development Program
LEA	Laboratory for Experimental Astrophysics

4.3 Acronyms

LIDAR	laser illumination detection and ranging
LIPS	Laboratory Integrated Prioritization System
LLNL	Lawrence Livermore National Laboratory
MFE	magnetic fusion energy
MOU	memo of understanding
MOX	mixed oxide
MWMF	Mixed Waste Management Facility
MSW	municipal solid waste
NAI	Nonproliferation, Arms Control, and Intelligence directorate
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NCST	National Council on Science and Technology
NEPA	National Environmental Policy Act
NERSC	National Energy Research Supercomputer Center
NESP	National Education Supercomputer Program
NEST	Nuclear Emergency Search Team
NIF	National Ignition Facility
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NOD	Notice of Deficiency
NO_X	nitrous oxide
NPT	Non-Proliferation Treaty
NRC	Nuclear Regulatory Commission
NSL	National Storage Laboratory
NSSC	Nuclear Systems Safety Center Consortium
OHER	Office of Health and Environmental Research
OMB	Office of Management and Budget
OPEX	operating expenses
ORR	Operational Readiness Review
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PCR	polymerase chain reaction
PEIS	program-wide environmental impact statement
PRISM	Property Information System
RAP	Recovery Assistance Program
RGS	reflection grating spectrometer
SCI	Sensitive Compartmentalized Information
SDP	Site Development Plan
SEROP	Strategic Environmental R&D Program
SLAC	Stanford Linear Accelerator Center
SNL	Sandia National Laboratories
START	Strategic Arms Reduction Treaty
SXRP	stellar x-ray polarimeter
TAISIR	temperature and imaging system infrared
TEAM	technologies enabling agile manufacturing
TCE	trichloroethylene
TPC	total project cost
TPX	Tokamak Physics Experiment
TTI	Technology Transfer Initiatives
U-AVLIS	uranium atomic vapor laser isotope separation
UC	University of California
USEC	United States Enrichment Corporation
VA	Veterans Administration
VOC	volatile organic compound
WAC	waste-acceptance criteria
WMD	weapons of mass destruction
XMM	X-ray Multimirror Mission

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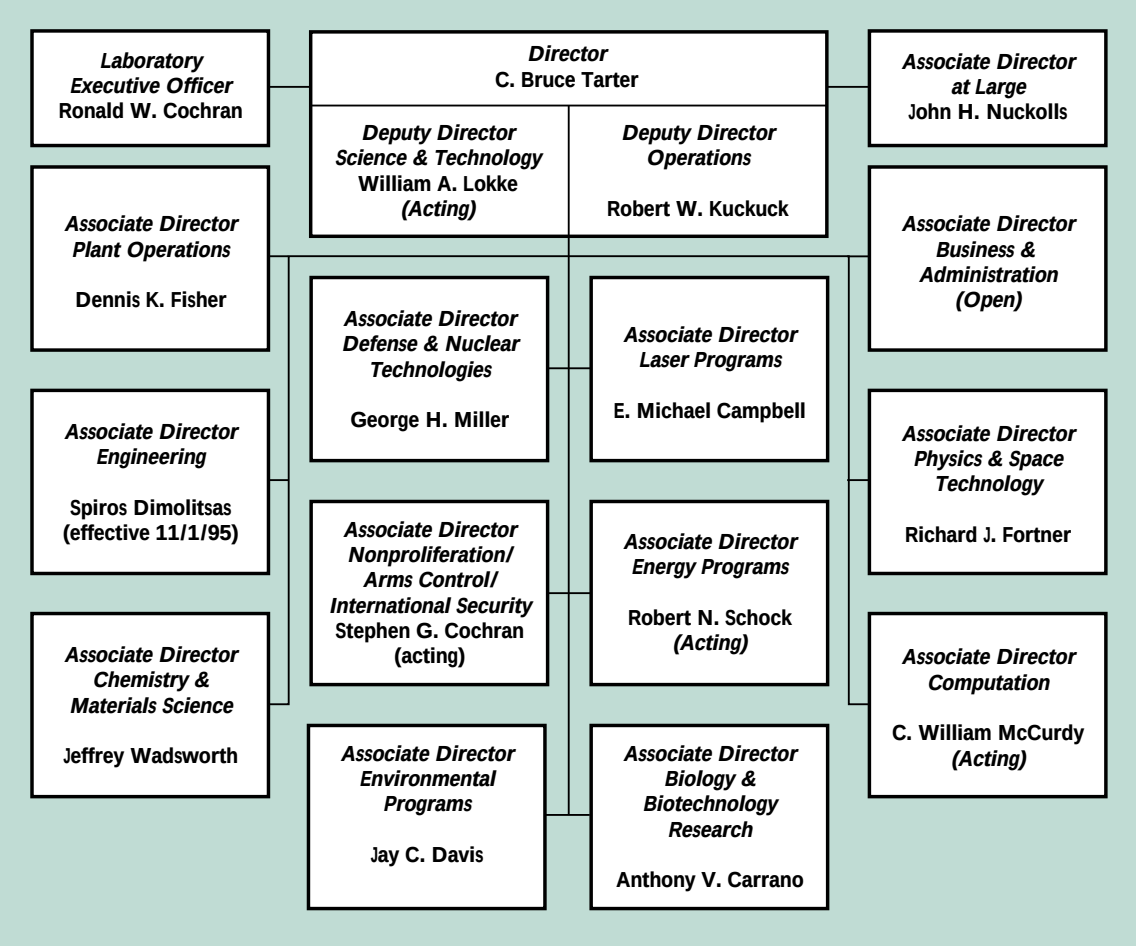

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