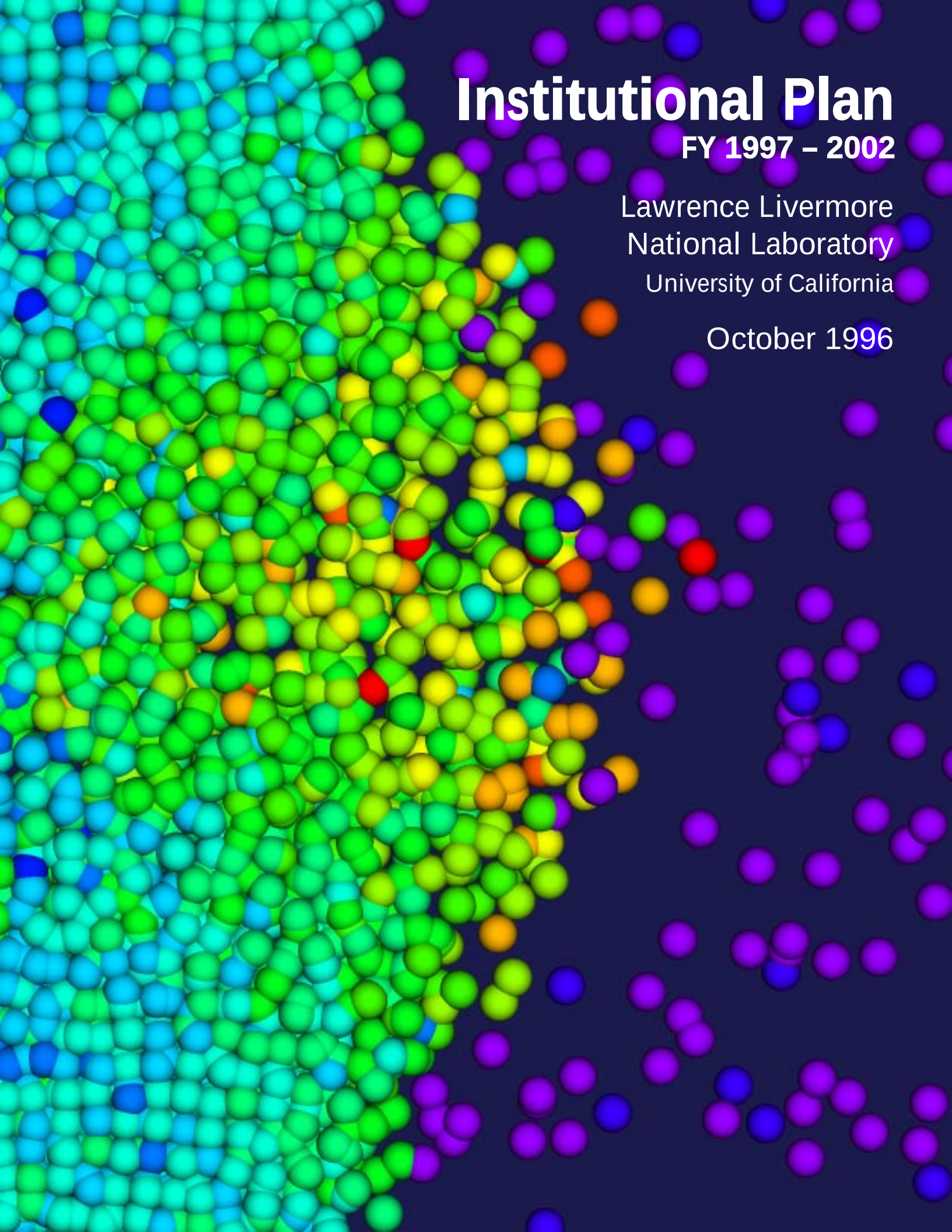

Institutional Plan

FY 1997 – 2002

Lawrence Livermore
National Laboratory
University of California

October 1996

Cover image: The DOE's Stockpile Stewardship and Management Program will assure that we can depend on experiments and simulations to predict, detect, evaluate, and correct problems affecting nuclear weapons without nuclear testing. An example of the simulations activities at Livermore is the molecular-level sequence of a shock wave from a piston driving into a piece of metal is shown on the cover. Developing molecular dynamics simulations using elements of the DOE's Accelerated Strategic Computing Initiative (ASCI) is made possible through partnering of massively parallel processing, software development, and data storage among the nation's three nuclear weapons laboratories.

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Institutional Plan

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Lawrence Livermore
National Laboratory
University of California

October 1996

UCAR-10076-15

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. The *Institutional Plan* is a Director's Office Publication, produced by the Technical Information Department, under the direction of the Office of Policy, Planning and Special Studies.

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. (This will be inserted in the final version of the *Institutional Plan*.)
	Section 1.1, A Framework for the Laboratory's 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.

Contents

Director's Statement 1

1 Planning for the Future 3

1.1 A Framework for the Laboratory's Future 5

Mission 5

Core Values: Integrity, Excellence, and Commitment 5

Vision and Goals 6

Applying Science and Technology to Solve Complex Problems 7

• Multidisciplinary Integration • Nuclear Science and Technology • Lasers and Electro-Optics • Computer Simulation of Complex Systems • Advanced Sensors and Instrumentation • Biotechnology and Health Care • Advanced Process and Manufacturing Technology

Focusing on Vital National Needs 9

National Security

• Stockpile Stewardship • Nonproliferation • Dismantlement • Advanced Conventional Weapons

Energy and Environmental Science

• Environment • Energy • Transportation and Advanced Manufacturing

Bioscience

• Genomics • Disease Susceptibility • Bioinstrumentationand Health-Care Technology Bioscience

Partnering as a Way of Doing Business 12

• Collaborations with Other Laboratories • Partnerships with Industry • Collaborations with Academia • Partnerships in California • Partnerships with Other Federal Agencies • International Partnerships

Managing Effectively in a Changing Business Environment 14

• Structuring for the Future • Assuring a Vital Laboratory Workforce • Managing for Quality • Achieving Excellence in ES&H • Opening up the Laboratory for Effective Partnering

Focus and Change 15

1.2 Strategic Plans 17

National Security 17

• Stewardship of U.S. Nuclear Weapons • Nonproliferation, Arms Control, and International Security • Dismantlement • Advanced Conventional Defense

Energy and Environmental Systems 21

• Magnetic Fusion Energy • Inertial Fusion Energy • Fission Energy and Systems Safety • Atomic Vapor Laser Isotope Separation (AVLIS) • Alternative and Advanced Energy • Environmental Programs • Energy, Manufacturing, and Transportation • Basic Energy Sciences

Bioscience 27

• Biotechnology and Health

Science and Technology 28

• Laboratory Directed Research and Development Program • Physics and Space Technology • Chemistry and Materials Science • Engineering • Computation

Collaborations 33

• Industrial Partnerships and Commercialization • University Collaborations • Science Education

Operations 36
• Management Practices • Human Resources • Environmental, Safety, and Health Management • Communication and Information • Site and Facilities

1.3 Initiatives 43

Assistant Secretary for Defense Programs 43
• National Ignition Facility (DP) • Contained Firing Facility (DP) • Accelerated Strategic Computing Initiative (DP) • Advanced Design and Production Technology Program (DP) • Accelerator Production of Tritium (DP)

Office of Energy Research 47
• Genomics and Structural Biology Research Laboratory (KP) • Structural Biology (KP) • Mammalian and Microbial Genomes (KP) • Center for HealthCare Technologies (KP) • Hydrogen as an Alternative Fuel (AR)

2 Scientific and Technical Programs 51

2.1 Department of Energy Sponsors 53

Assistant Secretary for Defense Programs 53

Stockpile Stewardship
• Infrastructure and Core Competencies • Weapon Physics • Computations and Modeling • Hydrodynamic Test Facilities • Inertial Confinement Fusion • Phebus–France: High-Energy Laser–Matter Interactions • Radiation Effects • Nuclear Weapon Information • Industrial Partnerships

Stockpile Management
• Enhanced Surveillance • Advanced Design and Production Technologies • Process Development • Dismantlement and Long-Term Storage • Pit Processing and Plutonium Recovery • Plutonium Disposition • Nuclear Safety • National Atmospheric Release Advisory Capability

Defense Technology (DOE/DoD Collaborations)
• Energetic Materials • Demilitarization • Special Munitions • Hydrodynamics Codes • Conflict Simulation

Office of Nonproliferation and National Security 63
• Intelligence Assessments • Support to the International Atomic Energy Agency • Detecting and Monitoring Nuclear Weapon Activities • Emergency Response and Measures Against Nuclear Smuggling • Control of Nuclear Material, Defense Conversion in the New Independent States, Arms Control, and Treaty Verification • Safeguards and Security Planning for Protection of Russian Material• Electronic Systems for Safeguards and Security • Computer Security Technology Center

Office of Fissile Materials Disposition 67
• Disposition of Fissile Material • Disposition of Surplus Fissile Material • Safeguards and Security of Nuclear Materials Disposition

Office of Energy Research 68

Fusion Energy
• Collaboration on DIII-D • International Thermonuclear Experimental Reactor • Advanced Fusion Assessment Program • MFE Theory and Computations • Heavy Ion Fusion

High-Energy and Nuclear Physics
• B-factory • Nuclear Physics

Health and Environmental Research
• Health and Biotechnology • Health Effects • Genomics
• Structure–Function Analysis • Radiation Oncology • Health Care
• Climate and Atmospheric Sciences • Atmospheric Radiation Measurement Program
Basic Energy Sciences
• Materials Sciences • Chemical Sciences • Geosciences • Advanced Energy Projects
Computer Systems Security
• Secure Software Distribution System
Assistant Secretary for Environmental Restoration and Waste Management **74**
Environmental Restoration
• Remediation Technology • Site Restoration
Waste Management
Waste Treatment
• Robotic Handling Systems
Assistant Secretary for Environment, Safety, and Health **77**
• Natural Phenomena Hazards Policy and Standards • Packaging Certification and Training
• Packaging and Transportation Technical Support
Office of Nuclear Energy **78**
• Uranium Handling
Office of Civilian Radioactive Waste Management **78**
• Yucca Mountain Project
Assistant Secretary for Fossil Energy **79**
Assistant Secretary for Energy Efficiency and Renewable Energy **79**
• Refinery of the Future • Hydrogen as a Fuel • Hydrogen Production from Municipal Waste • Optimized Hydrogen-Fueled Internal Combustion Engine • Chemical Kinetic Modeling of Hydrogen Applications • Hydrogen Storage in Engineered Microspheres
• Hydrogen Infrastructure Studies • Energy Storage: Fuel Cells and Supercapacitors
• Rapid Prototyping and Multilayer Coating Manufacturing • Low-Temperature Solid Oxide Fuel Cell • Hydrocarbon Combustion Modeling • Resource Recovery
Assistant Secretary for Human Resources and Administration **82**
• Computer Incident Advisory Capability
Assistant Secretary for Policy and International Affairs **82**
• Assessments of the Potential of Energy Technologies • Nuclear Materials Stewardship
DOE Field Offices and Other Laboratories **83**
• Pantex Plant—Security Systems Upgrades • Idaho National Engineering Laboratory—Electronic Security Systems • Nuclear Criticality Safety Support to Oak Ridge Field Office
• Safeguards and Security Support to Savannah River Operations Office
• Technical Support to Albuquerque Operations Office

2.2 Department of Defense Sponsors **85**
Office of the Secretary of Defense **85**
• Counterproliferation • Radar Ocean Imaging
• Strategic Environmental Research and Development Program
Joint Chiefs of Staff **86**
• Conflict Simulation Systems
Defense Advanced Research Projects Agency **87**
• Vapor Phase Manufacturing Program • Diamond Cold Cathode Technology for Field Emission Displays Manufacturing • Microfabricated Chambers for Chemical

Reactions • Optical Computer Interconnects • Optoelectronic Device Packaging • Field Emission Flat-Panel Display Technology
Ballistic Missile Defense Organization 88
• Clementine 2 • Diamond-Turned Optics • National Test Facility Security System Upgrades
Defense Nuclear Agency 89
• Man-Portable Land-Mine Detector
Multiple DoD Offices 89
• Advanced Conventional Weapons Systems • High-Power Radiofrequency Countermeasure Techniques • Warhead Design Technology • Advanced Materials • High Explosives • Demilitarization for Molten-Salt Destruction
Department of the Army 90
• Modular Armor
Department of the Navy 90
• Laser Radar • Wall Surveyor • Alameda Naval Air Station FastTrack Project • Kara Sea/Russian Naval Waste Assessment
Department of the Air Force 91
• Night-Ellipse Project: Backlash • Tactical Imaging Constellation Architecture Study • Satellite Imaging • Electronic Commerce

2.3 Other Sponsors 93
Arms Control and Disarmament Agency 93
• Defense Conversion Workshops
Veterans Administration 93
• Electronic Commerce
Environmental Protection Agency 93
• Biogeochemical Processes and Climate Modeling
National Aeronautical and Space Administration 93
• Environmental Management Technology Development • Atmospheric Sciences Research • Superconducting X-Ray and UV Spectrometers • Observations and Analysis of Accretion-Powered Cosmic Sources • Spectroscopic Modeling • Gamma-Ray Optical Counterpart Search Experiment
Federal Highway Administration 95
• Highway Design • Bridge Deck Inspection
California Department of Transportation 95
Federal Aviation Agency 95
• Human Factors in Security
Nuclear Regulatory Commission 96
• Support to Office of Nuclear Materials Safety and Safeguards • Support to Office of Nuclear Reactor Regulation • Support to Office of Nuclear Regulatory Research • Information Technologies
National Institutes of Health 96
• Detection of Low Levels of Damage to Proteins and DNA • Chemical Carcinogens
United States Enrichment Corporation 97
• Atomic Vapor Laser Isotope Separation • Uranium Feed Preparation • Alternative Applications of AVLIS
Work for Others 98
• Center for Accelerator Mass Spectrometry • California Department of Toxic Substance Control

2.4 Special Programs 99

Industrial Partnerships and Commercialization 99

• Energy, Manufacturing, and Transportation Technologies • Center for Microelectronics and Optoelectronics • Partnership for a New Generation of Vehicles • Center for Healthcare Technologies

Laboratory Directed Research and Development Program 103

University Collaborative Research 104

• Department of Applied Science Student Employer Program • Institute of Geophysics and Planetary Physics • A Search for Dark-Matter Axions • Institute for Scientific Computing Research • Electron Beam Ion Trap • Glenn T. Seaborg Institute of Transactinium Science • Energetic Materials Center • Open Computing Facility • Campus–Laboratory Collaboration Program • Program for Climate Model Diagnosis and Intercomparison

Science and Mathematics Education 106

• Curriculum Improvement • Teacher Enhancement • Student Support • Educational Technology • Education Outreach • Diversity Efforts

User Facilities 110

• Center for Advanced Manufacturing and Productivity • Livermore User Facility for Inspection and Characterization • Virtual Laboratory Testbed

3 Institutional Infrastructure 111

3.1 Management Practices 113

• Diversity Action Steering Committee • Cost-Cutting Iniative Task Force • Workforce Restructuring Plan

Audit and Oversight 113

Contract Administration 114

Budget, Finance, and Resource Information and Analysis 114

Procurement and Materiel 115

Business Affirmative Action and Vendor Assessments 115

Property Management 115

Safeguards and Security 116

Electronic Data Interchange 117

Travel Service 117

3.2 Human Resources 119

Workforce Management 119

Workforce Restructuring

Human Resources Organiznitiatives

• Career Center • RESUMIX • Formal Brokering • Use of Competencies in Workforce and Performance Management • Information Technology • Employee Wellness and Fitness

Diversity and Affirmative Action 121

• Building Diversity • Diversity Survey and the Diversity Action Steering Committee • Affirmative Action

3.3 Environmental, Safety, and Health Management 127

Current Conditions 128

• Air Emission Standards • Waste Water Discharges • Storm-Water Discharges • Oil Pollution Prevention • Hazardous Waste Operations • Assessing the Impact of LLNL Operations • Sensitive Species Protection and Management • Radionuclide Emission Sources • Waste Minimization • Chemical Tracking • Waste Certification Program • Corrective Actions

Environmental Training 131

• Environmental and Waste Management Training • Resource Conservation and Recovery Act Training • Superfund Amendments and Reauthorization Act /Occupational Safety and Health Act Training • Department of Transportation Training • Radioactive Waste Certification Program • Environmental and Waste Management Education

Safety and Health 132

• Industrial Hygiene • Radiation Protection • Industrial Safety • Case Management • Ergonomics Program • Employee Assistance and Other Health Programs • Health Promotion • Stockpile Dismantlement Health and Safety Effects • JIGSAW-95 • Emergency Medical Services

3.4 Communication and Information 135

Chief Information Officer 135

Administrative Information 135

Scientific and Technical Information 135

Information Archive 136

Information to Employees and the Public 136

Congressional Support 137

Community Involvement 137

3.5 Site and Facilities 139

The Livermore Site 139

Site 300 139

Facilities Maintenance 141

Facilities Plans and Options 141

Facilities Resource Requirements 143

• National Ignition Facility • Site 300 Contained Firing Facility • Protection of Real Property—Roof Replacement • Site 300 Fire Station/Medical Facility • Sensitive Comparted Information Facility • Site-wide Storm Drain Rehabilitation • Building 511 Renovation Project • Building 151 Plant/Seismic Upgrade and Office Modification • Genomics and Structural Biology Research Facility

4 Appendices 147

4.1 Program Resource Requirement Projections 149

4.2 References 171

4.3 Acronyms 175

4.4 Index 177

4.5 Organization Chart 183

Director's Statement

The end of this institutional planning period—the year 2002—will mark the 50th birthday of the Lawrence Livermore National Laboratory. It will be an occasion to reflect on 50 years of Laboratory accomplishments contributing to national security and the advance of science and technology on many fronts. A crucial part of that history is occurring right now. Our national security activities and other major programs have changed significantly to meet new national needs of the 1990s. What we accomplish in the next five years and the steps we take during this planning period to become the Laboratory of the 21st century are critically important.

Livermore must continue to be a resource the country can turn to when faced with vital national challenges that involve science and technology and that demand innovative and effective solutions. By integrating many, often disparate, areas of science and engineering, we transform basic-science concepts into technologies that solve real-world problems. In the process, we expand the boundaries of fundamental science. Mission-directed, multidisciplinary teamwork is the key to Livermore's successes.

As a national security laboratory, we are focusing our efforts on two of the nation's top priorities—stewardship of the U.S. nuclear stockpile and stemming the proliferation of weapons of mass destruction. The U.S. successfully led the international initiative to eliminate nuclear test explosions. Together with the Department of Energy and Los Alamos and Sandia national laboratories, we remain responsible for ensuring the safety, security, and reliability of the nation's nuclear

C. Bruce Tarter
Director

stockpile. To meet this challenge, scientific excellence in laboratory experimentation and computational modeling of nuclear weapons must substitute for nuclear testing, now banned by international treaty. We are dedicating increased effort to the surveillance and continuing evaluation of the existing stockpile. We are beginning to build the facilities vital for long-term stewardship, such as the National Ignition Facility. And, we are working with U.S. industry to advance the state-of-the-art in scientific computing by factors approaching 10,000 so that we can better simulate the physics of nuclear explosions.

We live in a world where the use of weapons of mass destruction is an all-too-real threat despite remarkable progress in arms control that includes indefinite extension of the Nuclear Nonproliferation Treaty. U.S. leadership in international efforts to reduce proliferation dangers relies heavily on the DOE laboratories' technology development, analysis, and policy support activities. We apply our nuclear expertise and other unique capabilities to counter the threats posed by proliferation and nuclear terrorism. As an example, sensor and forensic technologies developed at Livermore promise to be a major factor in detection and characterization of weapons of mass destruction in support of arms control initiatives and deterrence.

Our challenging national security activities necessitate a broad range of core strengths at the Laboratory. These include weapons physics and nuclear materials, advanced laser systems, scientific computing, materials science, sensors and instrumentation, and engineering technologies and systems integration. We apply and enhance these special capabilities by also focusing on other missions of national importance where we can make unique and valuable contributions.

Several examples illustrate how Livermore applies its special capabilities to make major advances in many other areas. In energy, the United States Enrichment Corporation has designated our technology for laser enrichment of uranium as the way to make reactor fuel in the 21st century. We must demonstrate that this process we developed over the past 15 years can work in a commercial setting. In the bioscience area, a Joint Human Genome Institute has been formed, uniting the efforts of Lawrence Livermore, Lawrence Berkeley, and Los Alamos National Laboratories. The joint center will enable researchers to contribute to the Human Genome Project more effectively and efficiently as we move to new challenges. For the last half dozen years, we have been mapping with

markers to lay out the structure of the genome; now we have to sequence it, that is, fill in all the details—a much more production-oriented activity. And, in the area of environmental remediation, we have proposed an accelerated clean-up of our site that uses recently developed technologies to meet regulatory goals much sooner and at much lower cost than conventional methods.

In all of our activities, we continue the innovative research that is the hallmark of the Laboratory. We earned six R&D 100 awards, tied for tops in the country; pioneered the petawatt laser, the highest laser power ever achieved; discovered metallic hydrogen; and recorded major achievements in health-care technologies.

We also must meet the high operational expectations of the outside world while working within increasingly tighter budgets. Efficient, cost-effective operations and a quality workforce with an appropriate mix of skills will enable the Laboratory to better meet current and future program needs. This requires special attention to the human resources, as well as to our business practices and facilities. We are now taking actions to standardize operations, improve management practices, reduce the size of the administrative workforce, and provide a more productive work environment. We have made special commitments to create a work environment that keeps safety as a top priority, that enhances opportunities for all members of an increasingly diverse workforce, and that provides a physical site better matched to interactions with the growing number of industrial and academic partners.

The University of California has again assessed our work as excellent and outstanding in nearly all areas—both scientific and operational. And we are pleased with DOE's and UC's decisions to enter negotiations to extend the UC contract for another five years.

This Institutional Plan details the steps we are taking as we enter the 21st century—our strategic plans and ongoing planning efforts, our current program accomplishments, and our new initiatives. Overall, our tasks are clear. We must deliver on our challenging programmatic commitments; we must continue with our efforts to be an efficient, competitive institution; and we must keep our programs and our competencies aligned with the future directions of the country.

Section 1

Planning for the Future

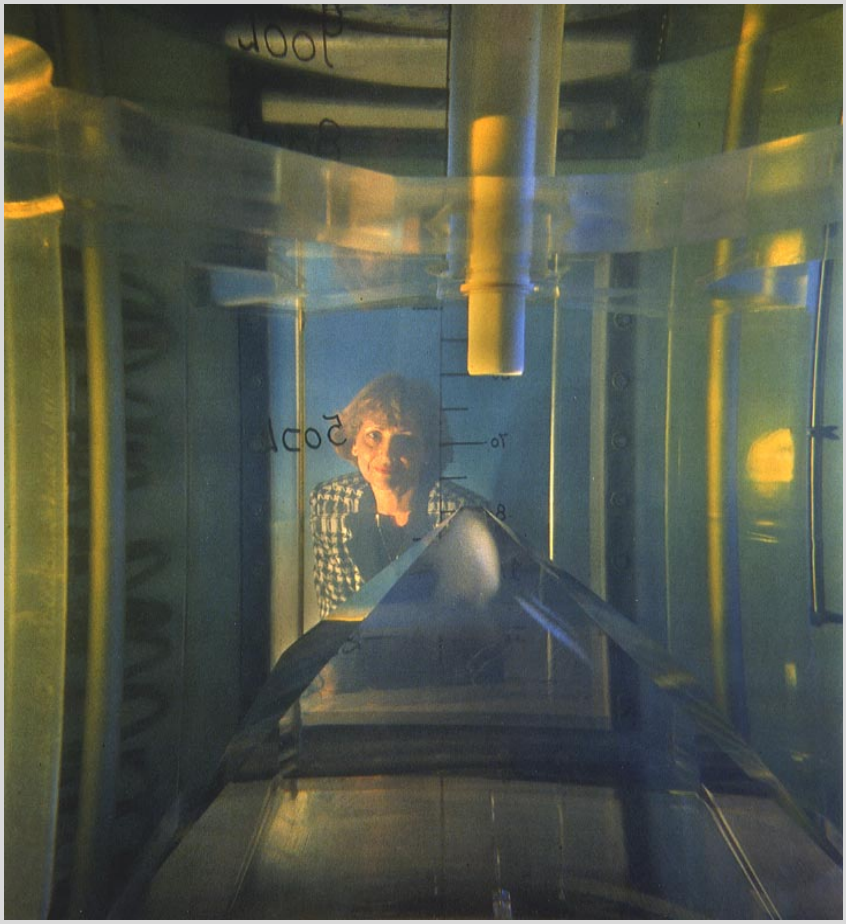


Photo: Livermore physicist Natalia Zaitseva helped pioneer the fast-growth method for very large KDP (potassium dihydrogen phosphate) crystals, a critical design element for the 192-beam National Ignition Facility planned for Livermore.

A Framework for the Laboratory's Future 1.1

BUILDING upon President Clinton's announcements last fall, which reaffirmed a long-term role in national security for the three DOE defense laboratories, Livermore embarked on the development of a more comprehensive strategic plan. We began this task in February 1996. This year-long activity, conducted primarily through five Strategic Councils, is focusing on a three- to five-year outlook and will lead to revamped roadmaps for Laboratory programs. Our *Institutional Plan* provides a point of departure for our efforts, beginning with this section, which updates *Framing the Laboratory's Future: A Vision for Lawrence Livermore National Laboratory* (1994).*

National examination of the future needs for science and technology will undoubtedly influence our missions in ways that are not yet well defined. However, in national security we do have clear and urgent responsibilities: to ensure the safety, security, and reliability of U.S. nuclear deterrent forces and to prevent or counter the proliferation of weapons of mass destruction. The Laboratory also has very significant contributions to make in the areas of energy and environmental technologies that are needed to ensure sustainable growth of our economy. In addition, LLNL-developed technology can lead to advances in bioscience to improve human well being. The Laboratory's Councils on National Security, Energy and Environmental Systems, and Biosciences are planning our program activities in these three significant mission areas. Two other councils also have important responsibilities: the Council on Strategic Science and Technology focuses on basic science programs and the scientific base at the Laboratory, and the Council on Strategic Operations is responsible for operations and management issues.

Mission

Lawrence Livermore National Laboratory is a national security laboratory whose mission is to solve complex scientific and technical problems of national importance. The hallmark of this laboratory is our ability to translate basic-science concepts into technologies that solve complicated real-world problems and expand the boundaries of fundamental science. We are focusing our efforts on two of the nation's top priorities—stewardship of the U.S. nuclear stockpile and stemming the proliferation of weapons of mass destruction—and on other missions of national importance where we can make unique and valuable contributions.

Core Values: Integrity, Excellence, and Commitment

To provide the great science and technological excellence needed to meet critical national missions, we must cultivate and inspire a quality-driven Laboratory staff guided by the highest principles. Our contract with the nation will be evaluated by how well we adhere to our core values.

- 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 most challenging technical problems, we will provide the best science, engineering, management, and people. This requires **excellence** in:
  - – Discovering and implementing creative, innovative, effective 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 environmental protection to achieve a high level of accountability in an

*Other formative bases for this *Institutional Plan* include the Department of Energy's responses to the Galvin Commission's *Alternative Futures for the Department of Energy National Laboratories* (February 1995); the *Stockpile Stewardship and Management Program* (May 1995) and draft plans; *Energy R&D: Shaping our Nation's Future in a Competitive World* (June 1995); the *Draft Programmatic Environmental Impact Statement for Stockpile Stewardship and Management* (February 1996); and the *Strategic Laboratory Missions Plan* (July 1996).

atmosphere of continuous improvement.
– Leading and participating in cost-effective partnerships.

• As a national laboratory, we will meet the nation's science and technology needs. This requires **commitment** to:
– Focusing our science and technology on national objectives.
– Meeting the goals and requirements of our customers.
– Continuously improving our productivity and efficiency.

Vision and Goals

The Department of Energy's national security 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 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.

Science, technology, and the world context have evolved through the laboratories' lifetime, but never so dramatically as in the past decade. National priorities are markedly different than they were even ten years ago. The success of our Laboratory, both today and in the future, demands flexibility to meet new national needs.

Experience has shown that these laboratories are most valuable when:
• The national interest is at stake.
• The best science and technology are required.
• Expertise in a variety of disciplines must be integrated.
• Large and complex research facilities are needed.
• The technical risk and the potential rewards are high.
• A sustained commitment is needed.
• Without national investment, the job will go undone.

Livermore was established to perform research on nuclear weapons and magnetic fusion energy, and national security remains the Laboratory's defining responsibility. That mission provides a foundation for wide-ranging capabilities and special expertise, which in turn foster strong programs in other areas that reinforce national security activities. We address pressing national and global challenges of long-term importance and make unique and valuable contributions in three principal areas:
• National Security.
• Energy and Environmental Science.
• Bioscience.

Our national security program has two major thrusts: to ensure the safety, security, and reliability of the U.S. nuclear stockpile, and to prevent or counter the proliferation of weapons of mass destruction. We will carry out our stockpile responsibilities through the Department of Energy's comprehensive Stockpile Stewardship and Management Program. Our nonproliferation activities will also be conducted as part of a nationally integrated effort. For both of these thrusts, the safe and secure "build down" of the world's stockpiled weapons will be a continuing responsibility. We will also work with the Department of Defense to enhance the nation's ability to use advanced technologies to contain regional conflicts.

Our energy and environmental programs build a scientific and technological base for a sustainable future. Integrating the demands of the world's economy with the needs of the environment is a crucial national and global issue. Achieving a balance will require energy sources that are safe, clean, and affordable as well as manufacturing processes and consumer goods that make wise use of resources and provide for the protection of the environment. We will contribute to all aspects of this challenge—determining and modeling the effects of human activities on the environment, 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 an exciting frontier of research. For the first time in history, the tools exist to decipher the genetic blueprint contained in DNA and reveal the basic science of life. This knowledge will make it possible to ameliorate, cure, or even prevent genetic diseases. We will contribute to efforts to improve the effectiveness and decrease the cost of health care through novel applications of Livermore-developed technologies. The fruits of our biology and biotechnology research will carry over into agriculture, environmental management, and industry.

Beyond these 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 will continue to foster 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 for our Laboratory, we will rely on our excellent and diverse staff. Quality management systems will ensure that Laboratory operations are cost-effective and meet measurable performance standards.

Attaining these goals will also require new forms of cooperation among the national laboratories, universities, and industry. Key national facilities are being built for use by multi-institutional teams of researchers, and laboratory sites are being made more readily accessible to outside partners.

Our vision for our Laboratory's future aligns well with the Department of Energy's strategic plan: protecting national security and reducing the nuclear danger, enhancing the nation's energy security, cleaning up and protecting the environment, and advancing the frontiers of science and technology. We will build on and enhance partnerships with Departmental staff to ensure excellence in the achievement of our common goals.

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 national security and other vital scientific needs of the nation.

Applying Science and Technology to Solve Complex Problems

To solve complex problems in its mission areas, Livermore has developed wide-ranging capabilities in applied science and technology and unique expertise in selected areas. This suite of strengths (see Table 1.1-1) enables leading-edge research and development in current and future technical endeavors.

Multidisciplinary Integration

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 weapons 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 satellite.

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.

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. We have applied our increasing knowledge to improve the performance, security, and safety of nuclear systems. To ensure the safety and reliability of the U.S. nuclear stockpile without nuclear testing, we must depend on a priori physics knowledge, detailed computer simulations, and advanced non-nuclear experiments at special national facilities that can create conditions of extreme conditions of matter. Our nuclear science expertise is also applied to stem nuclear proliferation; to develop innovative, lower-cost techniques for environmental cleanup; and to improve the efficacy of radiation treatments of cancer.

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), a prototype beamline for the National Ignition Facility, and the industrially qualified atomic vapor laser isotope separation (AVLIS) system. The laser for the planned National Ignition Facility 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.

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

● Critical to program
• Significant to program

Mission Area / Major Activity	Multidisciplinary Integration	Nuclear Science and Technology	Lasers and Electro-optics	Computer Simulation	Sensors/ Instrumentation	Biotechnology	Process/ Manufacturing
National Security							
Stewardship of U.S. Nuclear Weapons	●	●	●	●	●		●
Nonproliferation and Arms Control	●	●	●	●	●	●	•
Disposition	●	●		●	●		●
Technology Infrastructure	●	●	●	●	●		●
Restructuring DOE National Security Enterprise	●	●		•	•		●
Advanced Conventional Weapons	●	•	●	●	●		•
Energy and Environmental Science							
Environmental Science	●	•	•	●	●	●	•
Environmental Technology	●	•	•	●	●	●	•
Magnetic Fusion Energy	●	●	•	●	●		•
Inertial Fusion Energy	●	●	●	●	●		•
Fission Energy	●	●		●	•		
Atomic Vapor Laser Isotope Separation	●	•	●	●	•		●
Conventional/Alternative Energy	●			●	•		•
Transportation	●			•	•		•
Manufacturing	●		●	●	●	•	●
Bioscience							
Genomics	●		•	●	●	●	•
Disease Susceptibility	●		•	●	•	●	•
Biomedicine and Health Care	●	•	•	●	●	●	•
Laboratory Science and Technology							
Basic Energy Sciences	•	•	•	●	•		●
Laboratory Directed Research and Development	●	●	●	●	●	●	●
Industrial Technology Base	●	●	●	●	●	●	●
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, the properties of potential new materials, and changes in global climate. This work requires world-class computational facilities. We operate a large national-security computer center and maintain an extensive open computing environment. Computer simulation, using experimentally validated models, is our method of first resort for examining and evaluating new concepts and systems.

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 phenomena. Concurrent development of fiber optics, microelectronics, and data-manipulation techniques has given us the capability to design and build sophisticated measurement and information-processing systems. These systems are finding widespread use in national security, environmental monitoring, and fundamental science.

Biotechnology and Health Care

Our biomedical sciences program was established three decades ago to determine the effects of ionizing radiation on humans. Over the years, we have extended our focus to understanding health issues at the molecular level and developing cost-effective, improved health-care technologies. This focus is possible because we can draw on Livermore's unique 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, chromosome paints, gene-mapping and DNA-sequencing technologies, and libraries of mapped DNA segments. Our state-of-the-art capabilities are also supporting innovative research in structural biology and the development of novel health-care technologies.

Advanced Process and Manufacturing Technology

Through our focus on applied science, we have developed a broad-based understanding of processing and manufacturing technologies. Livermore is specifically known for innovation in chemical, biological, and photon processes as well as advanced materials, precision engineering, microfabrication, nondestructive evaluation, and complex-system control and automation. We are applying this expertise to the development of efficient, environmentally responsible technologies for stockpile stewardship, advanced energy and transportation systems, manufacturing, and the management of natural resources.

Focusing on Vital National Needs

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

National Security

The dramatic reduction of the threat of global nuclear conflict is one of the greatest accomplishments of this era. Nevertheless, nuclear dangers remain today and will be with us for the foreseeable future. Dangers also arise from the threat of chemical and biological weapons.

We have a continuing responsibility to help maintain a strong and flexible national defense. We are tackling the challenges of ensuring the safety, security, and reliability of the U.S. nuclear stockpile, preventing nuclear proliferation, and dismantling and disposing of the materials from thousands of nuclear weapons. We are also applying our capabilities to meet the needs of the Department of Defense for enhanced sensors, information technologies, and advanced conventional weapons.

Stockpile Stewardship

Now that the U.S. is no longer conducting nuclear tests, new ways of ensuring confidence in the safety, security, and reliability of the U.S. nuclear stockpile are needed. As stockpile weapons age beyond their

original design lifetime and beyond our base of experience, we will rely on advanced non-nuclear experiments and detailed computer simulations instead of an empirical approach to stockpile stewardship. The Department of Energy and the national security laboratories have jointly developed the Stockpile Stewardship and Management Program to:

• Advance the state of the art in supercomputing and numerical simulation to develop the computational capabilities required to compensate, to the extent possible, for the ban on nuclear testing.
• Conduct sophisticated non-nuclear experiments to validate our computer models and improve our ability to anticipate potential problems (particularly those related to aging) in stockpile weapons.
• Use advanced facilities, like the National Ignition Facility and the Contained Firing Facility, to provide data needed to resolve stockpile issues and to attract and train the high-quality staff necessary for the stewardship program.
• Work with the weapons production plants to develop cost-effective, environmentally responsible materials and processes for refurbishing or remanufacturing weapons.
• Develop new procedures for formally certifying the safety, security, and reliability of stockpile nuclear weapons.

Nonproliferation

Preventing, detecting, reversing, and responding to the proliferation of weapons of mass destruction are top priorities for national and global security. To support these goals, we will:

• Support cooperative activities with Russia and the other Newly Independent States to speed the safe and secure dismantlement of their nuclear weapons and the conversion of their weapons laboratories to civilian projects.
• Provide expertise and technology for dismantling and tracking nuclear weapons, weapon components, and fissile materials.
• Develop more effective technical capabilities for detecting and intercepting smuggled nuclear materials and for locating and neutralizing battlefield and terrorist nuclear explosives.
• Provide intelligence-based assessments to the U.S. government of existing and potential activities worldwide related to weapons of mass destruction.
• Develop sensors for detecting signatures of foreign programs to develop weapons of mass destruction, for helping verify international arms-control and inspection agreements, and for supporting military operations in the presence of proliferation threats.
• Assess counterproliferation strategies using computer-based conflict simulation and comprehensive systems analysis.

Dismantlement

We have enduring responsibilities for ensuring the safe and environmentally sound dismantlement of weapons retired from the U.S. stockpile. Of particular concern are the safe storage and long-term disposition of the nuclear materials. To this end, we will:

• Develop technologies and procedures for verifying the dismantlement of nuclear weapons, for processing the materials for disposition, and for placing the nuclear materials under international safeguards without releasing information that would aid proliferant nations.
• 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 applied to Department of Defense needs in the areas of highly intelligent weapons systems, high-performance explosives, ballistic missile defense, information security and management, and high-technology countermeasures. These activities will provide the dual benefits of maintaining and enhancing our nuclear-weapon core competencies while addressing challenging military requirements.

Energy and Environmental Science

A sustainable, growing economy requires that the demands of production and consumption be in harmony with the global environment. This balance requires energy that is abundant, safe, and clean and transportation systems that do not pollute. This balance also requires production and consumption processes that use resources wisely, recycle materials efficiently, and dispose of wastes safety. In addition, to make wise decisions about tradeoffs among competing objectives, we need sophisticated capabilities for understanding, modeling, and assessing risk. For these advances to be most effective, they must address the global situation and must provide for

widespread economic development without causing adverse ecological changes.

Achieving this vision will require the best efforts of the world's scientific and political institutions. Re-engineering the industrial–economic system to one that supports both economic growth and the environment must be a global endeavor. We are developing technologies that will support U.S. leadership in this effort.

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 potential risks involving hazardous substances. We will broaden the scope of these efforts to develop the elements of a comprehensive Earth-system model so that we can predict and assess the impact of human and natural activities on Earth's environment.

Near-term issues of importance are related to environmental remediation and the treatment of toxic wastes. Our ability to predict the transport, deposition, and bioavailability of radioactive and toxic materials in the ecosystem is unique. We are providing the technical bases for major elements of the Yucca Mountain Repository program to provide safe disposal of high-level radioactive waste. We are planning to test technology for treating previously untreatable mixed waste (waste that is both radioactive and chemically toxic). In addition, using such Livermore capabilities as the National Atmospheric Release Advisory Center and advanced tools for dosimetry and dose reconstruction, we will provide life-cycle analyses of myriad environmental issues.

Energy

A mix of fossil, fission, and renewable energy—each producing progressively less environmental damage—can meet our nation's energy needs for the next half-century. 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 transferring our AVLIS technology to the U.S. Enrichment Corporation, the largest technology transfer project in the history of the national laboratories. We are continuing our efforts to improve 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, carried out in collaboration with U.S. and international partners, is developing the tokamak concept for fusion reactors as well as alternative concepts that might lead to small, less expensive fusion reactors.

We are the world leader in inertial fusion research. The National Ignition Facility is building on the accomplishments of our Nova laser and our expertise in laser science and technology. With the National Ignition Facility, we expect to demonstrate fusion energy gain for the first time ever in the laboratory.

Transportation and Advanced Manufacturing

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

Our contributions to the transportation sector will come from work on technologies for assessing the structural safety of highways and bridges, on electric and electromechanical energy-storage systems for electric vehicles, on ultrahigh-mileage gasoline-powered vehicles, and on the use of hydrogen as an alternative transportation fuel.

We will also apply our expertise in lasers and electro-optics, precision fabrication, advanced materials, and nondestructive evaluation to improve the quality, efficiency, and environmental soundness of commercial manufacturing processes.

Bioscience

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.

Our research in bioscience is inherently multidisciplinary, drawing not only on the life sciences but also on all the physical sciences, engineering, and computing sciences. A variety of Laboratory technologies and capabilities not normally associated with biological research are central to our efforts, including accelerator mass spectrometry, lasers, robotics, and microfabrication. We have the

opportunity to make truly significant discoveries that will dramatically improve the well-being of mankind, now and in the future.

Our goal is nothing less than an understanding of the basic physics and chemistry of life as coded in DNA—the genome, or master template, for an organism's genetic heritage. The knowledge gained will be applied to determine the causes of genetic disorders, 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 in 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 recently completed a high-resolution map of human chromosome 19. We have identified some 250 of the genes on this chromosome and are starting to decipher the underlying genetic code. In addition, we are working 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.

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 and provide a sound basis for making cost/benefit decisions. 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.

Assessing the health risk associated with variation in disease susceptibility genes—and developing strategies for ameliorating health risks—requires knowledge of the proteins that these genes produce and how they interact with DNA. We will unravel the three-dimensional structure of proteins and other biomolecules to learn how these molecules interact with DNA and how genetic variation affects these molecules and their interactions. This knowledge will be gained through effective coupling of genetic, biochemical, biophysical and computational capabilities at LLNL with DOE's major structural biology facilities. With this knowledge, it will be possible to design or engineer specific biomolecules to improve health.

Bioinstrumentation and Health-Care Technology

An integral part of our biotechnology research is the development of advanced tools and instrumentation. Our Center for Healthcare Technologies focuses these efforts on opportunities for improving the quality and decreasing the costs of health care. The Center coordinates the Laboratory's multidisciplinary efforts in biotechnology and facilitates partnerships with academic and industry partners. We have promising projects in such areas as 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 our bioinstrumentation and health-care efforts will be measured by health problems avoided or cured, health-care cost savings, and extended benefits for other human needs.

Partnering as a Way of Doing Business

Partnering—with the Department of Energy, other laboratories and government agencies, industry, and academia—is an important mechanism for accomplishing our programmatic objectives. We will form partnerships when they are smart business decisions both for our programs and for our prospective collaborators. Our goal is to make this Laboratory user-friendly and readily accessible to the technical community and the public. We want partnering with the Livermore Laboratory to be a compelling business decision.

The knowledge, tools, and technologies developed at Livermore will be applied in and transferred to the public and private sectors. Our partnering efforts will be successful if the parties involved find that these

endeavors enhance their scientific research, lead to technically improved, cost-effective products, or provide for more effective use of capabilities and facilities.

Collaborations with Other Laboratories

The national laboratories will coordinate and integrate their programmatic efforts to provide the best scientific and technical capabilities for the fewest dollars. Collaborations are growing through the development of integrated national programs like the Stockpile Stewardship and Management Program and through the design, construction, and shared use of specialized research facilities. For example, the National Ignition Facility is being jointly designed by the three national laboratories and academi. Weapons scientists from the national laboratories as well as other researchers from the laboratories and elsewhere will use this facility for a wide range of laser fusion and fundamental science experiments.

Partnerships with Industry

Our partnerships with industry will help us meet our programmatic goals cost effectively. Our scientific activities will drive advances in high-technology industries. Super-computing, for example, is a vital component of science-based stockpile stewardship. We will purchase from U.S. industry prototype super-computers that are many thousands of times more powerful than current commercially available machines. We will work with our industry partners to refine these prototype machines, and these improvements will help ready the supercomputers for the wider marketplace. The design and construction of the National Ignition Facility also will require extensive partnerships with industry. We will work with industry to develop the unique components required by this next-generation laser facility and, whenever possible, we will purchase commercially fabricated optics and electronics.

We will also collaborate with industry through the licensing of Livermore-developed technologies. Our micropower impulse radar—the so-called "radar on a chip"—has been licensed in the past two years to more than ten companies for such applications as automotive safety, home security, medical diagnostics, and sensing the levels of solid or liquid products in tanks. In addition, we will work with many hundreds of U.S. companies, individually or as members of consortia, through a variety of cooperative research and development arrangements in which we will share intellectual property rights and provide assistance to small businesses.

Collaborations with Academia

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

The Livermore Laboratory has a long history of collaboration with academia. The University of California at Davis Department of Applied Sciences is located on our Livermore site. In addition, we are home to a half-dozen formal institutes and centers that support hundreds of ongoing projects with university faculty, post-doctoral fellows, and graduate students. 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, providing nationwide access to our experimental facilities and scientific 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 provide a cost-effective mechanism for addressing complex issues facing California, many of which are also challenging the nation.

Partnerships with Other Federal Agencies

Complex national issue— such as health care, the environment, and crime—increasingly require collaboration among the Department of Energy laboratories and other federal agencies. At Livermore, we have unique facilities (e.g., genetics, environmental, and 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 Transportation, and the Department of Defense, among others. We will build on these existing relationships and seek new collaborations where our technical expertise can assist.

International Partnerships

The growing number of international partnerships in our scientific and technical programs reflects the globalization of economies and R&D activities. We are engaged in major laser projects with France and England and in several hundred cooperative projects with the Newly Independent States. Closer to home, we are looking for opportunities where we can assist NAFTA (North American Free Trade Agreement) countries achieve economic growth while preserving the environment.

Managing Human Resources Effectively and Improving Business Practices

Our goal is to perform world-class research and development to solve problems of national importance. To achieve this goal, our Laboratory must be a well-managed, cost-effective, forward-looking organization. We need the best people with the right skills to meet the demands of our programmatic activities. We also must continue to increase the efficiency our business practices and reduce costs.

Using the findings of a cost-cutting initiative and diversity action teams, we are improving Laboratory operations. We are taking steps to standardize databases and procedures, improve management practices, reduce the size of the administrative workforce, and provide a more productive work environment.

Strong partnerships with the University of California, the Department of Energy, our suppliers, and others who have key roles in Laboratory operations will be critical to our success. We will strengthen team efforts to facilitate the development and implementation of the adaptable management systems we need in today's complex business environment.

Structuring for the Future

We will structure the Laboratory to meet programmatic and business goals. Matching the skills and talents of our staff to these goals will be an important component of this process. As a result of a workforce structuring action, the Laboratory will have a smaller administrative workforce and a better match among our technical skills and capabilities and what we need for our current and future programs.

We are identifying ways to increase efficiency and effectiveness. Many improvements stem from the ongoing revolution in information technology. Changes being implemented include contracting out work, simplifying procedures, decentralizing, redeploying major functions, and changing business processes to reflect "best commercial practices." Our goal is improved methods for managing our workforce, facilities, and equipment and for supporting the Laboratory infrastructure in a long-term, cost-effective manner.

Assuring a Vital Laboratory Workforce

The Laboratory's principal asset is its quality workforce. Our goal is to create a work environment that is 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 performances contribute to the Laboratory's objectives. We will recognize the importance of partnering by rewarding excellence for team as well as individual accomplishment. We will ensure the continued vitality of the Laboratory workforce by taking pride in and responsibility for our work, by providing all employees the opportunities for career development and professional growth, and by increasing the skills and accountability of our management team.

Managing for Quality

The Laboratory will operate through a system of quality management in an atmosphere of openness and trust. We will apply performance measures in both our scientific and technical work and in our administrative and operational activities. We look not only to meeting contractual and ethical standards but also to being evaluated on how well we meet or exceed our programmatic and institutional goals.

Achieving Excellence in ES&H

We will set the standard among major research laboratories for environment, safety, and health (ES&H). We will protect the health of Laboratory employees and the public. We will integrate life cycle environmental quality in all our operations and activities. The challenge we face is to achieve ES&H excellence within the cost benchmarks of best industrial practices. We and the Department of Energy have undertaken a new look at ES&H system requirements, compliance, and regulation to assure the protection of employee and public health and safety and the protection of the environment in an appropriate and cost-effective manner.

Opening up the Laboratory for Effective Partnering

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

Focus and Change

We have defined the values and capabilities of Lawrence Livermore. These capabilities enable us to make unique and valuable contributions to solving important problems in national security, energy and environmental science, and bioscience.

As an institution, we are committed to openness, partnership, and a new way of doing business. Our Laboratory has a strong record of changing to meet new national needs. Changes of even greater magnitude will be demanded of us in the years to come. We welcome and will continue to meet the challenges posed by these changes.

Strategic Plans 1.2

We have formed specific strategic plans for each of our major program areas and institutional activities. These plans stem from the DOE's strategic plan, planning activities within Defense Programs (DP) for Stockpile Stewardship and Management, and our expectations about future Laboratory program interactions with customers and others. Responsibility for strategic planning at the Laboratory now resides in five strategic councils. The organization of this section tracks along council lines.

The Council on National Security oversees all of our defense work. Principal elements include stockpile stewardship management, arms control and nonproliferation, and advanced conventional defense. The Council on Energy and Environmental Systems covers our energy, environment, transportation, manufacturing, and basic energy sciences programs. There is a separate Council on Biosciences. The Council on Strategic Science and Technology oversees the Laboratory Directed Research and Development (LDRD) Program and capabilities in physics and space technology, chemistry and materials science, engineering, and computation. Laboratory collaborations, including industrial partnering and science education, also fall under the purview of this council and are treated in a separate section.

The Council on Strategic Operations is responsible for operations and management issues and planning. The Operations section is organized according to DOE's critical success factors:-management practices, human resources, environmental safety and health, communications and information, and our site and facilities.

National 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, nuclear testing has stopped, and negotiations have been completed for a comprehensive test ban treaty. Still, nuclear deterrence remains central to our national defense structure. We face the extraordinary challenge, mandated by President Clinton, of keeping critical expertise intact and certifying the safety and reliability of our nuclear stockpile without the ultimate validation provided by the underground tests. Furthermore, the danger of nuclear proliferation and the possibility of incidents of nuclear terrorism are of increasing concern.

The President recognized the enormity of the challenge confronting us in an announcement on September 25, 1995: "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."

Two new processes exemplify the mutually corrective and confirmatory role of the nuclear weapons laboratories in assessing the stockpile. One is an annual certification review. Scientists from Livermore, Los Alamos, and Sandia work closely with Strategic Command to examine and assess all currently available data and report their findings to the Secretaries of Energy and Defense. In the second process, Dual Revalidation, teams from the three laboratories independently evaluate a particular weapon system to see whether it conforms to requirements and to identify potential aging problems. An activity taking several years per weapon system, Dual Revalidation provides a more in-depth analysis than is possible with an annual certification.

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. We are working closely with DOE to develop the Stockpile Stewardship and Management Program, and our plans are an integral piece of that effort.

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, enhanced experimental facilities, and improved computer modeling.
• The capacity to sustain into the future a reliable and safe 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.
• A cost-effective infrastructure.
• 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 nurtured to provide innovative problem solving, peer review, and certification of weapon systems.
• Implementing the programmatic environmental impact statement (PEIS) and 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, arms control, and nonproliferation.
• Maintaining a competent scientific and technical staff.

Strategies

• Use a mix of enhanced facilities and capabilities to maintain confidence in the stockpile, including
  – Advanced hydrodynamic facilities to test primary implosion physics.
  – The current Nova laser and the planned National Ignition Facility to test aspects of high-energy-density physics.
  – Enhanced computational capabilities for better modeling of the physics of nuclear weapons and their performance and safety (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.
• Encourage industrial partnership and the development of supportive industrial technology integral to Advanced Design and Production Technologies (ADaPT).
• Investigate post-doctoral and other programs to attract and retain personnel.

Success Indicators

• Development of advanced engineering and manufacturing capabilities to help maintain the stockpile and new scientific capabilities to improve surveillance.
• 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.

Goals

We are working closely with other DOE laboratories to support DOE's nonproliferation strategic plan objectives, which are to:

• Control nuclear materials, technology, and expertise.
• Reduce nuclear weapons worldwide.
• Roll back proliferation development programs.
• Prevent acquisition of nuclear weapons.
• Avoid proliferation surprise.
• Respond to proliferation emergencies.

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 to make nonproliferation a high-priority program and to strengthen the role in intelligence assessments.
• A strong program that helps ensure interagency–laboratory communications and planning, including temporary exchange assignments of experts between agencies.

Strategies

• Support cooperative activities with Russian and other Newly Independent States (NIS) to speed the safe and secure dismantlement of NIS nuclear weapons and the conversion of their weapons laboratories to civilian projects.
• Provide expertise and technology to establish dismantlement, tracking, disposition, transparent accountability regimes, and other agreements for the control of nuclear weapons and fissile materials worldwide.
• Develop more effective technical capabilities to intercept smuggled nuclear materials and to locate and neutralize battlefield and terrorist nuclear explosives.
• Provide intelligence-based assessments to the U.S. Government of existing and potential weapons-of-mass-destruction activities worldwide.
• Develop remote sensors and information analysis techniques—integrated into space, air, and ground-based platforms—to detect signatures of foreign nuclear and other weapons-of-mass-destruction programs, to help verify international arms control and inspection agreements, and to support U.S. battlefield objectives.
• Assess counterproliferation strategies using computer-based conflict-simulation and comprehensive systems analysis.
• Develop advanced non-nuclear weapon and sensor systems for use by the military.
• Support specific core competencies for the U.S. effort needed in international security.

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 also 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 are 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.
• Awards to NAI personnel for excellence in supporting DOE and other government organizations and for national recognition of technology development.

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 should occur in the stockpiles of both countries, particularly with the full implementation of the START I treaty and the pending ratification of START II in Russia. Thousands of warheads have already been dismantled. Because of the backlog of weapons and the full pipeline of returns, the DOE's Pantex Plant in Amarillo, Texas, will continue to dismantle over one thousand weapons per year through 1998.

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 completing the dismantlement of LLNL-designed retired warheads, specifically the W48, W55, W56, W68, W70, W71, and W79. 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 the 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, sensor and electro-optic technology, and 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 in national economic security.

Goal

• Establish a more substantial, sustained, and successful working relationship with the Department of Defense (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.

Energy and Environmental Systems

Programs in the areas of energy and environmental systems combine to build the scientific and technical base for a sustainable future. Activities are focused on technologies that offer an abundant, safe, and clean supply of energy and reduced pollution from transportation systems. We also are developing improved manufacturing technologies that use resources wisely. Our environmental programs assess and mitigate human risk from hazardous substances as well as develop and demonstrate new cleanup technologies.

Magnetic Fusion Energy

Magnetic fusion worldwide has shown steady scientific progress during the past 15 to 20 years, with the key confinement parameter approximately doubling annually; it is preparing to enter the burning-plasma regime. However, during this past year, federal budgetary constraints have caused a shift from a schedule-driven, energy-focused program to a fusion energy science program with the mission to "advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source."

We are participating in the research, development, and engineering design of the International Thermonuclear Experimental Reactor (ITER). We are also heavily involved in the DIII-D tokamak at General Atomics. 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

To make attractive fusion power plants a reality in the 21st century.

Issues

• Increasing power density.
• Reducing technological complexity.
• Developing low-activation materials.

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 and provide "virtual

experiments" to permit faster and less expensive progress toward a fusion power source.
• Explore innovative magnetic fusion concepts seeking significant 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.
• Develop comprehensive computational tools for modeling fusion plasmas in a large-scale, integrated manner. We are leaders in the national magnetic fusion energy computational initiative.
• 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.
• Positive effect of computational modeling on fusion understanding and experimental advances.
• A thorough and convincing evaluation of exploratory concepts.
• Significant contributions to engineering design, 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 energy resources.

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 (LBNL) on their Induction Linac Systems Experiment to evaluate heavy-ion-driver options for an inertial fusion Engineering Test Facility.
• Work with Los Alamos National Laboratory 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.

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 multidisciplinary 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.

Atomic Vapor Laser Isotope Separation (AVLIS)

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 United States Enrichment Corporation (USEC), a government corporation. The USEC board has decided to take the first steps to construct and operate an AVLIS enrichment plant.

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.
• Integrate the AVLIS technology and organization with the USEC organization and deployment team.
• Continue risk reduction in key technical and operations areas of plant-scale equipment in support of AVLIS deployment.
• Support USEC in key activities, including plant licensing, deployment, and strategic planning.
• Lead design and engineering to support licensing, construction, and production operations for the uranium plant.

Issues
Several risk factors could impact achievement of overall goals, including:
• Continuing need in the enrichment market for a low-cost production capacity when blended-down recycled material from weapons enters the civilian fuel cycle.
• Regulatory schedule delays associated with Nuclear Regulatory Commission licensing.
• Continued cost–risk reduction for enrichment equipment performance.
• 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 pilot demonstration for USEC.
• Participation of LLNL technologists and engineers in USEC's plant deployment project organization.
• Integration of AVLIS technology with USEC and its suppliers, and activation of an AVLIS-based enrichment plant at a production site.
• Successful collaborative efforts that transfer 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 can be used for intermittent storage of energy from renewable sources or as a clean transportation fuel.

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.

Success Indicator

• The commercialization of one major innovation of energy technology each year.

Environmental Programs

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 multidisciplinary 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.

Issues

• Lack of clear focus and coordination for overall environmental R&D work (risk to remediation) within DOE in particular and across agency lines in general.
• "Stovepipes" within agencies that inhibit adoption of novel techniques and that discourage support of multidisciplinary R&D.
• Project micromanagement that interferes with development and application of an integrated systems approach involving several technologies.

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 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.
• Work with DOE offices and outside evaluators of DOE programs to facilitate cooperation and coordination across internal barriers.

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 Advanced Design and Production Technologies (ADaPT) programs, 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.

Issues

• Can LLNL maintain a funds-in program with industry that maintains our core competencies?
• Will industry adopt components designed and tested by LLNL for use in advanced manufacturing, transportation, and energy systems?
• Can EMATT maintain an advanced manufacturing program with industry in partnership with Defense Programs?

Goals

• In manufacturing, we will work to integrate the past Technology Transfer Initiative (TTI) manufacturing thrusts into programs to enhance manufacturing capabilities for Defense Programs and other sponsors. We will identify, develop, and leverage advanced technologies to meet program needs and, in the process, stimulate and deploy leapfrog advances in manufacturing technologies to enhance near-term U.S. competitiveness.

• In materials, our goal is to develop novel materials and processing tools to a maturity suitable for use 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' 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 fuel cells and hydrogen-fuel capability for vehicles.

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 fuel cells, 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 fuel cells, 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 (Defense Programs) manufacturing. We will identify, develop, and leverage advanced technologies to meet DP needs and, in the process, stimulate and deploy leapfrog 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

Success is measured by the positive impact on Laboratory programs of mutually beneficial industrial partnerships. We strengthen the Laboratory's technology base and enhance its programs through partnerships in several areas:

• 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/Energy Efficiency and Renewable Energy and the heavy oil upgrading and deepwater production activities in DOE/Fossil Energy, maintain our participation in DP's advanced manufacturing activities, 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. 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 gain new insight and understanding of the fundamental scientific processes that govern the behavior of energy, materials properties, and biological systems.

Issue

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.

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 maintain a vital and innovative science and technology base.
• Use innovative research projects as an opportunity to attract and evaluate new staff.

Issue

Because of declining program budgets, there is pressure to use LDRD

funds to maintain Laboratory core competencies rather than engage in research in other areas.

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 with 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, and environmentally conscious manufacturing.

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 planned 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 multidisciplinary 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 core workforce and conduct a vigorous post-doctoral 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 receives.

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 directorate, and it is our continuing goal.

The Chemistry and Materials Science Directorate'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 programs. 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 the High Explosives Applications Facility and at Site 300.
• Nanostructures, i.e., 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.

Vision

We will provide the innovative, high-quality scientific and technical support in chemistry and materials to Laboratory programs so that they can succeed and grow.

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 and educational communities 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 continue our tradition of technological leadership and dynamic, innovative problem solving for Laboratory missions. We combine our own core capabilities and the expertise of industrial partners to achieve breakthrough engineering solutions to challenging Laboratory programs in national security, energy and environment, and biosciences and biotechnology.

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 science and systems engineering.
• Computational mechanics, electronics, and electromagnetics.
• Power conversion.
• Optics engineering.

Vision

We will be the growth engine for the Laboratory and help the Laboratory become indisputably the very best research and development organization in the world.

Mission

Our mission is to make Laboratory programs succeed by developing the people and cutting-edge technologies necessary to foster programmatic growth and future success. We will provide unique, world-class engineering resources that enable Laboratory directorates to translate their objectives into physical deliverables on time, within budget, and to specifications.

Goals

Our mission can be translated to a set of specific, strategic goals that Engineering will pursue based on technology differentiation and organizational flexibility.
• Become increasingly accountable for programmatic success by providing Laboratory directorates with the appropriate technical services, equipment, and people to ensure success in every phase of any project. We will provide the best solutions possible in terms of quality, cost, and schedule, enabling Engineering to be a full-service, one-stop organization for our customers, the Laboratory programs. We will outsource for technical services when it best serves our customers' needs.
• Foster the unique science-based technologies that will make a substantial difference in the Laboratory's ability to initiate and execute the programs of tomorrow. This requires that we develop a portfolio of technologies that enable program success, and that such a portfolio must contain technologies that are unique, the best, and relevant and are brought into being in a timely fashion.
• Contribute to Laboratory organizational agility by ensuring that Engineering is technically diverse, productive, cost effective, and capable of frictionless movement of people and resources.
• Generate business growth by technical knowledge fusion and diffusion. Engineering's size and central role in the Laboratory gives it a

unique cross-cutting view of the intersections of problems and technologies. This can be exploited to create innovative solutions to new problems, thus helping the Laboratory grow through an expanding customer base consistent with overall Laboratory vision and mission.
• Foster Laboratory synergism by serving as an integrating thread through Lab programs and promoting multidisciplinary collaborations.
• Enhance Laboratory visibility by supporting external collaborations. We can capitalize on our functional placement between science and the marketplace to gain greater external recognition.
• Plan for optimal solutions that put the Laboratory's interests ahead of Engineering's. It makes no sense to seek solutions that benefit Engineering but are disadvantageous to the Laboratory as a whole.

Strategies

• Invest in core technologies crucial to the support of the Laboratory's mission and core competencies.
• Acquire the financial resources necessary to proactively develop core technologies that contribute to a thriving Laboratory.
• Develop full partnerships between Engineering and each customer to facilitate breakthrough scientific and technical solutions.
• Continuously increase value to customers by managing costs.
• Develop decisive, flexible, and skilled leaders across Engineering for future programmatic, functional, and institutional roles.
• Foster a high-caliber, customer-focused workforce.

Success Indicators

• Success in achieving Laboratory program objectives, supported by Engineering's people and technologies, as seen through their eyes.
• Evidence of Laboratory program growth in important national mission areas supported by Engineering's contributions.
• Organizational and professional recognition through external partnerships, patents, awards, citations, fellowships, conferences, and publications.
• Excellent records for safety and security, and compliance with environmental and business requirements.
• Continuing ability to attract the very best engineering talent to the Laboratory.

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, the National Ignition Facility, United States Enrichment Corporation, 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 National Storage Laboratory, through the High Performance Storage System Project (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, and computer 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 the data's integrity is secure.
• 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 and information technologies.
• Help guide LLNL and DOE management to assure that appropriate computing resources are selected, acquired, and implemented.
• Apply our computing experience to computation, communication, and information-sharing challenges of the DOE missions.
• Develop testbed environments on which to integrate key information 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 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

Industrial Partnerships and Commercialization (IP&C) assists Laboratory programs as they pursue opportunities for collaborations with industrial partners. We focus on partnering activities that support and enhance our programmatic effort to meet important national needs in a cost-effective manner. At the same time, we are providing opportunities for industry to tap into our cutting-edge technologies and facilities to bolster its global competitiveness. These collaborative efforts provide valuable support to our programs, support the needs of the industrial sector, and develop and maintain skills of our technical staff to meet mission requirements in defense, energy, the environment, biosciences, and health care.

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. We will achieve our goals by forging partnerships and building alliances between Laboratory programs and U.S. industry, other DOE laboratories, academic institutions, and government agencies.

Goals
• Continue to pursue partnership opportunities to accomplish our programmatic goals in the most cost-effective manner.
• Ensure that technology developed in the pursuit of our national missions has the maximum possible positive impact on the U.S. economy.
• Continue to streamline and simplify the processes for establishing various types of collaborative agreements.
• Ensure effective and efficient management of our industrial collaborations and of the Laboratory's intellectual property.

Status Update
This year's U.S. budget resulted in a difficult situation for some of our partnerships with private industry. LLNL received about two-thirds of what was expected to fund Technology Transfer Initiative (TTI) projects. These funds support about three-quarters of our Cooperative Research and Development Agreements with industry. DOE issued guidelines that asked for the highest priority to be

given to the partnerships that add the most value to the Laboratory's weapons programs. The overall result was that a few partnerships were terminated, and the remainder had cuts from zero to 40%. Others that were under negotiation are not proceeding.

We continue to work closely with industry on high-performance computing and technologies associated with advanced laser systems and electro-optics. These partnerships are tied to ASCI and the planned NIF. Many other activities with industry also continue. These include licensing, non-Technology Transfer Initiative- funded Cooperative Research and Development Agreements, User Facilities Agreements, and encouragement of start-up businesses.

Strategies

• Develop in conjunction with representatives from Laboratory programs a long-term strategy for Industrial Partnerships and Commercialization.
• Rely increasingly on funds from programs and other industrial partners, rather than on direct funding of TTI, to support 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.
• Increase the number of facilities available for use by our industrial partners and simplify the security requirements for accessing these facilities.
• Work with the DOE and representative industry leaders to develop streamlined processes for R&D partnerships.
• Establish and implement a system for measuring performance, identifying deficiencies, and addressing any corrective actions.

Success Indicators

• Demonstrated increase in cost-effectiveness in accomplishing DOE goals.
• Documented successful partnerships.
• Number of license agreements.
• Value of royalty streams and related support of R&D.
• Number of user facilities and level of utilization.
• Number of start-up businesses based on Laboratory technology.
• Improved efficiency of administrative operations.

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; institutes that use resources distributed among the partners; K-12, college, and post-doctoral programs; and the Campus–Laboratory Collaborations (CLC) collaborative research program run by the University of California (UC) office of the President. 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.

Vision

In the past we have concentrated on scientific and technological projects in the areas of materials, plasmas, astrophysics, planetary physics, scientific computing, and instrumentation. In our new initiatives we will also engage in 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, 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 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 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 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 programs are 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 DOE Defense Programs, Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL).

Vision

Through our many programs and activities, we hope to stimulate greater interest in science among students, teachers, and administrators; to encourage more students to pursue careers in science; and to foster a technically and scientifically literate generation. Program participants can enter LLNL's world of science and learning in a variety of ways. Our informal science activities are designed to increase public awareness and curiosity about science and to increase science literacy. We have other activities that help participants to acquire basic scientific inquiry skills and further their understanding of the

nature of science. Thematic immersion activities and curricula allow students and teachers to explore global scientific themes that are tied to the Laboratory's core competencies. Finally, we coordinate and support a number of programs in which students and instructors—from elementary school to college level—may conduct their own research aided by Laboratory scientists and others.

Goals

Science Education, as a catalyst for change, applies 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 the Laboratory's 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 under-represented teachers and teachers of under-represented students.
• Provide access to Laboratory personnel, facilities, and equipment.
• Provide role models and mentors to students and teachers.
• 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 under-represented groups pursuing careers in science, math, engineering, and technology.
• Increased level of customer demand for our curriculum and resources.
• Increased interaction with Laboratory personnel.
• Enhanced scientific and technical literacy.
• Improved ability to use technical tools and equipment.

OPERATIONS

Efficient, cost-effective operations are important to the future success of the Laboratory. This requires special attention to the human resources at the Laboratory, as well as to our business practices and our facilities. Our strategic plans for Laboratory operations build on three important activities in FY 1996.

• **The Diversity Action Steering Committee.** As a follow-on to the all-Laboratory employee survey on diversity taken in May and June 1995, Diversity Action teams and a Diversity Action Steering Committee (DASC) were constituted to develop findings and propose recommendations in the areas of job opportunity, performance management, career development, and employee empowerment.
• **The Cost Cutting Initiative Task Force.** In August 1995, the Laboratory Director formed a Cost Cutting Initiative (CCI) Task Force to conduct a comprehensive, Laboratory-wide study of where we spend our resources, and to recommend aggressive steps for reducing costs. The task force identified potential cost reductions in three major areas: centralization and standardization of operations, improved management practices, and reductions in the size of the workforce.
• **Workforce Restructuring Plan.** The Laboratory is undertaking a workforce restructuring that will lead to the separation of up to 600 employees in selected areas. The workforce restructuring is intended to reshape the Laboratory so that Livermore has an appropriate mix of skills needed for current and future work.

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.

Human Resources

The cornerstone of the Laboratory's strength is its world-class workforce. Our goal is to maintain vitality and excellence as the Laboratory's mission changes. Two important strategies supporting this objective are workforce management and diversity management.

Vision

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

Goal 1

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

Strategies

• Undertake a workforce restructuring that will lead to the separation of up to 600 employees in selected areas to reshape the Laboratory so that it has an appropriate mix of skills needed for current and future work. Use the Voluntary Separation Incentive Program and employee redeployment as the principal means for achieving restructuring goals.
• Apply new technologies to support the redeployment of employees within the Laboratory and to enhance recruiting efforts as Laboratory priorities change.
• Provide employee assistance in career planning and opportunities for career development, including mentoring and other programs to enhance job performance and expand skills for future challenges.
• Establish a mandatory training program for supervisors and managers to expand and deepen necessary skills in areas such as personnel management, finances, safety, and policy implementation.
• Explore new approaches to sustaining excellence through effective performance management.
• Recognize the link between health and performance excellence by providing health promotion programs.
• In communications, increase accessibility to resources and information by using state-of-the-art technologies.

Success Indicators

• Ability of managers to attract and hire strong, qualified personnel, while correctly sizing Laboratory staff.
• Successful redeployment of employees within the Laboratory to meet changing programmatic priorities.
• Availability of resources to employees for their career development.

• Ability of managers and employees to identify competencies required for successful job performance and consider options for development.
• Improved access to an employment information network among Laboratory employees, managers, and the external community.

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.
• Implement findings and recommendations from the DASC, and continue to use data from the Laboratory-wide diversity survey to identify and address specific diversity issues.
• Strengthen management commitment and accountability.
• Provide every employee access to ombuds-like assistance to resolve issues as early and informally as possible.
• 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. In addition, we expect to initiate a "Work Smart Standards" process in FY 1997.

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.
• Continue to 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 ES&H program approach for increased integration among Health Services, Hazards Control, and Environmental Protection.
• Implement a proactive accident prevention program.
• Assist employees in meeting high environmental, safety, and health standards through training and performance evaluations.
• Work to prevent pollution, minimize waste, and use energy efficiently.
• Initiate a "Work Smart Standards" process in FY 1997.

Success Indicators

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

• Improved audit and inspection results.
• Improved performance on the UC Contract Appendix F ES&H performance measures.

Communication and Information

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

Our principal product is scientific and technical information that describes the research, development, and performance of prototype systems relevant to our missions. We must disseminate this information as widely as possible. We also generate significant administrative information in managing our programs. Improved management of information internal to the Laboratory can help reduce costs by increasing our productivity and efficiency. We are using the current explosion in communications technology to assist us in reaching our goals.

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.
• Provide immediate access to knowledge through a variety of media.
• 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.

To improve internal Laboratory information management, we will:
• Standardize desktop systems, software, and databases, which will lead to significant cost savings and improvements in operational efficiency.
• Develop information systems at the Laboratory and an architecture for those systems that will enable the Laboratory to operate in a much more unified manner in an age dominated by information technologies.

Goals

• To be both responsive to and proactive with employees, our communities, and the news 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, both 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.
• To achieve improved productivity and efficiency and lower operational costs through standardization of desktop systems and integration of Laboratory databases.

Issues

• 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 make an effective transition to the use of electronic media?
• Can we resolve the conflicting requirements of openness and security?

Strategies

• Survey 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 Laboratory.
• 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.
• Appoint a chief information officer of the Laboratory, whose responsibilities are to provide the vision and leadership for the development of an information system architecture for the future, to propose and implement standards for hardware and software, and to develop information system strategies that balance cost, technology, and service.

Success Indicators

• Results from sponsor and customer surveys indicate the level of satisfaction 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.
• Cost reductions through hardware and software standardization and improvements in the efficiency of Laboratory operations.

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 that utility systems can provide present and future program support reliably and economically.
• Enhance road and pathway systems to provide safe, efficient traffic 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.
• 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.

• Continue to apply the recently developed 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.
• Develop with the DOE/Oakland Office the mechanism, such as lease-to-own and pay-from-savings, to acquire needed capital assets.
• Consider special issues, such as redevelopment zones and adaptive reuse renovation for suitable underutilized facilities.

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 access and functionality for both federal programs and industry–university collaborations.
• Less energy usage, continuously improved energy efficiency.

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. Listed after each initiative title is its Budget and Reporting Code designation.

Assistant Secretary for Defense Programs

National Ignition Facility (DP)

The National Ignition Facility (NIF) Project supports the DOE mandate to maintain nuclear weapons science expertise required for stewardship of the stockpile. In announcing the extension of the nuclear testing moratorium (July 1993), the President reaffirmed the importance of maintaining confidence in the enduring U.S. nuclear stockpile during a test ban. Even without full-scale testing, the weapons laboratories must continue to certify the safety and reliability of this country's nuclear weapons. The DOE's Defense Programs (DP) is developing a science-based stockpile stewardship program to meet this need.

A vital element of this program, the 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. In addition, other specially designed targets will provide testbeds for weapon physics and effects studies. 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 (FY 1996–2002) were validated by an Independent Cost Estimator team commissioned by the DOE.

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 initiated the line-item funding cycle for the project. In 1995, Congress appropriated the full FY 1996 Project request of $37.4 million in plant and capital equipment funds (see Table 1.3-1) for preliminary design of the conventional facilities and special equipment. These funds were released by DOE in December 1995 to the project following the Secretary's determination that the NIF construction supports the nonproliferation objectives of the U.S. (Key Decision One Prime). Congress appropriated $23.6 million of FY 1996 operating funds, including advanced conceptual design, optics vendor facilitation, and National Environmental Policy Act activities. The NIF is a part of the Stockpile Stewardship and Management (SSM) Programmatic Environmental Impact Statement (PEIS). The SSM PEIS reaffirms the secretary's statement at Key Decision One that Livermore is the Preferred Alternative site for the NIF. Site selection will occur after public review of the SSM PEIS and a formal Record of Decision by the Secretary. Tables 1.3-1 and 1.3-2 show the resources required for this effort.

Contained Firing Facility (DP)

Funding began in FY 1996 for the $49.7-million Contained Firing Facility, a 2,700-m^2 enhancement to the flash x-radiography (FXR) facility at Site 300. The facility, which houses the newly upgraded FXR machine, is the most versatile and complete explosive test facility in the world. The containment addition will include a reinforced firing chamber, a support staging area, and additional diagnostic space. The enhanced capability will 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 (DP)

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 computer-based methods for assuring the safety, reliability, and performance of the U.S. nuclear stockpile. It will provide the ability to analyze, evaluate, maintain, and prototype nuclear weapons and weapons components in the absence of nuclear testing and with a reduced weapons infrastructure.

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.

A new generation of weapons simulation codes that combines advanced fundamental physics models, much greater spatial resolution, and the ability to model weapons behavior in 3-D will provide the virtual testing and prototyping capability needed to compensate for the loss of nuclear testing.

Using these codes will require computers hundreds to thousands of times more powerful than the best available today. The three DP laboratories are working with industrial partners to accelerate the development of new High Performance Computing Platforms with these levels of capability.

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) or required (R) amounts, as indicated. All costs are in "as spent" year dollars, consistent with NIF project data sheets.

Fiscal year	NIF Project TEC funded construction[a,b]	NIF Project OPC funded costs[a,c]	ICF Program OPEX-funded NIF annual operating costs[d]	NIF ESAAB milestone schedule
1993	0.0	6.0 (A)	0.0	Justification of mission need, KD0
1994	0.0	6.2 (A)	0.0	Complete Conceptual Design Report (CDR)
1995	0.0	6.0 (A)	0.0	KD1, Advanced conceptual design
1996	37.4 (A)	23.6 (A)	0.0	Congressional project start, Title I design
1997	131.9 (R)	59.2 (R)	0.0	KD2, Title II design, CD-3,[e] start construction
1998	197.8 (R)	31.3 (R)	0.0	Continue construction
1999	198.8 (R)	11.6 (R)	0.0	Continue construction
2000	191.3 (R)	31.7 (R)	0.0	Continue construction, begin start-up activities
2001	75.4 (R)	37.5 (R)	17.6 (R)	Continue construction, begin experiments
2002	10.0 (R)	17.9 (R)	54.4 (R)	Complete construction and final ORR,[f] project complete, CD4
2003	0.0	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 site-specific insfrastructure, estimated to be about $26 M.
[c] The OPC required for the NIF includes the CDR, NEPA documentation, U.S. optics industry facilitization, and NIF facility start-up. The estimated total OPC 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 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] The Key Decision Process was replaced by the Critical Decision Process in FY 1995.
[f] 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).

This table reflects the 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 1994, 1995, 1996, 1997, and 1998. After FY 1997, amounts are in constant FY 1998 dollars.

BA requirement numbers (operating and capital) reflect continuous Nova operations through FY 1999 by all three Defense Programs' national laboratories as a national user facility for stockpile stewardship physics experiments. Beginning in FY 1996, experiments on Nova will include qualified experiments by universities in areas such as high-energy-density physics.

BA requirement numbers also include additional dollars needed for prototype cryogenic targeting components and NIF diagnostics.

If the NIF is sited at LLNL, then additional dollars from the national ICF program would be available for NIF operating costs to begin operational check-out experiments in FY 2001 and fully operational, ignition experiments in FY 2003.

Fiscal year	LLNL ICF Program operating costs	LLNL ICF Program capital equipment
1994	77.6 (A)	3.5 (A)
1995	75.8 (A)	4.6 (A)
1996	83.8 (T)	3.0 (T)
1997	83.4 (T)	3.0 (T)
1998	95.5 (T)	3.0 (T)
1999	100.0 (R)	10.0 (R)
2000	100.0 (R)	10.0 (R)
2001	100.0 (R)	10.0 (R)
2002	120.0 (R)	10.0 (R)
2003	140.0 (R)	20.0 (R)

The DP labs are also creating a Problem Solving Environment to accelerate the development of the new ASCI simulation codes and their application to the problems of stockpile stewardship by our weapon scientists. Key elements of this environment are advanced code development tools, very large and fast data storage facilities, and a high-speed communications links for both classified and unclassified data. A long-term goal is to permit pervasive collaboration and sharing of computer resources among the laboratories in support of both ASCI and the larger Stockpile Stewardship and Management Program.

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 1998 dollars after FY 1997).

Fiscal year	Budget authority
1996	6.6
1997	17.1
1998	19.3
1999	6.7
2000	0.0
2001	0.0
2002	0.0

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

The ADaPT Program is a DOE-complex-wide effort that integrates the skills and facilities of the three weapons labs—Livermore, Los Alamos, and Sandia—with the four production plants—Savannah River, Pantex, Oak Ridge Y-12, and Kansas City. Through ADaPT, the complex will develop innovative technologies for new processes and practices to enable cost-effective production of stockpile elements.

Table 1.3-4. Resources required for the Accelerated Strategic Computing Initiative (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs[a]
1996	27.0	0.0	27.0	90
1997	52.0	0.0	52.0	115
1998	67.0	0.0	67.0	140
1999	82.0	0.0	82.0	170
2000	90.0	0.0	90.0	187
2001	90.0	0.0	90.0	187
2002	90.0	0.0	90.0	187

[a] FTE is full-time equivalent employee.

The enduring ingredients of the weapons stockpile, as well as workforce skills, will be maintained by a combination of repairs, refurbishments, and as-needed replacements.

The ADaPT Program has defined five areas of strategic investment to meet its objectives:

• Integration of product and process design.
• Advanced process development and qualification.
• Advanced materials development and characterization.
• Implementation of agile manufacturing practices.
• Enterprise integration.

In the near term, priorities are to:

• Implement a secure communications network that will provide a testbed environment for concurrent design software, electronic procurement software, and automated design-driven tooling.
• Pursue multiscale material model development and validation to support advanced process modeling.
• Explore the feasibility of minimum-waste processes such as net-shape and near-net-shape forming of nuclear components, i.e., mold-extrusion casting, precision die casting, and spin forming.
• Develop and apply an object-oriented, enterprise-level simulation of modular manufacturing to produce plutonium components.
• Explore new, reversible disassembly processes that permit reassembly without remanufacturing.

Particularly relevant to the ADaPT mission are the following Livermore skills, equipment, and facilities:

• R&D facilities for plutonium and uranium processing.
• Advanced laser materials-processing capabilities and associated metrology facilities.
• Precision engineering, machining, and metrology facilities.
• Capabilities for formulation, synthesis, and evaluation of high explosives at the Site 300 Contained Firing Facility and the Livermore site's High Explosives Applications Facility.
• Material characterization capability (at a scale of atoms to millimeters): TEM, SEM, AFM, and positron diagnostics using a 100-MeV LINAC.
• Massively parallel computational capability.

The resource requirements for ADaPT at Livermore are shown in Table 1.3-5.

Table 1.3-5. Resources required for the ADaPT Initiative at Livermore (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Operating	Equipment	Total cost	Direct FTEs
1996	2.4	2.0	4.4	10
1997	7.0	3.0	10.0	30
1998	15.0	2.5	17.5	45
1999	25.0	5.0	30.0	90
2000	25.0	5.0	30.0	90
2001	25.0	5.0	30.0	90
2002	25.0	5.0	30.0	90

Accelerator Production of Tritium (DP)

Livermore is a major partner with Los Alamos, Brookhaven, Sandia, and Savannah River National Laboratories on the DOE's Defense Programs initiative to develop a high-power, high-energy proton accelerator to produce tritium for the nation's nuclear weapon stockpile. The Accelerator Production of Tritium (APT) project uses the laboratories' strengths in three major areas:

• Accelerator design and performance (superconducting radio-frequency sources, power supplies, vacuum, shielding, halo-formation mechanisms).
• Systems design (controls, reliability, availability and maintainability analyses, costs and schedule).
• Target design and performance (experimental program, modeling, and essential databases).

The long-term goal of the APT initiative is to construct a 100-mA, 1.7-GeV, cw proton accelerator by 2007. The accelerator, which is expected to be located in Savannah River, South Carolina, will bombard tungsten targets with high-energy protons, producing spallation neutrons that interact with helium-3 to produce tritium. The design of the accelerator and the target region represent substantial technical challenges for the multilaboratory team. See Table 1.3-6 for resource requirements.

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 6,500-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 $40.5 million. The conceptual design for this facility is completed and will be submitted for validation as a line item for the FY 1999 budget. See Table 1.3-7 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 1.3-8 shows the resource requirements for this program.

Mammalian and Microbial Genomes (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 have expanded our DNA sequencing output through incremental improvements in technology and by reprogramming efforts formerly devoted to mapping. To make substantial additional

Table 1.3-6. Future resources required for the Accelerator Production of Tritium (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Total cost	Direct FTEs
1996	2.1	8
1997	5.1	14
1998	8.0	28
1999	8.0	28
2000	6.0	18
2001	4.0	10
2002	4.0	10

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

Table 1.3-7. Resources required for the Genomics and Structural Biology Research Facility (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Construction cost	Other project cost	Total project cost
1997	0.0	0.00	0.00
1998	0.0	0.20	0.20
1999	7.0	0.00	7.00
2000	24.0	0.16	24.16
2001	10.0	0.30	10.30
2002	0.0	0.00	0.00

increases in output we need increased funding. Table 1.3-9 gives the resource requirements for this effort.

Center for Healthcare Technologies (KP)

The Center for Healthcare Technologies was formed two years ago in response to industry and clinicians requesting assistance in developing new, cost-effective healthcare technologies. The Center's mission is to be the LLNL point of contact and to provide coordination, marketing, and strategic direction in healthcare fields. The Center ensures that LLNL individual investigators have access to customers/partners and that customers/partners get the best technical team Livermore has to offer. As a complement to these goals, the Center developed a protocol for seeking and exploring business leads, establishing a methodology for evaluating business markets, and developing a strong, viable business plan in which to present LLNL's core expertise to the business community.

Several million dollars of external support for Livermore's healthcare technology projects are funded from technology transfer initiatives, industry, and work for others. Several internal LDRD healthcare projects were initiated in almost every Directorate at Livermore and often remain in the originating Directorate.

Current projects include tissue welding, improving the optics for carpal tunnel surgery, development of minimally invasive testing of blood pathology, diagnosis and treatment of ischemic stroke, computerized patient records, telemedicine, computer-assisted diagnosis using image processing, digital mammography, and rational device design.

Table 1.3-8. Resources required for the Individual Susceptibility: Genetic and Structural Basis (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1997	3.0	0.4	3.4	9
1998	4.4	0.2	4.6	12
1999	4.5	0.2	4.7	12
2000	4.7	0.2	4.9	12
2001	4.7	0.2	4.9	12
2002	4.7	0.2	4.9	12

Table 1.3-9. Resources required for the Mammalian and Microbial Genomes Initiative (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1997	17.6	4.1	21.7	81
1998	24.3	2.3	26.6	118
1999	29.4	2.0	31.4	150
2000	31.9	2.0	33.9	167
2001	31.9	2.0	33.9	167
2002	31.9	2.0	33.9	167

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 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 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 the Office of Energy Research. Table 1.3-10 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 1.3-10. Resources for Hydrogen as an Alternative Fuel[a] (BA in millions of FY 1998 dollars after FY 1997).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1997	3.0	0.2	3.2	15
1998	3.5	0.3	3.8	17.5
1999	4.0	0.1	4.1	20
2000	5.0	0.1	5.1	25
2001	2.0	0.1	2.1	10
2002	2.0	0.1	2.1	10

[a] Funds are split 90% from the Assistant Secretary for Energy Efficiency and Renewable Energy and 10% from the Office of Energy Research.

Section 2

Scientific and Technical Programs

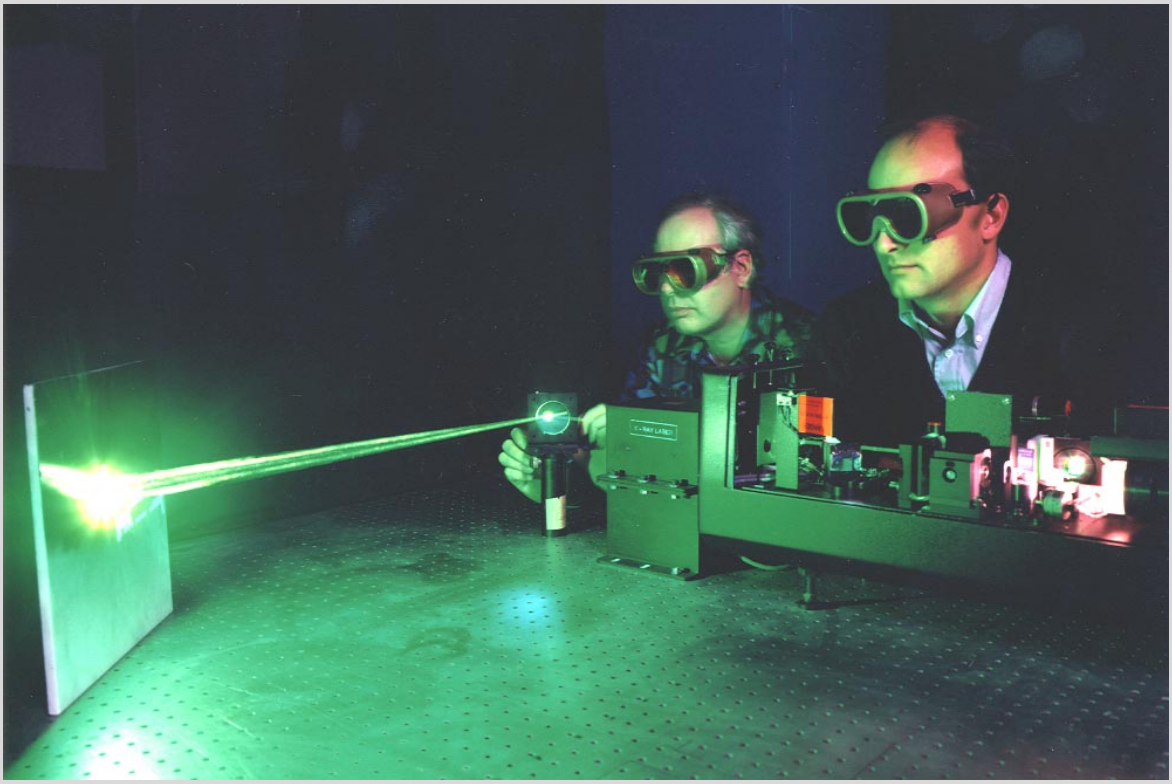


Photo: Livermore researchers Stan Mrowka (left) and Peter Celliers do early experiments to remove graffit from surfaces such as cement and metal with a high-average-power, solid-state, neodymium-doped glass laser.

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 (DoD) 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 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
Defense Programs				
DP-01 Core Stockpile and Stewardship	197.1	196.2	203.9	246.2
DP-02 Inertial Confinement Fusion	71.9	83.8	83.4	95.5
DP-02-07 National Ignition Facility[c]	3.9	20.0	0.0	0.0
DP-03 Technology Transfer and Educ.	57.6	43.8	17.7	3.0
DP-04 Weapons Stockpile Management	9.5	27.6	25.0	50.9
DP-05 Program Direction	6.1	0.0	8.5	8.7
GB-01 Indust Partnering with NIS	1.3	0.0	0.0	0.0
Total[c]	347.4	371.4	338.5	404.3
Nonproliferation & National Security				
GC Nonprolif & Verif R&D	36.5	34.3	32.0	33.0
GJ Arms Export Control and Nonprolif	16.4	15.5	21.0	22.5
ND Emergency Management	0.0	0.6	0.5	0.5
NT-01 Analytical Support	7.0	5.5	5.4	5.3
NT-04 Technical Support	0.4	0.0	0.0	0.0
GD-03 Classification Resources	0.6	1.0	0.9	0.6
GD-05 Operational Support	0.3	0.5	1.2	0.9
GD-06 Technology & Systems Devel	3.7	3.3	19.2	20.0
GH Related Security Investig Activity	4.1	4.3	3.1	1.6
Total	69.0	65.0	83.3	84.4
Fissile Materials Disposition				
GA Storage and Disposition Options	8.6	7.5	10.5	10.8
Total	8.6	7.5	10.5	10.8
Energy Research				
KP-00 Biological & Environmental Res	0.0	0.0	0.0	0.0
KP-01 Analytical Technology	0.1	0.0	0.0	0.0
KP-02 Environmental Research	0.4	0.6	0.5	0.5
KP-03 Health Effects	1.0	0.5	0.7	0.5
KP-04 General Life Sciences	12.0	11.4	11.6	11.3
KP-05 Carbon Dioxide Research	6.1	5.7	5.6	5.6
AT-00 Magnetic Fusion	0.0	0.0	0.0	0.0
AT-05 Applied Plasma Physics	11.9	9.3	6.5	7.2
AT-10 Confinement Systems	4.7	3.2	3.8	3.6
AT-15 Development & Technology	6.4	3.3	5.4	5.8
AT-25 Inertial Fusion Energy	1.4	1.8	2.2	4.5

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.
[c] National Ignition Facility funding for FY 1997–2002 is not included pending site selection.

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 retired nuclear weapons.
- Developing and applying technologies in support of U.S. nonproliferation and counterproliferation policies.
- Participating in the restructuring of the DOE weapon production complex.
- Using and enhancing our capability to support DOE Defense Programs (DP) through partnerships with U.S. industries.
- 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. 57) 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, ultrashort 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 management program will place significant demands on this infrastructure. Success depends on retention and recruitment of personnel with critical weapon skills. The

Table 2.1-1, continued. Major program operating fund summary (in millions of dollars); from FY 1998 budget submission, April 1996; not including construction or equipment.

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
Energy Research, continued				
KC-02 Materials Sciences	3.0	3.2	3.7	4.3
KC-03 Chemical Sciences	0.4	0.3	2.0	0.8
KC-04 Engineering & Geosciences	1.5	1.9	3.0	3.4
KC-05 Advanced Energy	1.3	0.7	0.0	0.0
KC-07 Applied Mathematical Sciences	28.7	9.2	1.0	1.1
KA-00 High-Energy Physics	0.0	0.0	0.0	0.0
KA-02 Facility Operations	0.1	0.0	0.0	0.0
KA-03 High-Energy Technology	1.0	0.5	0.5	0.6
KB-01 Medium-Energy Physics	0.3	0.0	0.0	0.0
KB-02 Heavy Ion Physics	0.3	0.3	0.3	0.4
KB-03 Nuclear Theory	0.1	0.0	0.0	0.0
KB-04 Low-Energy Physics	0.3	0.3	0.5	0.5
Total	81.0	52.2	47.3	50.1
Environmental Restoration & Waste Management				
EW-11 Corrective Activities (Defense)	0.2	0.0	0.0	0.0
EW-20 Environmental Restoration	24.9	23.5	21.6	19.3
EW-31 Waste Management (Defense)	29.5	29.7	34.6	33.3
EW-40 Technology Development	6.5	4.3	4.9	4.2
EX-60 Program Direction	0.1	0.0	0.0	0.0
EW-70 Facility Transition & Management	0.3	0.1	0.4	0.4
Total	61.5	57.6	61.5	57.2
Environment, Safety, & Health				
HA Environment, Safety, & Health	4.3	2.2	3.1	2.8
HP Nuclear Safety Policy Contr Support	0.7	0.7	0.7	0.7
HS Security Evaluation	1.3	1.2	1.5	1.5
NS Emergency Management	0.0	0.3	0.4	0.4
HR Marshall Island Program	2.1	2.3	2.3	2.3
Total	8.4	6.7	8.0	7.7
Nuclear Energy				
AF Light Water Reactors	0.1	0.0	0.0	0.0
AJ Naval Reactors Development	0.3	0.3	0.3	0.3
CD-10-04 HEU Eqp & Inv Dis	0.0	0.0	0.0	0.0
CD-10-06 Nuclear Safety	0.3	0.0	0.0	0.0
CD-10-07 Maint. of Leased/non-Leased	0.0	0.2	0.3	0.3
Nuclear Energy, continued				
CD-10-08 AVLIS	0.8	0.0	0.0	0.0
CD-10-09 Technology Partnerships	0.5	0.1	0.2	0.2
CD-10-12 Program Management Services	2.0	1.0	1.3	1.1

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

Table 2.1-1, continued. Major program operating fund summary (in millions of dollars); from FY 1998 budget submission, April 1996; not including construction or equipment.

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
CD-10-13 Transparency Measures	3.2	3.2	7.0	7.0
CD-10-15 Depleted Uran Hxflr Cyl & M	2.5	2.2	2.3	2.0
Total	9.7	7.0	11.4	10.9
Fossil Energy				
AA Advanced Research & Tech Devel	0.1	0.0	0.0	0.0
AB Natural Gas Research	0.2	0.0	0.0	0.0
AC Oil Technology	2.3	1.6	3.9	3.9
CB Naval Petroleum Reserve Nos 1&2	0.1	0.1	0.0	0.0
Total	2.7	1.7	3.9	3.9
Energy Efficiency & Renewable Energy				
AK Systems and Materials Research	0.1	0.0	0.0	0.0
AM Geothermal Technology Devel	0.0	1.0	0.8	0.9
AR Hydrogen Research	1.4	1.4	2.0	2.0
ED-21 Process Heating & Cooling	0.2	0.3	0.0	0.0
ED-22 Materials & Metals Processing	0.1	0.0	0.0	0.0
EE-50 Alternative Fuels Utilization	0.0	0.0	0.0	0.0
EE-51 Materials Technology	0.1	0.2	0.4	1.3
EE-53 Electric & Hybrid Propulsion Devel	0.2	0.3	0.3	0.0
WB In-house Energy Mgmt	0.9	0.0	0.1	0.5
Total	3.0	3.2	3.6	4.7
Human Resources & Administration				
WM Human Resource & Admin	0.7	0.5	0.7	0.7
Total	0.7	0.5	0.7	0.7
Science Education & Technical Information				
KT Laboratory Coop Science Ed Center	1.2	0.7	0.7	0.8
Total	1.2	0.7	0.7	0.8
Work for Integrated Contractors	42.4	35.6	23.9	20.4
Work for other DOE Installations	53.9	52.1	73.2	82.5
TOTAL DOE[c]	689.5	661.2	666.5	738.4
Department of Defense	63.8	63.1	96.4	83.3
NASA	3.5	1.6	3.6	1.6
U.S. Enrichment Corporation	45.5	87.0	90.0	80.0
Other Federal Agencies	13.4	18.8	20.2	17.2
Non-Federal Agencies	37.5	40.5	39.8	21.0
TOTAL NON-DOE	163.7	211.0	250.0	203.1
TOTAL LABORATORY	853.2	872.2	916.5	941.5

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.
[c] National Ignition Facility funding for FY 1997–2002 is not included pending site selection.

principal strategy for providing the necessary capabilities within a restricted budget is to consolidate among DOE facilities and, where possible, construct national facilities with broad capabilities such as the planned 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, modeling, and independent technical validation. 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, 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.

In FY 1996, 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. Nova experiments provide valuable data to validate certain aspects of our computational models. A particular highlight was the use of Nova experiments to provide insight into two separate stockpile- related concerns. In addition, we conducted successful 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.

Computations and Modeling

We use scientific and modeling tools to constantly expand our understanding of complex physical phenomena. The following programs exemplify how we are using our core competencies to achieve our strategic goals.

The Accelerated Strategic Computing Initiative (ASCI) is an effort to rapidly move test-based methods to computational-based methods of assuring the safety, reliability, and performance of our enduring nuclear stockpile. To meet the long-term needs of the Stockpile Stewardship and Management Program, ASCI supports the development of a new generation of weapon-simulation codes that will achieve high-fidelity, three-dimensional, full-physics, and full-system modeling capabilities. To satisfy the computing needs of these new codes, ASCI is partnering with U.S. industry to accelerate the development of supercomputers ten thousand to a hundred thousand times more capable than those used today. ASCI is being planned and implemented as an integrated, three-Laboratory (Livermore, Los Alamos, Sandia) program that is closely coupled to ongoing core activities in computation and modeling.

Major initial steps in the ASCI program at Livermore include:

• Selecting IBM for the award of a $93 million contract to build the world's fastest supercomputer, a 3.2-teraflop system to be delivered early in FY 1999. As part of this contract, IBM has already delivered a development system to LLNL that is the most powerful massively parallel processor yet built by IBM.

• Linking into the first high-speed, secure (encrypted) network to connect the three Defense Programs laboratories. This network will allow secure computing resources (especially other ASCI platforms) to be shared across the DP complex and will support much closer collaborations among nuclear weapons scientists and engineers than ever before.

• Starting development of large-scale, next-generation nuclear weapons performance and safety simulation codes.

Livermore operates a computing facility called Livermore Computing (LC) with secure and unclassified components. Both components are focused on the development of a balanced computing infrastructure for its Defense Sciences mission and for the institution as a whole, but with particular emphasis placed on preparing for the teraflop, massively parallel processing (MPP) supercomputer that will arrive within the next two years under the aegis of the ASCI Program.

The Center takes the view that in the new computing paradigm the network is the computer; in other words, the infrastructure consists of computers, disks, tertiary (long-term) storage, and data visualization hardware—all components necessarily integrated through a high-performance network and mediated by and controlled by high-performance workstations. In this view, the computer is not an independent entity directing bits into its local disk. The platform is simply the computing component of a larger entity that is controlled by a high-performance network. It is critical that each component be sized and integrated into the network seamlessly. Avoiding choke points and inefficiencies is a software and hardware challenge.

The LC is involved in a number of software and hardware projects:

• In partnership with the ASCI and other industrial and government collaborators, LC is developing the High Performance Storage System (HPSS), which will permit parallel input/output (I/O) to and from tertiary storage.

• The scalable I/O facility seeks to eliminate the I/O bottleneck currently

experienced by MPPs in writing to disk and other devices.

• We are initiating a series of procurements for both the storage and networking that will accommodate the tremendous computing capability of the MPP system being acquired as a part of ASCI. For instance, the storage system will evolve to terabytes (10^{12}) this year and to the petabyte (10^{15}) range by 1998. Simultaneously, the Center must concentrate on satisfying the current needs for capacity and capability of all of its customers. Today, these needs are being met by a secure Meiko 256-node massively parallel system accompanied by a 48-node unclassified system, an unclassified Cray 256-node T3D, secure clusters of Cray J90 symmetric multiprocessors (SMPs), and an unclassified cluster of DEC SMPs. Many of these systems (as well as the storage environment) are being upgraded this year to accommodate current demand.

• We are collaborating with DOE researchers and American industry in a number of areas. For example, the High Performance Parallel Processing Project (or H4P) is a collaboration among Los Alamos, Livermore, Cray Research, and 16 industrial partners to develop software and scientific applications targeted at the T3D and other parallel computers. The applications target fluid-structure interactions, molecular dynamics, oil-well logging, subsurface contaminant flow, and electromagnetics. A number of these applications are running routinely in production on the T3D. In a partnership with Cray, LLNL also has developed a gang scheduler, which allows multiple customers to share a parallel computer efficiently.

In addition, the Computational Sciences Research Program at Lawrence Livermore broadly supports Laboratory programs through research on problems in computational fluid dynamics, flow in porous media, turbulence modeling, and neutron and radiation transport. These research activities entail collaboration among programs at the Laboratory and with scientists at other federal laboratories, in industry, and in universities.

Hydrodynamic Test Facilities

Hydrodynamic testing remains the only direct experimental means for evaluating some aspects of 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. 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.

Bunker 801 at Site 300 remains the most versatile and complete hydrodynamic testing facility in the world. This year we began a major upgrade to Bunker 801 to accommodate containment of the high-explosive detonation and its products, thus ensuring continued use of the facility under increasingly restrictive environmental regulations. Improvements also include upgrading the flash x-ray (FXR) accelerator combined with the newly developed gamma-ray camera, which will allow us to conduct device-implosion imaging experiments with higher resolution, and at higher densities than ever before possible. Other diagnostic capabilities at Site 300 include laser holography, laser velocimetry, high-speed optical cameras, and pin-dome technology. The final ten beams of our velocimetry system are now under construction. During the next two

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
DP-01 Core Stockpile and Stewardship	197.1	196.2	203.9	246.2
DP-02 Inertial Confinement Fusion	71.9	83.8	83.4	95.5
DP-02-07 National Ignition Facility[c]	3.9	20.0	0.0	0.0
DP-03 Technology Transfer and Educ.	57.6	43.8	17.7	3.0
DP-04 Weapons Stockpile Management	9.5	27.6	25.0	50.9
DP-05 Program Direction	6.1	0.0	8.5	8.7
GB-01 Indust Partnering with NIS	1.3	0.0	0.0	0.0
Total[c]	347.4	371.4	338.5	404.3

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.
[c] National Ignition Facility funding for FY 1997–2002 is not included pending site selection.

years we will develop and implement double-pulse technology in the FXR.

Experiments began at the Big Explosives Experimental Facility at the Nevada Test Site, which can accommodate larger high-explosive charges than can be fired at Site 300. Diagnostics at this facility now include x-ray radiography, target-penetration-rate switches, streak cameras, fast-framing cameras, laser image converter cameras, and multibeam laser velocimetry.

We continue planning for the Advanced Hydrotest Facility. This flash x-ray machine's multiple temporal and spatial pulses will be more powerful and versatile than the FXR. This machine will enable us to record multiple images 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 and serve as a testbed for studying the disablement of terrorist nuclear devices.

This year, we will reactivate the ETA-II accelerator for use as a test bed of solid-state power, long-pulse accelerator cores, kickers, and beamline optics, which are essential elements of this new technology.

Inertial Confinement Fusion

The Inertial Confinement Fusion (ICF) Program is a research and advanced technology development program focused on the goal of demonstrating controlled thermonuclear fusion ignition and energy gain. The ICF Program conducts ignition physics optimization studies and weapons physics experiments in support of the Defense Programs' stockpile stewardship goals. The ICF Program also develops laser and optics technologies needed to meet the performance, schedule, and cost goals of the National Ignition Facility (NIF) Project, a key element of the DOE's Stockpile Stewardship and Management (SSM) Program. In addition to its primary Defense Programs' goals, the ICF Program provides research opportunities in fundamental high-energy-density physics and supports the longer-term application of inertial fusion energy for electric power generation. Finally, technologies developed to support ICF continue to have spin-off applications for other government and commercial uses.

The technical bases for the expectation of achieving ignition with the NIF are our extensive experiments using the Nova laser, including those specified by the Nova Technical Contract (National Academy of Sciences, September 1990), which were completed at the end of FY 1995. The Target Physics Contract defined within DOE's five-year plan for the ICF national program describes the experiments required to resolve important issues regarding ignition. It is expected that these experiments will be completed at the time of the decision to start Title II for the NIF.

In addition to these experiments, the ICF Program is focusing on core science and technology research in the areas of target physics, target chamber development and diagnostics, target fabrication, laser technology, and optics manufacturing.

Target physics work within the core program includes advanced target concepts with radiation shields, hydrodynamic instability experiments for benchmarking 3D simulation codes, further studies of stimulated Raman and Brillouin scattering (SRS/SBS) to examine trade-offs between laser and target designs, and experimental investigation of the petawatt-laser fast-ignitor concept, an alternative approach to ignition.

Target-chamber development activities include characterization of target debris and radiation threats to target chamber hardware and the development of design responses to these threats. Target diagnostics—such as x-ray, neutron, gamma-ray, and optical detectors—will be improved to meet the more stringent conditions of future Nova and NIF experiments. Target component and fabrication development activities will cover fuel capsule and hohlraum manufacturing technologies, including the cryogenic systems needed for the formation of solid hydrogen fuel layers.

Laser developments include advanced components and subsystems, such as the optical pulse generator, power amplifier, optical switch, frequency converter, diffractive optics, pulsed power system, laser diagnostics, alignment systems, structural supports, optics cleaning systems, and control systems. The NIF prototype, the Beamlet laser, uses a multipass amplifier cavity and active switch to generate output energies up to 12.5 kJ at 1054 nm (infrared fundamental) in a square 34-cm beam. The average fluence is equivalent to that for the NIF when operated at 3 ns. The initial results at the third harmonic (351 nm) exceeded the fluences required on the NIF and show a peak conversion efficiency of near 80%. The Beamlet will also provide the basic science, small-scale testing, and integrated performance of a single NIF beam to confirm fundamental principles of the laser design and

operation, including its initial activation.

Optics manufacturing development will focus on all aspects of producing large-aperture, high-quality optics in large quantities. This includes laser glass, KDP crystals, fused silica, high-damage-threshold coatings, and the testing and characterization to prove that the optics meet the demanding optical NIF specifications. Emphasis will be placed on improved manufacturing processes and quality control that significantly reduces the unit cost of each large-aperture optic. This development must be completed as part of the NIF Title II design (expected to be at the end of FY 1997) because of the long manufacturing time required to produce the large quantity of optics required for the NIF (3,700 laser slabs, 600 KDP crystals, and 1,400 mirrors, all at full aperture).

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 (LANL) 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 to produce threat-level environments in most portions of the x-ray spectrum and other facilities to test gamma-ray and neutron hardness. The Saturn x-ray facility at Sandia, Albuquerque, and the Decade machine under construction near Manchester, Tennessee, can meet some of our x-ray testing needs. The planned NIF will be an excellent testbed for the radiation effects of nuclear environments on weapons and other complex systems. It will provide capability for some types of testing that is not available in any other existing or planned facility. We will be able to use this family of facilities to test the radiation hardness of all stockpile warheads, satellites, and other hardware.

Nuclear Weapon Information

As the pool of experienced staff and engineers decreases, we are more reliant on records of our past experience in weapon development and testing, which we are assembling into a comprehensive database. We are compiling the data in forms that will be accessible and understandable in the future by those who will be new to the weapons program.

The database will include computer archives of the historical and ongoing work done in the DOE weapons complex. It will also include analyses performed using continually improving physics, chemical, and engineering codes as they become available. Future data will include non-nuclear experiments that support the maintenance, safety, and reliability of U.S. stockpiled systems.

Industrial Partnerships

Partnerships with outside industry have enhanced the technical base required to maintain the weapons program. We focus on partnering activities that support and enhance our programmatic effort to meet important national needs in a cost-effective manner. At the same time, we are providing opportunities for industry to tap into our cutting-edge technologies and facilities to bolster its global competitiveness. These collaborative efforts provide valuable support to our programs, support the needs of the industrial sector, and develop and maintain skills of our technical staff.

Our activities in this area include:
• Developing high-bandwidth photonic systems for commercial communication and computer networking. These systems will help reduce costs associated with the National Information Infrastructure.
• Adapting and improving 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.

Other industrial partnerships are described under Industrial Partnerships and Commercialization in section 2.4 Special Programs, beginning on p. 101.

Stockpile Management

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

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 (SSM PEIS). We are working with DOE/Albuquerque to develop proposals for the future nuclear weapons complex with a goal of making a much smaller and more efficient complex. LLNL employees are participating on all working teams as well as the steering committee, helping to determine the preferred alternatives for the reconfiguration of the entire complex.

Enhanced Surveillance

We are expanding current surveillance efforts to include focused archiving of our experience in physics, engineering, chemistry, and material science. New surveillance technologies—coupled with enhanced predictive capabilities for the effects of age on material component and weapon performance—also are needed so that we can better detect the onset of potential safety or reliability problems before they become serious.

Within the Laboratory, we are working to improve the science of surveillance so that we can better understand and predict effects of age on weapons. These efforts are one key to an affordable manufacturing capability because they will enable a more timely refurbishment and preventive maintenance program than an expensive and high-production-rate replacement program when age effects are found. We are conducting R&D in the use of advanced sensors to allow nondestructive examination of weapon components in a more detailed and fundamental way, which will greatly enhance the effectiveness of stockpile surveillance. We are working with DOE to plan and implement a three-lab program in this area.

Advanced Design and Production Technologies (ADaPT)

The challenges that face the new DOE manufacturing complex are being met by technologies under development in the Advanced Design and Production Technologies (ADaPT) Program. This effort will focus and improve the functions of the complex by utilizing computer and computationally based technologies to integrate the DOE manufacturing complex, increase the agility of the manufacturing plants, develop new processes to respond to environmental and cost concerns, and develop hedge strategies to respond to unforeseen circumstances.

Process Development

We are continuing the efforts to develop technologies that will greatly improve the efficiency of the future weapons complex:
• We have demonstrated that the plutonium precision casting process can produce components with weapons quality. We built a precision cast and laser-welded pit to demonstrate the use of laser welding for replacing electron beam welding for all pit fabrication welds. Laser welding has the benefits of reduced equipment requirements and increased flexibility. In future work we will continue process characterization/refinement, conduct production prototype engineering, and transfer the technology to LANL for use in pit remanufacturing.
• 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 plutonium precision casting and near-net-shape casting of uranium have demonstrated the value of using 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.

• Laser cutting technology is being developed for disassembly of nuclear weapons with reuse of high-value components. We have demonstrated an ability to make cuts narrower than the width of a human hair through thick sections of material with no damage to the surrounding material. We will provide full-scale cutting technology this year and will deploy a number of prototype laser systems at DOE's Y-12 Plant in Oak Ridge, Tennessee, in FY 1997.

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 complex.

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 in addition to defense needs.

Dismantlement and Long-Term Storage

Warhead dismantlement 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.

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

We have been full partners with Sandia, Los Alamos, and Pantex to develop processes and procedures for dismantling retired weapons and rebuilding stockpile weapons. Bringing our technical expertise to bear on the critical operations of this partnership (Seamless Safety) will ensure the continued safe weapons operation at the Pantex facility.

Pit Processing and Plutonium Recovery

We are recovering the plutonium from a number of unneeded pits. We will employ disassembly hardware and a hydriding process to remove the plutonium and convert it into a form suitable for storage and shipment.

We are working with Los Alamos to develop a modular system for the recovery of plutonium from retired or excess pits. This system, termed the Advanced Recovery and Integrated Extraction System (ARIES), will consist of five interconnected glovebox modules. We have the lead responsibility for two of these modules: one to bisect apart the returned pits, and a second to recover plutonium by converting it to plutonium hydride, which is then oxidized in-situ to a stable form for long-term storage or disposition.

The design, test, and integration of these modules emphasizes minimization of worker radiation exposure, module compactness, minimization of waste, and overall safety implementation.

Plutonium Disposition

In early 1993, the U.S. National Academy of Sciences (NAS) issued a report calling for mutual disposition of fissile materials in the U.S. and Russia that were excess to defense needs. The NAS recommended treatment to render these materials unsuitable for subsequent weapons use. Reactor burning of mixed oxide fuels and immobilization in glass spiked with highly radioactive, high-level waste were identified as candidate means for disposition. Shortly thereafter, a Presidential Decision Directive was issued, initiating a program consisting of (1) declarations of excess materials stocks and (2) a program to study and implement disposition. An interagency task force was set up, and DOE was identified as the lead agency. DOE tasked Livermore to lead the study of the immobilization alternative and to lead a study of an additional alternative

that would dispose of the excess fissile materials in a deep borehole.

The Laboratory has nearly completed the study phase of the effort, which will lead to a Record of Decision that is scheduled for December 1996. We provided information regarding the immobilization and deep borehole alternatives in support of a PEIS that was issued in the spring of 1996. In the fall of 1996, we issued Technical Summary Reports describing the technical feasibility, schedule, and cost for the immobilization and deep borehole alternatives. Both appear to be feasible, although the siting of the deep borehole may be impractical. In conjunction with Westinghouse Savannah River, Livermore has developed the can-in-canister option. This option takes advantage of the existing Defense Waste Processing Facility to achieve inexpensive, timely, and novel means for disposition. We have also developed programs of joint study for the two alternatives with Russian Institutes.

If either the immobilization or the deep borehole alternative approach is selected in the upcoming Record of Decision, Livermore will complete the development processes and work with a plant site (to be determined) for construction of a pilot plant.

Nuclear Safety

We provide technical support in a number of areas relating to safety of nuclear facilities and nuclear explosives operations by:

• 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 environment, safety, and health (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 DP facilities.
• Developing software for preparing seismic hazard maps and guidelines for system qualifications related to seismic events.
• Developing a clearinghouse 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 explosive operations.
• Providing criticality safety benchmarks to support facility operations.

National Atmospheric Release Advisory Capability (NARAC)

Our National Atmospheric Release Advisory Capability is a facility that is operated by the Regional Atmospheric Sciences Division to provide 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, our mission has 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.

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

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 done under the auspices of the MOU. Other direct DoD funded efforts are reported in Section 2.3.

Energetic Materials

The DOE and DoD 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, the reduction of

hazards in accidents are the motivations for the use of insensitive high explosives. Each department is concerned about safety in manufacturing. We are synthesizing and formulating new inexpensive explosives that promise improved performance for DoD applications. We are also developing extrusion-cast and paste explosives for precision munitions that are of interest to both DoD and DOE.

We are exploring enhanced conventional penetrating bomb loads that preserve safety and significantly improve performance. On the higher end of the scale of energetics, we are exploring materials that fill the gap between conventional organic explosives and nuclear weapons. These materials 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, and they have a vast potential for the deposition of a broad spectrum of civilian hazardous and mixed wastes.

Special Munitions

We are developing several new designs for shaped charges and explosively formed, projectile-penetrating munitions for the DoD. The DOE interest in this area lies in using these concepts for nuclear-safe destruction of improvised nuclear devices. In addition, the code design and benchmarking experimental diagnostics have been mutually beneficial. Several munition concepts are being developed for hardened buried targets.

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 are very significant for enhanced understanding of the response of nuclear weapons to various accident scenarios. The DoD interest lies in warhead design as well as in target vulnerability and lethality assessments.

Conflict Simulation

We are continuing to develop and apply high-resolution combat-simulation software in order to assess military use and effects of both nuclear and conventional weapons. Our Conflict Simulation Laboratory has the ability to simulate a wide scope of operations. For example, it can be used to analyze combat scenarios and to plan and rehearse strategies for protecting headquarters or nuclear/conventional weapon storage depots against theft, sabotage, or terrorism. Because this capability supports such diverse 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 special warfare scenarios. The DoD, especially the Army, has found it to be very useful for training battlefield commanders and for developing tactics for joint warfighting 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 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, 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 weapons development 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 of smaller, simpler instruments for field use. We have also:

• Developed 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 in support of the United Nations Special Commission.

• 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 and the DOE Office of Nonproliferation and National Security. We support the Nuclear Emergency Search Team (NEST), 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.

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
GC Nonprolif & Verif R&D	36.5	34.3	32.0	33.0
GJ Arms Export Control and Nonprolif	16.4	15.5	21.0	22.5
ND Emergency Management	0.0	0.6	0.5	0.5
NT-01 Analytical Support	7.0	5.5	5.4	5.3
NT-04 Technical Support	0.4	0.0	0.0	0.0
GD-03 Classification Resources	0.6	1.0	0.9	0.6
GD-05 Operational Support	0.3	0.5	1.2	0.9
GD-06 Technology & Systems Devel	3.7	3.3	19.2	20.0
GH Related Security Investig Activity	4.1	4.3	3.1	1.6
Total	69.0	65.0	83.3	84.4

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

Recently 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.

• Hosted the International Conference on Nuclear Smuggling Forensic Analysis, which brought together a mix of technical, intelligence, and law enforcement experts from 14 countries to compare experiences and techniques.

• 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 nuclear materials.

Control of Nuclear Material, Defense Conversion in the New Independent States (NIS), Arms Control, and Treaty Verification

In our interactions with Russia and other states in the NIS, LLNL supports U.S. nonproliferation goals by assisting in the conversion of institutes and facilities previously involved in weapons work to commercially viable work in nonweapons and civilian applications. Much of the effort is focused toward controlling special nuclear materials and engaging the nuclear weapon institutes on arms control and nonproliferation issues.

Arms control agreements are important to national security, and they are becoming increasingly more difficult to verify, thus challenging the inventiveness of the DOE laboratories. While our support to treaties for stockpile drawdown continues, our work is focusing more on nonproliferation-related issues, such as support of the IAEA, the Comprehensive Test Ban Treaty (CTBT), the Conference on Disarmament, the Fissile Material Cutoff Treaty, the Chemical Weapons Convention, and regional security. In recent activities:

• LLNL is a principal participant in the DOE Industrial Partnering Program aimed at defense conversion of former nuclear weapon institutes in the NIS. In this program LLNL contracts with various nuclear weapon institutes for reports and collaborative work in nonweapons areas that have commercial value. Over 400 NIS weapons scientists are employed in carrying out these activities.

• LLNL is contributing to the Los Alamos-led multilaboratory DOE program with Russia for nuclear material protection, control, and accountability (MPC&A), which is developing state-of-the-art approaches to monitor and account for nuclear materials at Russian facilities. LLNL is the lead for assessing the vulnerability of storage facilities and is providing measurement systems for fissile material to Russian institutes.

• LLNL has the lead technical role in the negotiations for Mutual Reciprocal Inspections (MRI) of fissile material removed from dismantled nuclear weapons. MRI is the lead element of the Safeguards, Transparency, and Irreversibility initiative with Russia to gain confidence in the process of nuclear warhead dismantlement. LLNL is now chairing an effort to evaluate warhead radiation signatures for tracking warheads through the dismantlement process. Continuing a process begun in 1994 to evaluate plutonium inspection instruments, we invitred Russian scientists for a second technical exchange meeting at LLNL, during which the Russians will be shown our evaluation of their suggested measurement technique.

• LLNL has continued its lead-laboratory role in the development, improvement, and implementation of transparency measures associated with the purchase of highly enriched uranium from Russia. LLNL has provided technical leadership for the two monitoring visits at the Ural Electrochemical Integrated Enterprise, the familiarization visit to the Seversk's metallurgical facility, and two transparency review committee meetings.

• President Clinton, in his August 11, 1995, speech, reaffirmed his commitment to complete a Comprehensive Test Ban Treaty (CTBT) and also to complete the research and development effort necessary for its effective monitoring. To help meet this goal, LLNL is working closely with other national laboratories to provide software systems that can accurately locate and identify events with explosion characteristics in regions of interest. We have already delivered research versions of event identification systems to our primary customer, the

U.S. National Data Center at Patrick Air Force Base. LLNL has also provided input to DOE on the effects of a CTBT on the maintenance of the U.S. nuclear stockpile. Our scientists have also provided expertise to the Conference on Disarmament, the international Group of Scientific Experts on seismic detection, and the On-Site-Inspection Working Group.

• We have made progress in three technical areas pertaining to CTBT evasion and detection. (1) We contributed one of the half-dozen credible evasive CTBT violation scenarios prepared by an interagency working group for the U.S. negotiation team. (2) We studied radiation-induced air fluorescence of fission debris and proposed it as an alternative prompt signature for those evasive test scenarios that suppress or distort the conventional optical detonation signature. (3) We began examining geomagnetic perturbations as a possible event-detection signature. Some of this work was performed in collaboration with the Russian Shmidt United Institute of Physics of the Earth.

• Beginning in 1995, LLNL has been conducting a training course for On-Site Inspection Agency (OSIA) personnel who deal with the collection and analysis of chemical samples relevant to implementation of the Chemical Weapons Convention (CWC).

• DOE, through LLNL, is supporting an initiative to use regional seismology as a confidence-building tool in the Arms Control and Regional Security (ACRS) working group of the Middle East Peace Process. This initiative, presented by LLNL and Arms Control and Disarmament Agency (ACDA) representatives at the latest ACRS meeting in Helsinki, proposes forming a group of regional seismologists who would conduct joint experiments and analyses using common analysis procedures and shared data to assure that nuclear testing is not taking place and provide confidence that such activity would be recognized if it does happen.

Safeguards and Security Planning for Protection of Russian Material

We are developing training classes and other materials so that we can 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 for 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.

Computer Security Technology Center (CSTC)

The CSTC, which supports a computer security R&D program at Livermore, comprises three complementary business elements: DOE Computer Incident Advisory Capability, for operational incident response; Advanced Security Projects, for R&D and product development; and Secure Systems Services, for consulting and professional services. The group researches information security issues and develops tools and architectures to enhance the security posture of computer systems and networks. Projects include:

• AIS Alarm Project—a joint effort of LLNL, Los Alamos National Laboratory, and Sandia National Laboratories—to demonstrate and implement, on a small-to-medium-sized local area network, an automated system that detects and responds to attacks with readily available tools and methodologies.

• Secure Software Distribution System, which will provide automated analysis, notification, distribution, and installation of security patches and related software to network-based computer systems (see the secure computing discussion p. 56).

• Security Profile Inspector, which performs distributed 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.

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 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 working on the immobilization and deep borehole options.

We have found that glass and ceramics are good candidates as materials for immobilization of plutonium. We have identified neutron poison candidates that can effectively prevent criticality incidents. We have studied facilities that can be used to perform the immobilization processing. Processes range from construction of a new plant to modification of existing facilities such as the Defense Waste Processing Facility at Savannah River. We have developed the can-in-canister approach as a cost-effective approach that would maximize use of existing facilities. The technical viability, cost, and schedule for these options have been evaluated. We are now in the process of comparing the proliferation resistance of the can-in-canister to that of spent nuclear fuel.

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.

Under the aegis of a U.S. DOE–Minatom agreement, we are working on joint papers with our Russian counterparts to assess immobilization and borehole disposition against a common set of criteria.

Livermore also is performing safeguards and security studies for each of these options and has provided 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 metric tonnes of Russian highly enriched uranium from dismantled nuclear weapons.
• To encourage the Russian Federation to remove excess fissile material from

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
GA Storage and Disposition Options	8.6	7.5	10.5	10.8
Total	8.6	7.5	10.5	10.8

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

weapons, we will work with them to 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.

Office of Energy Research

Table 2.1-5 shows projected funding from this office.

Fusion Energy

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.

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 1,500-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

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
KP-00 Biological & Environmental Res	0.0	0.0	0.0	0.0
KP-01 Analytical Technology	0.1	0.0	0.0	0.0
KP-02 Environmental Research	0.4	0.6	0.5	0.5
KP-03 Health Effects	1.0	0.5	0.7	0.5
KP-04 General Life Sciences	12.0	11.4	11.6	11.3
KP-05 Carbon Dioxide Research	6.1	5.7	5.6	5.6
AT-00 Magnetic Fusion	0.0	0.0	0.0	0.0
AT-05 Applied Plasma Physics	11.9	9.3	6.5	7.2
AT-10 Confinement Systems	4.7	3.2	3.8	3.6
AT-15 Development & Technology	6.4	3.3	5.4	5.8
AT-25 Inertial Fusion Energy	1.4	1.8	2.2	4.5
KC-02 Materials Sciences	3.0	3.2	3.7	4.3
KC-03 Chemical Sciences	0.4	0.3	2.0	0.8
KC-04 Engineering & Geosciences	1.5	1.9	3.0	3.4
KC-05 Advanced Energy	1.3	0.7	0.0	0.0
KC-07 Applied Mathematical Sciences	28.7	9.2	1.0	1.1
KA-00 High-Energy Physics	0.0	0.0	0.0	0.0
KA-02 Facility Operations	0.1	0.0	0.0	0.0
KA-03 High-Energy Technology	1.0	0.5	0.5	0.6
KB-01 Medium-Energy Physics	0.3	0.0	0.0	0.0
KB-02 Heavy Ion Physics	0.3	0.3	0.3	0.4
KB-03 Nuclear Theory	0.1	0.0	0.0	0.0
KB-04 Low-Energy Physics	0.3	0.3	0.5	0.5
Total	81.0	52.2	47.3	50.1

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

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 Tokamak Physics Experiment.
• 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 goals are 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 Fusion

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 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:
• Accelerator experiments, including planning, engineering, and execution in beam bending, magnetic transport, steering, and recirculation at LLNL; and participation in a variety of experiments at LBNL.
• Development of improved driver concepts, including advanced linacs and recirculating induction accelerators.
• 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 studies.
• 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 the planned National Ignition Facility (NIF) relevant to 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.

LLNL has responsibility for integrating the Instrumented Flux Return, a major detector system that will identify muons and hadrons, consisting of 1,000 tons of steel plate, and 3,000 m^2 of muon chambers. Livermore scientists are leaders in physics simulation for the detector.

We have also entered into a partnership with SLAC, LBNL, and Fermi National Accelerator Laboratory, on R&D for the Next Linear Collider (NLC), a TeV-class, 30-km-long electron-positron colliding beam facility that could begin construction in 2001. The Laboratory's major roles are in developing the relativistic klystron, a future high-power microwave drive system, and the second interaction region for gamma–gamma collisions at several hundred giga-electron volts of energy. The gammas are created by Compton-backscattering ultrashort pulse laser beams from the incoming electrons. The NLC will enable precision studies of physics beyond the standard model.

Nuclear Physics

Our Nuclear Physics Program has several 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 we are elucidating the nuclear structure associated with the second well of the nuclear potential energy surface.

We are using the techniques developed in the GAMMASPHERE project to measure a series of reaction cross sections that historically have been beyond the state of the art. Because of the promise of this Livermore-led program, a major DOE detector facility (the HERA array, an array of many Compton-suppressed germanium detectors) is being pursued. It is expected that this program will provide precise measurements of cross sections such as ^{239}Pu(n,2n).

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 being built at Brookhaven National Laboratory (BNL). We are also coordinating work for the central drift chambers of the PHENIX detector.

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 distributions of reaction products resulting from proton nucleus collisions that create nuclear matter at densities as high as five times normal.

We have developed techniques and technologies to use particle beams for both static and dynamic radiography and tomography. We are involved with programs developing both neutron and proton radiography. One particularly challenging problem

concerns innovative detector and sensor development.

We are continuing to develop a new database for use in applications as radiation oncology, accelerator production of tritium, and accelerator transmutation of waste. 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 six major areas: tools for assessing disease susceptibility, genomics infrastructure, structural biology, healthcare technologies, 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.
- Generated a metric physical map of chromosome 19 that spans 95% of the chromosome in 23 ordered islands of overlapping clones.
- Developed chromosome painting probes for the mouse, rat, and hamster in order to evaluate the persistence of chromosome damage following exposure to ionizing radiation.
- Cloned the human repair genes XRCC2 and XRCC9 and showed that they are required for chromosome stability and resistance of cells to a wide variety of DNA-damaging agents.
- Completed the DNA sequence of over 1.3 million bases for human chromosome 19 and selected DNA repair genes in the mouse and human.
- Developed robotic technologies for spotting recombinant DNA clones at high density.
- Developed new optical-acoustic approaches useful for thrombolysis.

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. 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 cDNA 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 and microbial genomes. 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 other human diseases 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. We will maximize our contributions to the understanding of the structural basis of disease susceptibility by coupling our knowledge of genomics and susceptibility studies and our newly developed capabilities of nuclear

magnetic resonance, x-ray diffraction, and structure prediction to the major DOE structural biology facilities at Stanford, LBNL, PNNL, LANL, ANL, and BNL .

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 and other long-standing Laboratory 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 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, Atmospheric Sciences 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.

Atmospheric Sciences Division also supports OHER's Atmospheric Radiation Project, using its mesoscale models to improve 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 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, the development of superplastic forming processes, and the in-situ, real-time phase relationships during welding. 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 (EBIT) to study the spectroscopy and interactions of highly charged atomic ions all the way to fully stripped uranium (U^{92+}). The spectroscopy research features high-resolution, high-accuracy measurements of transition energies in few-electron heavy ions to test predictions of quantum electrodynamics (QED), nuclear-size, and relativistic correlation effects on energy levels. Studies of electron–ion interactions focus on dielectronic recombination, impact excitation, and ionization to provide benchmarks for testing various theoretical methods. We are also measuring radiative lifetimes in regimes inaccessible to traditional ion sources. Such experiments complement both energy-level determinations and measurements of excitation cross sections. We are studying dipole-forbidden transitions of highly charged ions that have radiative lifetimes in the range of 1 to 100 microseconds.

We are developing a low-noise, high-throughput optical spectrometer for measuring the hyperfine transition in hydrogenic ions. This instrument will enable us to probe the contributions of QED, nuclear-size, nuclear magnetization and polarization to the energy levels of hydrogenic ions. We plan experiments on HO^{66+}, Re^{74+}, Ti^{80+}, and Bi^{82+}, where the hyperfine transitions fall into the visible part of the spectrum between 3,800 and 7,500 Å. The accuracy will be about 1 Å, or 0.0008 eV. To achieve even better accuracy, we plan to do laser spectroscopy on hydrogenic ions trapped in the new RETRAP device.

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. We are also simulating formation and emission of toxic chemicals, particularly polycyclic aromatic hydrocarbons (PAH), from industrial sources, and we are assessing the potential of hydrogen as a low-pollution alternative fuel for automotive and industrial applications.

Geosciences

The Geophysics and Global Security 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:

- 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.

Computer Systems Security

Secure Software Distribution System (SSDS)

SSDS will provide automated analysis, notification, distribution, and installation of security patches and related software to network-based computer systems. This system will allow a network administrator to query, maintain, and upgrade the software integrity of hundreds of individual systems from a central point through largely automated means. This effort will establish a centralized software installation and configuration system to provide the following services for client systems:

• Automated notification of new vendor security patches.
• Automated determination of patch applicability to target systems.
• Automated installation of security patches and critical system software.
• Ability to "back-out" installed patches, restoring a system's previous state.
• Provision for rapid system "trust" determination and site-wide software patch status metrics.

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
EW-11 Corrective Activities (Defense)	0.2	0.0	0.0	0.0
EW-20 Environmental Restoration	24.9	23.5	21.6	19.3
EW-31 Waste Management (Defense)	29.5	29.7	34.6	33.3
EW-40 Technology Development	6.5	4.3	4.9	4.2
EX-60 Program Direction	0.1	0.0	0.0	0.0
EW-70 Facility Transition & Management	0.3	0.1	0.4	0.4
Total	61.5	57.6	61.5	57.2

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

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's Geosciences and Environmental Technologies Program 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 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 groundwater 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. This technology is now being deployed at an industrial site by a contractor at a cost approximately half that demonstrated in the R&D phase at Livermore.

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

• Have begun site characterization and process validation for the Accelerated Cleanup Initiative, a project to use thermal and bioremediation techniques to greatly accelerate remediation of the Livermore main Site. This project, currently given phased startup support by EM-40, EM-5, and laboratory LDRD for selected activities, offers the prospect of completing remediation operation within the 10-year goal set by EM. Additionally, the work will be executed with a corporate partner whose role will be engineering and economic validation of our integrated processes, making possible rapid corporate deployment of our technologies on other sites.

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 DOE , environmental, and regulatory requirements.

• Conduct our activities in a safe, cost-effective 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 developing 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 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 that 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 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, chlorofluorocarbons, and solvents.

Waste Treatment

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.

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,

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 to 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.

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

In FY 1995, DOE's Office of Civilian Radioactive Waste Management delegated authority to consolidate and integrate all work performed on the Yucca Mountain project to TRW, the prime contractor to the Yucca Mountain Site Characterization Office. TRW serves as the management and operating contractor and uses the most qualified subcontractor/laboratory to perform necessary research and development on disposal of high-level nuclear waste and spent nuclear fuel at the site. Livermore is participating in studies for a potential nuclear waste respository 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

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
HA Environment, Safety, & Health	4.3	2.2	3.1	2.8
HP Nuclear Safety Policy Contr Support	0.7	0.7	0.7	0.7
HS Security Evaluation	1.3	1.2	1.5	1.5
NS Emergency Management	0.0	0.3	0.4	0.4
HR Marshall Island Program	2.1	2.3	2.3	2.3
Total	8.4	6.7	8.0	7.7

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

environment. 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 "localized 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 (waterborne transport) of radionuclides. We are developing conceptual models, computer codes, laboratory experiments, and field tests to demonstrate the validity of this "localized 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.

Assistant Secretary for Fossil Energy

The DOE Assistant Secretary for Fossil Energy sponsors Laboratory research on gas and oil. Table 2.1-9 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.

Assistant Secretary for Energy Efficiency and Renewable Energy

Table 2.1-10 shows projected funding from this office.

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
AF Light Water Reactors	0.1	0.0	0.0	0.0
AJ Naval Reactors Development	0.3	0.3	0.3	0.3
CD-10-04 HEU Eqp & Inv Dis	0.0	0.0	0.0	0.0
CD-10-06 Nuclear Safety	0.3	0.0	0.0	0.0
CD-10-07 Maint. of Leased/non-Leased	0.0	0.2	0.3	0.3
CD-10-08 AVLIS	0.8	0.0	0.0	0.0
CD-10-09 Technology Partnerships	0.5	0.1	0.2	0.2
CD-10-12 Program Management Services	2.0	1.0	1.3	1.1
CD-10-13 Transparency Measures	3.2	3.2	7.0	7.0
CD-10-15 Depleted Uran Hxflr Cyl & M	2.5	2.2	2.3	2.0
Total	9.7	7.0	11.4	10.9

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

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.

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

Table 2.1-9. Fossil Energy operating funds (in millions of dollars).

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
AA Advanced Research & Tech Devel	0.1	0.0	0.0	0.0
AB Natural Gas Research	0.2	0.0	0.0	0.0
AC Oil Technology	2.3	1.6	3.9	3.9
CB Naval Petroleum Reserve Nos 1&2	0.1	0.1	0.0	0.0
Total	2.7	1.7	3.9	3.9

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

Table 2.1-10. Energy Efficiency and Renewable Energy operating funds (in millions of dollars).

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
AK Systems and Materials Research	0.1	0.0	0.0	0.0
AM Geothermal Technology Devel	0.0	1.0	0.8	0.9
AR Hydrogen Research	1.4	1.4	2.0	2.0
ED-21 Process Heating & Cooling	0.2	0.3	0.0	0.0
ED-22 Materials & Metals Processing	0.1	0.0	0.0	0.0
EE-50 Alternative Fuels Utilization	0.0	0.0	0.0	0.0
EE-51 Materials Technology	0.1	0.2	0.4	1.3
EE-53 Electric & Hybrid Propulsion Devel	0.2	0.3	0.3	0.0
Total	2.1	3.2	8.7	7.9

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

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 mm 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:

- 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 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 with thicknesses between 0.1 and 1.0 µm, the operational temperatures can be reduced from 1,100°C to 450–650°C. We have completed the first cell using a yttrium-stabilized zirconia layer 1 µm thick.

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 1,500 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.
- 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 free of charge to the DOE community. Table 2.1-11 shows projected funding from this office.

Assistant Secretary for Policy and International Affairs

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.

Nuclear Materials Stewardship

Livermore is organizing a series of workshops for DOE Policy and International Affairs on nuclear materials stewardship. DOE needs crosscutting and accessible technical information, analytic tools, and programmatic insights for optimum coordination of its nuclear materials stewardship activities. The first workshop will identify information and analytical needs regarding nuclear materials management and operations, and it will begin to develop a foundation for understanding the status and direction of nuclear material stewardship policies. Subsequent workshops will focus on the implications of alternative approaches to nuclear materials stewardship and the development of findings and implications for paths forward. The objective is to organize and make

Table 2.1-11. Human Resources and Administration operating funds (in millions of dollars).

Reporting category	FY 1995 BA[a]	FY 1996 BA[b]	FY 1997 BA[a]	FY 1998 BA[b]
WM Human Resource & Admin	0.7	0.5	0.7	0.7
Total	0.7	0.5	0.7	0.7

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

Table 2.1-12. Field Management operating funds (in millions of dollars).

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[b]
WB In-house Energy Mgmt	0.9	0.0	0.1	0.5
Total	0.9	0.0	0.5	0.5

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

available data, information, analytical tools and processes that will assist responsible and interested organizations in decision making regarding nuclear materials stewardship.

DOE Field Offices and Other Laboratories

Table 2.1-12 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) programs sponsored 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 1995, the DoD was the largest sponsor of Laboratory work outside the DOE, funding 8% ($65 million) of our operating budget. This includes work for the Office of the Secretary of Defense (OSD), the Joint Chiefs of Staff, the Defense 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 for operating funds.)

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.

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 ATSD/NBC(CP) sponsors several systems studies relevant to counterproliferation technologies. LLNL is a participant in these studies. 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 the Assistant Secretary of Defense for Atomic Energy.

As part of the broader topic of counterproliferation, our Proliferation Interdiction Response Analysis effort evaluates the military, economic,

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
Department of Defense	63.8	63.1	96.4	83.3

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

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 effort is Livermore's Atmospheric Release Advisory Capability (ARAC) calculational analyses. We have provided preliminary option and consequence analyses for several scenarios to agencies, including the Commanders in Chief of the Strategic Command, the Special Operations Command, and the National Proliferation Center.

One of our 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. We have recently obtained significant new funding and a charter to bring this capability to fruition in the near future.

Radar Ocean Imaging

We continue our work in the Joint U.K.–U.S. Radar Ocean Imaging Program, sponsored by the OSD. This program focuses on the detection by radars of surface manifestations of moving, submerged submarines. Technology areas that are being explored include hydrodynamic signature generation and propagation, surface wave interactions and electromagnetic scattering, radar system development and deployment, and advanced signal processing and detection methods. Many of our field experiments will be conducted jointly with our U.K. collaborators. Radars to be developed will be state of the art for this application and will be fielded on fixed-wing aircraft and on static airborne platforms.

The Airborne Experimental Test Bed (AETB) with its high-resolution synthetic aperture radar (SAR) is a high priority system for this joint program. Our long-term objectives include real-time SAR-image formation, full-resolution SAR for off-line processing in the field, limited image enhancement and analysis for field experiments, a ground-based signal-processing workstation, and collaboration with the Institute of Applied Physics in Russia to continue experiments in the large thermo-stratified tank.

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 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.

Joint Chiefs of Staff

Conflict Simulation Systems

We have a long-term interest in developing and applying high-resolution conflict 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 (JTS), 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 (JCM) 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.
- Joint Conflict and Tactical Simulation, a new code borne of JTS and JCM, will combine the resolution of the former with the large combat area of the latter, plus many new

enhancements of capabilities, to provide a state-of-the-art, entity-level simulation tool.

Defense Advanced Research Projects Agency (DARPA)

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 DARPA, DOE, and industry. Two of the DARPA-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.

Critical for efficient field emitters in commercial flat-panel displays is the development of an inexpensive process that can fabricate a uniform array of submicron structures over very large dimensions. Typical requirements are sub-quarter-micron structures placed on a micrometer spacing over display sizes as large as 2,500 cm^2 (i.e., a 20-inch diagonal display). While these structures have been fabricated over limited areas (less than 1 cm^2) with electron-beam lithography, commercial products require a cost-efficient, high-throughput lithographic tool and process. LLNL has been working with several U.S. display manufacturers to develop and demonstrate optical interference lithography to field emitter fabrication. To date, successful displays have been fabricated and demonstrated. LLNL is now working with display manufacturers and tool vendors to transfer this technology to the U.S. display industry.

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)

Clementine 2

In 1994, the Clementine 1 spacecraft—the first U.S. mission to orbit the moon in more than two decades—demonstrated lightweight miniature digital sensors for multispectral remote sensing from a deep space probe. The follow-on mission, Clementine 2, jointly sponsored by DoD and NASA, will go a step further by demonstrating a fully integrated microspacecraft complete with lightweight propulsion, high-performance computers, miniature communication systems, and sensors that execute complex autonomous robotic operations. The primary scientific and technological objectives of the mission are to carry out the first close-up observation of Earth-crossing asteroids and to impact a man-made object on the surface of an asteroid. To accomplish these objectives, Clementine 2 will fly close to as many as three asteroids in the span of about one year. Just prior to each asteroid encounter, an autonomous probe will be launched by the mothership to impact the asteroid. As they plunge toward their asteroid, the probes will telemeter images and data to the mothership for later transmission to the Earth. The mothership will carry an advanced sensor payload to image the impact event between the probe and asteroid and to collect scientific data about the asteroid.

LLNL is responsible for the payload of the mission, which will include two Clementine 1 star trackers, a wide-field visible/UV camera, a high-spatial-resolution CCD camera (0.3–1-μm range), and near- and mid-infrared cameras with a common aperture, covering the 1–5-μm spectral range. In the near term, LLNL is working on the mission's concept definition, identifying asteriod science experiments, and investigating possible additional instruments for the payload. The launching is planned for 2000.

Diamond-Turned Optics

We continued to operate the Large Optics Diamond Turning Machine for the BMDO program.

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.

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.

Defense Nuclear Agency (DNA)

Man-Portable Land-Mine Detector

Micropower Impulse Radar (MIR) was developed at LLNL in 1993 as an evolution of government-sponsored work on radar and laser-driven nuclear fusion research. We are planning to design, construct, and field test a field-ready, man-portable, land-mine detector based on the MIR technology with optimized detection efficiency for the DNA. The agency has identified a number of candidate technologies that will help meet emerging requirements of future arms control scenarios. A man-portable land-mine detector based on MIR technology would provide enhanced capability in peace-keeping and humanitarian efforts to locate and remove land mines.

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 Lagrangian 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 thermochemical code for predicting the performance of high-explosive formulations, was distributed for testing to 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 for 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.

Wall Surveyor

Using Micropower Impulse Radar (MIR) technology, we developed a prototype wall surveyor system for functional evaluation by the Office of Special Technology. Based on emitting and detecting very low amplitude and short microwave impulses, the MIR has a very sensitive window for accurately detecting reflections from boundaries between different materials. The hardware package can be made very small and has low power requirements. We will optimize and package the evaluation wall surveyor into a hand-held unit.

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 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

Night-Ellipse Project: Backlash

Under the sponsorship of the U.S. Air Force Space Warfare Center, we are undertaking a program to develop and demonstrate a real-time threat warning system, based on LLNL's recently demonstrated, in-house, bullet-tracking technology that uses infrared sensors. Near-term milestones include integration of the sensor and the processor, testing the prototype system at LLNL, and a ground-based demonstration at a DoD proving ground such as Ft. Carson, Colorado.

Tactical Imaging Constellation Architecture Study (TICAS)

We are working with the U.S. Air Force to develop low-cost alternative concepts for tactical remote sensing using a constellation of small satellites. LLNL will concentrate on developing concepts for tactical radar imaging from small satellites and will support the sponsor in system analyses and technology evaluations. LLNL also will begin a new classified study for the sponsor in FY 1997.

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.

Other 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.

Veterans Administration (VA)

Electronic Commerce

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

Environmental Protection Agency (EPA)

Biogeochemical Processes and Climate Modeling

Livermore plays a leading role in climate research. Our goal is to better understand global climate and humanity's impact on it. We develop and apply climate models that represent key processes affecting the atmosphere, oceans, and biosphere. Using these complex models, we seek to improve scientific understanding of the mechanisms of global change in the environment and climate. Our main sponsor for this work is the DOE.

In FY 1996, EPA supported a project to develop a comprehensive and flexible Earth systems modeling framework to understand how biogeochemical processes affect climate. With a prototype framework that includes representative models of physics and chemistry of the atmosphere, oceans, and land surfaces, we conducted a series of experiments to elucidate the role of biogeochemical processes in shaping global climate conditions. Our efforts focused on the temporal and special distributions of atmospheric carbon dioxide concentration for both preindustrial and contemporary conditions.

National Aeronautical and Space Administration (NASA)

Environmental Management Technology Development

Livermore conducts fundamental and applied research to develop, demonstrate, and commercialize innovative technologies for solving environmental problems. The main sponsor for environmental restoration

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

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
NASA	3.5	1.6	3.6	1.6
U.S. Enrichment Corporation	45.5	87.0	90.0	80.0
Other Federal Agencies	13.4	18.8	20.2	17.2
Non-Federal Agencies	37.5	40.5	39.8	21.0

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

and waste management research and development is the DOE Office of Environmental Management. Key business areas include research and development for site investigation, in-situ remediation, and ex-situ waste destruction applications. In an effort jointly sponsored by DOE and NASA, 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.

Atmospheric Sciences Research

LLNL's Atmospheric Science Division houses the core modeling center for the NASA AEAP (Atmospheric Effects of Aviation Program). Our goal is the development of a single validated and efficient 3-D atmospheric chemistry model for the environmental assessment of aircraft. In this effort, we are bringing together researchers from around the world to collaborate and we are making use of the high performance computing capabilities at the Laboratory. In addition, we are involved in the NASA Upper Atmospheric Research Satellite program where we are using our modeling capabilities to gain knowledge of the inter-relationships between stratospheric photochemistry and dynamics and how these influence the distribution of chemical species in the stratosphere. Finally, LLNL is applying regional modeling capabilities to study the impacts of large scale meteorological variability on regional water resources and agriculture in southern Asia. We are working with NASA and the Korean Meteorological Research Institute in this effort.

Superconducting X-Ray and UV Spectrometers

Superconducting tunnel junction (STJ) detectorsare being developed for high-resolution x-ray spectroscopy. When cooled to temperatures below 1 K, an air STJ detector can provide higher spectral resolution than other detectors, with high efficiency across a wide energy range. STJ detectors can also provide high spatial resolution, which will allow spectral imaging of extended objects such as supernova remnants and hot gas in clusters of galaxies.

An STJ x-ray spectrometer consists of two thin films of superconducting material that are isolated from each other by a thin barrier. An x ray is absorbed in one film and excites millions of superconducting electrons. The excited electrons tunnel through the thin barrier, resulting in a precise signal. The number of excited electrons is proportional to the x-ray energy. Resolutions of 29 eV at 6 keV, and 12 eV at 1 keV have been measured with STJs at LLNL. In principle, resolving powers as high as 1,000 may be possible.

Observations and Analysis of Accretion-Powered Cosmic Sources

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 star binaries, and active galactic nuclei. Recent work has centered on high-resolution ($\lambda/\Delta\lambda$ = 200) spectra of high-accretion-rate cataclysmic variables obtained with the Extreme Ultraviolet Explorer (EUVE). Absorption edges of the Ne VI have been detected in the photospheric spectrum of the magnetic cataclysmic variable AM Herculis. We have made photometric and spectroscopic observations of the nonmagnetic cataclysmic variable VW Hydri during one of its outbursts simultaneously with EUVE (70–400 Å) and the Voyager satellite (912–1,200 Å). These observations reveal the temporal evolution of the physical conditions of the inner accretion disk and boundary layer of a nonmagnetic white dwarf during all stages of its outburst. EUVE observations of the nonmagnetic cataclysmic variable U Geminorum reveal a spectrum rich in emission lines from such species as O VI, Ne VI-VIII, Mg VI-VII, and Fe VIII-X. The relative line strengths indicate that the line-emitting region is photo-ionized, but work on detailed models to quantify this result have just begun.

Spectroscopic Modeling

Under NASA sponsorship, we are pursuing the development of detailed atomic models for interpreting x-ray spectra from astrophysical and laboratory x-ray sources. The current emphasis is on radiation-driven plasmas, such as those found in accretion-powered x-ray sources. We have recently achieved a successful interpretation of the 2-10 keV spectrum of Cygnus X-3, a bright x-ray binary, acquired with the joint Japan/U.S. satellite ASCA. These results provide tight constraints on global models of the source. Further model

development is under way, with plans to apply similar techniques to the spectra of active galactic nuclei. In addition, we are collaborating with the Harvard–Smithsonian Center for Astrophysics and the Space Research Organization Netherlands to improve the plasma emission codes currently used to analyze x-ray data from mechanically heated plasmas, such as those found in stellar coronae, supernova remnants, and galaxy clusters. The models are being applied to the Centaurus galaxy cluster, the corona of the RS CVn binary AR Lacertae, and the local hot component of the interstellar medium as test cases, in preparation for the next generation of satellite-based, x-ray observatories XMM, AXAF, and ASTRO-E.

Gamma-Ray Optical Counterpart Search Experiment (GROSCE)

Under NASA sponsorship, Livermore is collaborating with NASA/Goddard and Marshall Space Flight Centers and the University of Michigan to search for optical counterparts associated with gamma-ray bursts. Gamma-ray bursts are mysterious flashes of gamma rays of unknown origin, lasting 1 to 1,000 seconds, that are detected approximately once a day by the Compton Gamma Ray Observatory (CGRO) satellite. The first-generation experiment, GROSCE I, which employs a wide-field-of-view telescope, has recorded over 3,600 observing hours since January 1993, but no positive optical counterparts have been identified at a sensitivity limit of about 8.0 MV. We are constructing a second-generation system, GROSCE II, which can reach ~14 MV with a 5-second exposure and takes only 4 seconds to slew to the correct position in the sky after receiving a trigger from CGRO. Routine observations with GROSCE II will start in late FY 1996.

Federal Highway Administration (FHWA)

Highway Design

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.

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 under way with FHWA, Caltrans, and the Oregon Department of Transportation.

Bridge Deck Inspection

Micropower Impulse Radar (MIR) technology, developed for laser fusion, has received an R&D 100 Award and is being applied to other sensor needs, including noninvasive inspection of bridge decks. This application is based on concepts developed at LLNL under its Ground Penetrating Imaging Radar (GPIR) development project. The bridge deck inspection system will integrate our unique image reconstruction algorithms and low-cost, high-performance impulse radar technology into an inspection system that offers capabilities that surpass those of existing technologies. We are working closely with the sponsor to provide the optimum system for its use.

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. The technology is being applied to toll bridges as the first application, and LLNL is verifying industry's hardware compliance.

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

We have evaluated bridge structures for earthquake engineering safety.

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.

• 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 a potential 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 to 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, which were used to bring online the Vice President's National Performance Review office, are being applied to develop Internet tools for the Acquisition Reform Network (ARNet) and the U.S. Business Advisor.

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 and should 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.

United States Enrichment Corporation (USEC)

Atomic Vapor Laser Isotope Separation (AVLIS)

The AVLIS Program is sponsored by the United States Enrichment Corporation, which is continuing to develop 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. 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:
• Industrial teams integrated into the plant project for design, licensing, and construction of the uranium-enrichment plant.
• Continued engineering design and development activities directly supporting plant construction.

The objectives for the next several years will focus on the uranium-plant construction projects. Key goals include:
• Completion of AVLIS hardware development and pilot demonstrations to meet goals for plant construction and operations.
• Completion of engineering design to support Nuclear Regulatory Commission license application and construction.
• Integration of AVLIS technology and organization into 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.

Uranium Feed Preparation

We are developing for the United States Enrichment Corporation the processes and equipment for the chemical conversion and casting of feed material for the USEC Atomic Vapor Laser Isotope Separation (AVLIS) uranium enrichment process. Several candidate feed forms are being assessed, and hardware for the continuous processing of the incoming feed material (uranium oxide, fluoride and chloride compounds) into metal feedstock for the AVLIS separator systems are being developed and

tested. Central to this effort is the development of a continuous high-temperature molten salt reactor for conversion of uranium compounds to metal.

Alternative Applications of AVLIS

A number of alternative applications for AVLIS technology have been identified as having scientific and commercial value, including:

- 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 prostheses.
- 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.

Work for Others

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 16,100 measurements of isotopic ratios in the past year. In 1996, 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, Japan, Korea, and the United Kingdom. The center serves external programs in archaeology, art history, clinical and nutritional medicine, and geoscience.

California Department of Toxic Substance Control

LLNL scientists are helping in the development and commercialization of new technologies under an agreement between the Laboratory and the California Department of Toxic Substance Control's Environmental Technology Certification Program. The 1995 Memorandum of Understanding provides services of skilled LLNL personnel and unique facilities to help evaluate new environmental technologies—in the areas of hazardous waste management, site clean-up, waste minimization, and pollution prevention—seeking certification. Technologies under this program receive state verification of their efficacy and efficiency, which adds credibility and improved marketing position to the technology, both domestically and internationally and helps in obtaining necessary regulatory permits.

Special Programs 2.4

Industrial Partnerships and Commercialization (IPC)

Industrial Partnerships and Commercialization works with the Laboratory's programs to pursue partnering opportunities that support DOE's programmatic goals. Through joint efforts with industry, we bring benefit to Laboratory programs in pursuit of national missions and have a positive impact on the U.S. economy through the technology that is developed.

These goals are achieved by forging partnerships and building alliances among Laboratory researchers and U.S. industry, other DOE laboratories, government agencies, and universities. Partnering includes managing the Laboratory's intellectual property to ensure cost-effective use of our R&D resources. In recognition of the institutional and national importance of these activities, the IPC reports 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 negotiate and administer all cooperative research and development agreements (CRADAs), negotiate technology licensing, provide institutional industrial outreach, and support small businesses in a variety of ways. Some partnerships were terminated this fiscal year and a number of others had budgets reduced because of Congressional budget cuts to the Technology Transfer Initiative. In the future, we will increasingly rely on program and industrial funds to support our R&D partnering efforts. By the end of FY 1995, we had 201 CRADAs in place with 220 companies. The ongoing CRADA efforts are shown in Table 2.4-2. The number of technology licenses is increasing, with more than 175 licenses and other agreements in place by year end (Table 2.4-3). There are 35 CRADAs in place with small businesses; 75 requests for technical assistance, involving up to a week of consulting from a Lab employee, were satisfied during the past year.

An internal Industrial Partnering Working Group has the goal of enhancing communication and streamlining 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 1994	FY 1995	FY 1996[a]	FY 1997[b]	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Funding for management ($)									
Program operations	4.6	6.2	5.3	4.6	4.6	4.7	4.7	4.8	4.8
Patent prosecution	0.8	1.0	1.0	1.1	1.1	1.2	1.2	1.4	1.4
Total	5.4	7.2	6.3	5.7	5.7	5.9	5.9	6.2	6.2
Staffing									
Program operations	35	49	44	38	38	39	39	39	39
Patent prosecution	3	6	7	7	7	7	7	7	7
Total indirect FTEs & SLOs	38	55	51	45	45	46	46	46	46
Collaborations ($)	52.0	78.8	65.5	41.5	45.0	50.0	50.0	50.0	50.0
FTEs for collaborations	196	281	233	148	160	178	178	178	178

[a] Estimated year-end totals.
[b] Discussions under way to determine future optimal staffing level.

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. A long-pulse laser, designed to remove port wine stain birthmarks, is undergoing a series of experimental tests, which is intended to culminate in clinical trials on humans. The laser systems are applicable to future DOE needs in areas such as remote sensing and biological research.

• As part of the High Performance Parallel Processing Project, we are in year two of 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 a number of industry sectors. Applications include atomic-level material simulation codes, oil-well logging, and support of DOE Defense Programs needs for high-explosive and material simulations.

• The Laboratory's radar-based technology continues to command high interest. In FY 1995, we granted a limited, exclusive technology license

Table 2.4-2. Projected technology transfer agreements.

	FY 1994	FY 1995	FY 1996[a]	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
New licenses	36	60	75	100	100	100	100	100	100
CRADAs (cumulative)	115	201	250	290	330	370	410	450	490
Other agreements[b]	20	49	50	70	100	100	100	100	100

[a] Estimated year-end totals.
[b] Other agreements include non-federal Work for Others Agreements, User Facility Agreements, Material Transfer Agreements, and Technical Assistance Agreements.

Table 2.4-3. Projected licensing and other earned or retained income and uses (in thousands of dollars).

	FY 1994	FY 1995	FY 1996[a]	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Income	567	1118[b]	1212	1762	2312	2800	4512	4512	4512
Uses of Income[c]									
Patenting and licensing	74	131	200	200	200	200	200	200	200
Scientific Research and Development[d]	0	454	455	727	881	1156	1680	2707	2707
Awards, inventors, authors' shares	180	418	425	545	705	925	980	1579	1579
Technology Transfer Facilitation	0	184[e]	147	182	264	347	420	677	677
Total	254	1003	1227	1654	2080	2628	3280	5163	5163
Reserve (accumulation)	808	1209	1194	1302	1564	1736	2968	2317	1666

[a] Estimated year-end totals.
[b] Includes $85K from LLNL Intellectual Property licensed by UCOTT (University of California Office of Technology Transfer)
[c] Uses 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).
[d] The LLNL Director has designated these funds for purposes such as education, training, 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.
[e] Includes $29K for State Share for Intellectual Property licensed by UCOTT (University of California Office of Technology Transfer).

for it to 12 new companies, bringing the total licenses issued for this technology to 14 at the close of FY 1995.

• We developed many new models for incorporation into our DYNA3D structural design code, which include automatic contact algorithms, new material characterizations, and rigid body handling models.

• We have an agreement with Power One (and PolyStar) to develop and commercialize aerocapacitors based on carbon aerogels for electronic and energy-storage applications.

• The small business activity helped transfer LLNL-pioneered techniques for reducing toxic chemicals and the recycling of costly chemicals to small job shops that are part of the Metal Finishers Association in Northern California. The project has been so successful that it will be transferred to the Southern California association. Impressed with the results, the Environmental Protection Agency is matching the funds that LLNL has put into this effort.

• We are exploring innovative approaches to encourage the creation of start-up companies based on Livermore-developed technologies, including the use of incubator facilities in Silicon Valley and in the city of Livermore.

• We are collaborating with the National Transparent Optical Networking Consortium to deploy a prototype transparent optical network and testbed in the Bay Area. Members of the consortium are LLNL, Nortel, Uniphase Telecommunications Products, Hughes, Rockwell, Pacific Bell, Sprint, Columbia University, Case Western Reserve University, and University of California at San Diego. Nortel is leading the consortium, and LLNL is leading the integration, deployment, and operation. The goal of this $17-million, three-year project is to demonstrate the benefits of an all-optical network and accelerate the deployment of a Lab-proven technology into a workaday field environment. The project is funded in part by the Defense Advanced Research Projects Agency as part of a Broadband Infrastructure Technology program geared to advance technology deployment by three to five years.

Energy, Manufacturing, and Transportation Technologies (EMATT)

EMATT has initiated more than 100 partnerships with private companies—partnerships intended to benefit Laboratory programs and enhance the global competitiveness of U.S. industry. The manufacturing projects can be grouped as follows: 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.

Recent work includes:

• Formation of Technologies Enabling Agile Manufacturing (TEAM) to create a significant reduction in the cost of developing and producing products. This year it demonstrated the transfer of information between ten different sites, each using different computer tools. These transfers are intended to be seamless by next year, reducing the time requirements needed from months to one day to identify improvements to the process plan and fixture design before committing to production.

• Raising the standard of accuracy in commercially competitive machine tools through a three-year, $8-million agreement with Cincinnati Milacron. The attained goal was a tenfold increase in machine tool accuracy without degrading productivity and with minimal impact on the capital cost of the equipment.

• Development of innovative alternative energy sources for alternative transportation vehicles. An LLNL-developed zinc–air fuel cell provides electric vehicles with some of the attractive features of gas-driven cars: a 250-mile range between refueling, 10-minute refueling, and safe highway acceleration.

• Collaboration with the University of California to establish an Institute for Precision Manufacturing Research, an Energy Institute, and a Center for Infrastructure Research.

• Application of techniques to significantly increase reliability of automobile components through nondestructive evaluation of cast parts to characterize their porosity.

Center for Microelectronics and Optoelectronics

This Center has programs in semiconductor processing and process modeling, lithography, electronic packaging, communication and computing systems, magnetic storage, and flat-panel display technologies.

Recent work includes:

• 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.

• Transfer of a low-cost manufacturing process for a new class of flat-panel displays, which are needed for future military aircraft, vehicles, and command centers as well as for portable computers. The process was developed at LLNL jointly with Silicon Video Corp. of San Jose, California, under DARPA, DOE, and corporate sponsorships. Two of the CRADA project leaders were awarded this year's Federal Laboratory Consortium Award for Excellence in Technology Transfer.

• Participation in the DARPA-sponsored Optoelectronic Technology Consortium to develop parallel fiber interconnects for computer clusters and massively parallel computers.

• Development of semiconductor manufacturing process technologies, including deep submicron copper metallization 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 connection of stacked integrated circuit chips. Applications include dense memories for portable electronics, supercomputers, satellite systems and munitions, and optoelectronic send and receive modules.

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 worked with Trinity Flywheel Batteries on a CRADA to evaluate the flywheel battery as part of a hybrid system to power future passenger vehicles. In this effort, we demonstrated the complete containment of a flywheel that was intentionally and safely burst at 62,000 rpm, thus allowing for a significant containment weight reduction. This collaboration could strengthen the DOE technology base in cost-effective energy storage and also address other DOE energy and environment needs. Trinity delivered a working model to its first customer in 1996.

We expect future research in our involvement with the Partnership for a New Generation of Vehicles to include hybrid vehicle development, superplastic forming and fabrication of production parts, viscoelastic lifetime models for polymeric materials, and accelerated material characterization methods.

Center for Healthcare Technologies

The Center for Healthcare Technologies was formed two years ago in response to industry and clinicians requesting assistance in the development of new, cost-effective healthcare technologies.

There are currently several million dollars of external support at Livermore for healthcare technology projects funded from the Technology Transfer Initiative, industry, and non-DOE government contracts. There are also several internal LDRD healthcare projects.

Some of our current projects include tissue welding, improving the optics for carpal tunnel surgery, development of minimally invasive testing of blood pathology, diagnosis and treatment of ischemic stroke, computerized patient records, telemedicine, computer-assisted diagnosis using image processing, digital mammography, and rational device design.

Laboratory Directed Research and Development (LDRD) Program

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 major components: Strategic Initiatives (formerly Director's Initiatives), Exploratory Research, and the Laboratory-Wide Competition.

The projects in the newly named Strategic Initiatives are selected on the basis of their alignment with the Laboratory's strategic directions and long-term vision. Proposals for these projects are responsive to the R&D needs of at least one of the following four Laboratory Strategic Councils: the Council on National Security, the Council on Biosciences, the Council on Energy and Environmental Systems, and the Council on Strategic Science and Technology.

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 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. The Laboratory-Wide Competition encourages the creativity of individual researchers.

In some of the major accomplishments of the program's projects, we have:

- 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 1995* (UCRL-53689-95).

University Collaborative Research

Individual collaborations between Livermore scientists and university faculty and students have taken place since the Laboratory was founded. Our research collaborations with university faculty and students are designed to blend basic research with applied researchers 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 subject 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 the Stockpile Stewardship and Management Program, 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 is at an annual level of more than 500 researchers from the University of California (see Table 2.4-4) 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.

Table 2.4-4. FY 1996 UC campus collaborations with LLNL.

UC	Faculty	Researchers	Students
UCB	64	25	64
UCD	68	40	118
UCI	9	3	5
UCLA	24	7	22
UCR	6	3	4
UCSB	15	6	12
UCSC	9	3	13
UCSD	16	7	18
UCSF	12	3	3
Total	223	97	259

Department of Applied Science Student Employer Program

In 1963, the Regents of the University of California approved the UC Davis Livermore site for graduate study. The Laboratory offers a limited number of temporary, part-time positions to selected University of California, Davis, graduate students who are pursuing their degrees in applied science or computer science. These students have the unique opportunity to work in a major research facility and to support the LLNL programmatic research effort while pursuing their graduate work at the Davis campus located adjacent to the Laboratory. Thesis research is related to the programmatic research work at Livermore.

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 1995, 40 faculty and students, 6 research staff, and 35 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 post-doctoral program.

Currently, nine post-doctoral fellows are working at IGPP. Each year, this institute also sponsors more than 50 seminars, and at least one workshop is conducted on site.

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 National 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 that constitutes perhaps 90% of the mass of our universe. The experiment, now taking data with cosmologically relevant sensitivity, 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, post-doctoral researchers and conducts seminars and workshops on neural networks, computer vision, computational physics, and applied computing. Current research includes medical and industrial image processing, biomechanical simulations and code development, parallel computing, and adaptive computing methods for noninvasive patient monitoring in biomedicine. In FY 1995, 33 faculty and students and 23 LLNL scientists participated in the ISCR.

Electron Beam Ion Trap (EBIT)

The EBIT Program emphasizes multifaceted experimental research to investigate the fundamental properties and technological applications of highly charged atomic ions. Many of the projects involve collaborations with faculty and students from universities. Major activities include:

- Precision x-ray and ultraviolet spectroscopy of highly charged heavy ions to validate theoretical models of atomic structure.
- Studies of the interactions of highly charged ions with surfaces to elucidate the fundamental phenomenon such as Coulomb explosion, which enhances the yield of secondary electrons and sputtered ions.
- Development of secondary ion mass spectroscopy for surface analysis using focused beams of highly charged ions to achieve significantly increased sensitivity.
- Experiments on clusters of cold, highly charged ions in the RETRAP device to study Coulomb crystals of binary ionic mixtures, which are the laboratory equivalents of matter found in certain astronomical objects such as white dwarfs.

During the past five years, more than 40 faculty, post-doctoral researchers, and students have participated in EBIT projects at Livermore.

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 post-docs 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, Livermore. 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.

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.

Campus–Laboratory Collaboration Program

The University of California Campus–Laboratory Collaborative Program supports collaborative research to improve the prediction of water resources in California and the Western U.S. Water resource issues cover a broad range of time and space scales and include hydrological events from floods to multiyear fluctuations in the water supply. A three-tiered set of observationally based global-, regional-, and watershed-scale models is being developed to better understand, diagnose, and predict the interrelated climate–weather–hydrologic system and the water-related variability in this region.

The partners in this collaboration are LLNL, Los Alamos National Laboratory, Scripps Institute of Oceanography, and the University of California campuses at Davis, Irvine, Los Angeles, San Diego, and Santa Barbara. This program supports approximately 10 graduate students and 10 post-doctoral fellows who are assisted by a comparable number of staff members at each institution.

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. The 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 Programme. 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. PCMDI also supports the intercomparison of coupled atmosphere-ocean models and their diagnosis for the detection of anthropogenic climate change.

Science and Mathematics Education

Promoting change in science, math, engineering, and technology education is at the very heart of the Laboratory's education programs. We are focusing our efforts on:

- Curriculum improvement.
- Teacher enhancement.
- Student support.
- Educational technology.
- Education outreach.
- Diversity efforts.

Table 2.4-5 shows FY 1995–1998 operating funds for all programs funded directly by DOE Defense Programs and DOE Energy Research. Table 2.4-6 summarizes the Laboratory's education programs and participants. Refer to the section entitled University Collaborative Research for additional activities with graduate and post-graduate students.

Curriculum Improvement

Laboratory scientists and technical staff work with educators to develop curricula and educational materials that are evaluated by the Science Education Ph.D. Program at

Oregon State University to ensure sound education value.

• The Global Concerns projects reflect a spectrum of issues, such as space exploration, environmental monitoring, nuclear proliferation, and genetic engineering.

These projects, springing from LLNL Defense Programs core competencies, 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.

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. Teachers develop classroom resources on lunar geology, remote sensing, and the origins of the universe.

The Biotechnology Education project is a two-week, thematic immersion curriculum 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 for elementary- and high-school teachers and students to explore the Earth's climatic variations.

In the Global Concerns project, a team of Livermore physicists and local high school teachers are designing an education module that focuses on worldwide proliferation of nuclear weapons.

• We established the Partnership for Environmental Education (PETE) in 1991, in an effort to create permanent regional public–private partnerships to assist two-year colleges. The organization has since grown to a national network of six regional partnerships serving all 50 states with over 400 participating colleges. The program's primary goal is to increase the output of qualified environmental technicians by establishing and maintaining a network of community colleges, technical colleges, and other organizations. These include private industry, federal laboratories, state and federal agencies, professional societies, and other nonprofit organizations.

The PETE partners have implemented several program initiatives, including a major instructional materials development project, minority programs such as the Tribal Colleges Initiative, and the Los Angeles Environmental Jobs Training Consortium. PETE is being funded in FY 1996 by DOE, EPA, National Science Foundation, and National Park Service.

Teacher Enhancement

The Laboratory offers a variety of workshops and activities for teachers. The focus of these programs is an inquiry-based approach to teaching, which encourages the creative thinking and problem-solving skills.

• Through the Student Science Research Associates program, K–12 students, their teachers, and Livermore researchers explore science in cooperative research teams that use computers, electronic communication, and analysis tools to study complex global issues.

• The Teacher Research Internship program provides opportunities for K–12 teachers to participate in ongoing research at the Laboratory from which they develop new curricula for their classes. In 1995, 60 teachers participated in the program.

• The Science and Technology Inquiry Partnerships is a series of workshops for teachers to develop and implement inquiry-based curricula for science and technology.

Table 2.4-5. Science Education and Technical Information operating funds (in millions of dollars).

Reporting category	FY 1995 BO	FY 1996 BA	FY 1997 BA[a]	FY 1998 BA[a,b]
KT Laboratory Coop Science Ed Center	1.2	0.7	0.7	0.8
Total	1.2	0.7	0.7	0.8

[a] 2.7% escalation FY 1997 and FY 1998.
[b] Guidance case.

Table 2.4-6. Science and mathematics education programs.[a]

Project	Grade[b]	Number of FY 1996 participants[c]	Focus area[d]	Description
Math Challenge	9–12	80	EO	One-day competition
Access to Science Teaching Careers	UG	10	SS	Internships for preservice education 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	1,800	EO	Young women's conferences
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
Global Security Cooperative Program	UG	100	SS	Research experience
Apprenticeship and Pre-Apprenticeship	UG	40	SS/ET	Year-round program
Explorer Post	9–12	60	EO	Research projects with scientists
Science and Engineering Research Semester	UG	52	SS	Cooperative research program
Lab Technology Resource Center (TOWER)	K–12	2,500	ET/CI	Electronic curriculum resources, electronic server, bulletin board, technology training, and desktop video conferencing
National Energy Supercomputer Program	4–12, UG	12,000	ET/TE	Week-long workshops for teachers; access to supercomputing resources
Science Appreciation	UG	150	EO/CI	Development of course and curriculum materials and classroom evaluation
Fun with Science	K–12	15,000	EO	Science and technology demonstrations
Career Speakers	K–12	5,000	EO	Presentations to school and community groups and tours
Historically Black Colleges & Universities (HBCU) Projects	UG	60	SS	Collaborative research and internships for faculty and students
Science and Technology Inquiry Partnerships	K–12	100	TE	Integration of introductory-level science curricula
Summer Research Internship Program	K–12, UG	10	TE	Research opportunities
Global Concerns Thematic Immersion Curricula			CI/TE	Multidisciplinary curricula integrated with technology, includes risk assessment
Biotechnology Education Project	9–12	15,000		Immersion of entire school in biotechnology
Global Concerns Curriculum	9–12	500		Centered around nuclear security and nonproliferation (under development)
QUAKES	6–12			Examine issues in seismology (under development)
Student Science Research Associates	K–12	3,000	CI/SS	Facilitated student research; includes international and multi-Lab collaboration
Scientific Visualization	6–12, UG			Access to advanced computing tools (under development)

[a] Does not include university collaborative research. See pp. 106–109.
[b] UG = undergraduate; GRA = graduate; K = Kindergarten.
[c] FY 1996 numbers are year-end estimates based in part on FY 1995 experience.
[d] CI = curriculum improvement, DE = diversity efforts; ET = educational technology; EO = education outreach; SS = student support; TE = teacher enhancement.

Student Support

The Laboratory offers a variety of internships and institutes for students, from high school through post-doctoral levels, that provide hands-on research and scientific enrichment experiences.

• The Laboratory sponsors Science and Engineering Research Semesters to encourage students to pursue advanced degrees and careers in science and engineering.

• In a collaboration called Partnerships with Industry and Education among businesses, universities, and LLNL, students intern at a business and continue research upon returning to college.

• 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.

• The Undergraduate Summer Institute is a two-week program offered to students in their junior year of college. With their mornings at lectures and afternoons working with researchers on projects in applied physics, chemistry, mathematics, or engineering, students present the results of these projects at a poster session.

• In a collaboration called the Teacher Certification Program with San Jose State University, Laboratory employees with advanced degrees in science or math earn a single-subject secondary teaching credential.

Educational Technology

The Laboratory, which has always been committed to advancing technology and demonstrating its application in science, extends this commitment to education. We provide access to cutting-edge scientific visualization tools not currently available to the education community.

• The Technology Resource Center provides technology training for teachers, administrators, and students throughout California. Through partnerships with the California state Systemic Initiative Projects for technology training and with the regional Department of Education laboratory, we bring the resources of the Center to the education community.

• The National Education Supercomputer Program (NESP) uses a Cray Y-MP as an educational resource for elementary through community college teachers and students across the nation. Teachers from across the U.S. attend tutorials and, with Laboratory professionals, work on projects from their classrooms to develop curricula that make use of this supercomputer. Then these teachers become “master” teachers who conduct workshops for teachers in their local areas and extend access to the NESP to more teachers and students.

Education Outreach

Our Education Outreach efforts are designed to increase public awareness and curiosity about science and increase science literacy with activities that demonstrate clear ties to Lawrence Livermore science and technology, through access to Laboratory people and ideas.

• The nationwide Expanding Your Horizons program encourages middle- and high-school girls to develop and maintain an interest in science. In FY 1995, we were involved in implementing four regional conferences that reached over 1,800 young women.

• The volunteer Fun With Science program stimulates students’ interest in science and heightens their curiosity about the physical world through demonstrations and hands-on activities.

Diversity Efforts

Some of our education efforts focus on increasing the participation of under-represented students and faculty in the scientific and technical fields.

• 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 that may include summer employment opportunities and joint research projects and the use of computer, engineering, and laboratory equipment.

• Research internships are provided for under-represented students to heighten

their awareness of the scientific process and further their pursuit of teaching credentials in science and mathematics. Graduate fellowships and research opportunities are provided through various Department of Energy programs for under-represented students pursuing Ph.D.s in science and engineering.

• In the American Indian Program, we offer teaching enhancement courses for elementary school teachers on the Navajo Reservation in partnership with the Navajo Community College in New Mexico.

User Facilities

Center for Advanced Manufacturing and Productivity (LCAMP)

This facility capitalizes on recognized expertise in precision machining and advanced manufacturing. The facility currently houses CRADA activity in manufacturing processes such as advanced lathes, grinders, diamond-turning machines, and measuring and inspection devices. Users have access to a variety of other specialized on-site servers and facilities.

Livermore User Facility for Inspection and Characterization (LUFIC)

This facility offers a suite of equipment and expertise that embraces three capabilities: materials testing and evaluation, nondestructive evaluation and characterization, and mechanical inspection.

Virtual Laboratory Testbed (VLT)

With five separate facilities, the VLT is the outgrowth of creating a "virtual enterprise" by linking DOE defense laboratories via high-speed, secure computer networks. Testbed users can engage in information technology, information surety R&D on high-speed wide-area and local-area networks, distributed computing, high-performance storage systems, middleware, and application software.

Section 3

Institutional Infrastructure

Photo: Attention to detail and quality is the order of the day for Diana Silva of Electronic Manufacturing in providing one-of-a-kind electronic products to a wide range of Laboratory customers.

Management Practices 3.1

Efficient, cost-effective operations are important to the future success of the Laboratory. This requires special attention to the human resources at the Laboratory, as well as to our business practices and our facilities.

Moreover, the Administration and Congress have identified improving operations as a particularly high priority for all federal laboratories. The Laboratory has been at the forefront of the DOE's efforts to implement performance-based management. The University of California pioneered this management concept, as applied to government-owned institutions, in the 1992 contract with the DOE for managing and operating the Livermore, Los Alamos, and Berkeley national laboratories.

The performance-based process involves:

• Annual negotiation of performance objectives and measures by the Laboratory, DOE, and UC.
• Self-assessment of Laboratory performance against these measures.
• DOE and UC evaluation and grading of LLNL performance.

The result is an improved, closer working relationship among the Laboratory, DOE, and UC. Additionally, as evaluated and graded by the DOE and UC, significant performance improvements, including more cost-effective operations, have been achieved.

Following are three particularly important steps that we took in the past year. They affect virtually all aspects of Laboratory management practices.

Diversity Action Steering Committee

To follow up the all-Laboratory employee survey on diversity taken in May and June 1995, Diversity Action Teams were formed to develop findings and propose recommendations in the areas of job opportunity, performance management, career development, and employee empowerment. The teams reported to the Diversity Action Steering Committee (DASC), which framed overall recommendations of the teams in terms of actions that are capable of being executed in a reasonable time and that will make a difference. We are acting on the DASC recommendations.

Cost-Cutting Initiative Task Force

In August 1995, the Laboratory Director formed a Cost-Cutting Initiative (CCI) Task Force to conduct a comprehensive, Lab-wide study of where we spend our resources, and to recommend aggressive steps for reducing costs. Completing its efforts in June 1996, the task force identified potential cost reductions in three major areas: centralization and standardization of operations, improved management practices, and reductions in the size of the workforce. Actions are being taken in all three areas.

Workforce Restructuring Plan

In June 1996, the Laboratory announced it was undertaking a workforce restructuring that will lead to the separation of up to 600 employees in selected areas. Restructuring is intended to reshape the Laboratory so that Livermore has an appropriate mix of skills needed for current and future work. It builds on recommendations made by the CCI and is reponsive to changes in technical programs and opportunities to streamline business practices.

Section 3 discusses Laboratory operations. It is organized in accordance with DOE's critical success factors: management practices; human resources; environment, health, and safety; communication and information; and the site and facilities.

Audit and Oversight

The Audit and 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 DOE.

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. Performance requirements are negotiated annually through a partnership involving DOE, UC, and Laboratory teams.

Over the last four years, the DOE Performance Ratings show that LLNL has made significant positive improvements in Science and Technology, which "Far Exceeds Expectations," and Administrative and Operations, which "Exceeds Expectations." Overall, LLNL continues to have the highest rating of the three UC-managed Laboratories.

The Laboratory and the UC are currently negotiating the renewal of the prime contract. Negotiations are being conducted consistent with DOE's Contract Reform Initiative and with recognition that UC is a not-for-profit California State entity.

The Laboratory and the UC are committed to strengthening the working partnership with DOE and to continuing the successful track record of performance-based contracting. 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 material 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 online 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.
- Uncosted obligations balance projections.

Procurement and Materiel

The Procurement and Materiel 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. We are committed to a customer-oriented process to ensure continuous quality improvement. In recent accomplishments, we:

• Reduced our costs by over 30% and staffing level by 38% since FY 1994.
• Established an efficient milestone-driven closeout tracking system.
• Implemented a comprehensive procurement-related training program.
• Implemented a self-assessment program to review compliance with documented procedures and Contract 48 Performance Objectives and Measures.
• Participated with the three UC laboratories to develop a Tri-Laboratory Procurement Policy and Standard Practices Manual.
• Received for FY 1995 an "exceeds expectations" rating from both the DOE and UC for the procurement self-assessment in the performance measures of the UC–DOE contract.

In the next few years, our goals are to:

• Continue implementation of the decentralized procurement system for low-value purchases through expansion of our ProCard program and development of a widely available Web-based system for accessing "systems" contracts. 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. A key element of this effort involves the adaptation of commercial procurement practices. The process to dramatically reduce the size and complexity of current written procedures is under way.
• Expand the use of integrated, flexible teams that can provide a broad range of service for programs that require a significant subcontracting effort.

Business Affirmative Action and Vendor Assessments

In March 1996, the Quality Assurance unit of Procurement and Materiel was assigned to the Business Affirmative Action Office, resulting in the creation of the Business Affirmative Action and Vendor Assessments Office. This consolidation of responsibilities provides a chance for the Laboratory to reduce its supplier base, to do business with vendors of higher quality, and simultaneously to achieve its socioeconomic goals.

In accordance with Contract 48, the DOE, the University of California, and the Laboratory jointly determine annual socioeconomic goals as a management performance measure. These goals call for the Laboratory to achieve a specified level of procurement activity related to small business (SBEs), small disadvantaged business (DBEs), and small women-owned businesses (WBEs). For the past two fiscal years (FY 1994 and FY 1995), the Laboratory has exceeded its goals in these areas.

The Business Affirmative Action and Vendor Assessments Office works closely with Laboratory programs, projects (such as the National Ignition Facility), and Plant Engineering to increase the opportunities for SBEs, DBEs, and WBEs on larger and more technical procurements. This office also helps programs to achieve affirmative action goals in selected socioeconomic categories.

In the next few years, our objectives are to:

• Pursue our socioeconomic goals and satisfy the respective performance measures.
• Integrate the socioeconomic efforts and supplier pre-qualification and vendor performance evaluation into routine Laboratory procurement activities.
• Establish LLNL, through continuous performance, as a leader among its peers in providing procurement opportunities to small businesses (including DBEs and WBEs).

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 the property's 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 1995, we successfully inventoried 100% of attractive property and accounted for 99.9% by dollar value. In FY 1996 we are piloting a new three-year inventory model that will reduce inventory costs.
•In 1995, we received a "far exceeds expectations" rating from both the DOE and the University of California for the property management self-assessment.
• Our Property Information System (PRISM) has been transferred to many DOE facilities, including the Nevada Test Site (Bechtel), Savannah River, and Y-12 (Lockheed).

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 under way 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

Working in cooperation with the Bank of America, LLNL's Technology Information Systems Program (TISP) developed a system to securely and reliably exchange sensitive financial information over the Internet. This system was nationally recognized as the first production system to exchange financial Electronic Data Interchange (EDI) transactions over the Internet in a secure, automated fashion. Through its use of national standards for secure e-mail and EDI, this system can be easily adapted to a variety of different applications.

After six months of successful pilot use, which involved making daily payments to a limited number of vendors, the pilot program will be expanded to include more vendors and larger sums of money. When this system ramps up to full production, it will be transferring payments of $1.4 million per day to several hundred LLNL vendors.

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. 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, Finance, LBNL, and LANL—designed the travel model. The working group established a number of project deliverables, the majority of which were implemented in 1995. They are:

- The travel reservation function was contracted out to a travel agency in December 1995. It provides reservation and ticketing services for a transaction fee; all commission revenue is returned to the Laboratory.
- In October 1995, a re-engineered business model was implemented; it defines roles and responsibilities for the Travel organization, directorates, travelers, and the vendor. The model simplified policies and procedures so they are consistent with UC travel reimbursement policy.

Now the group will focus on initiatives for reducing travel costs through negotiated agreements with travel services providers, using the Travel Miser program to inform travelers of ways to minimize travel costs, and leveraging available technology to further streamline the administrative process.

Human Resources 3.2

The Laboratory's strength is its world-class workforce, which we must draw from the diverse population of California and of our nation. We are attracting and retaining a workforce with the skills and flexibility that are required to meet Livermore's objectives. Our goal is to make the Laboratory an employer of choice for all who can contribute to the Laboratory's missions. To this end, we are taking steps to restructure the workforce so that the skills at the Laboratory match the needs for current and anticipated future programs. We also are responding to recommendations of the Diversity Action Steering Committee (DASC) to ensure a more satisfying and productive environment for all Laboratory employees.

Workforce Management

Workforce Restructuring

The changes in our national missions and the job skills that are needed to carry them out, plus the operational recommendations by the Laboratory's Cost Cutting Initiative (CCI), require significant changes in the structure of our workforce. To accomplish these changes we are undertaking a workforce restructuring under Section 3161 of the National Defense Authorization Act (formally announced by the DOE), which will result in the elimination of up to 600 jobs. This action reflects our specific needs in terms of a better job skills mix, estimates from the associate directors, and the spirit of the CCI recommendations. We received approval from DOE to offer the Voluntary Separation Incentive Program (VSIP) to help accomplish this goal; results of the VSIP will determine whether further actions are needed to achieve the goals of the CCI.

Human Resources Organization Initiatives

LLNL's Human Resources organization provides services, systems and programs to hire, develop, and retain the most outstanding, diverse workforce possible. To accomplish this objective, Human Resources staff members work in partnership with Laboratory managers to help them meet their workforce planning and management goals. Staffing composition is given in Table 3.2-1.

Human Resources provides services in the areas of recruitment and employment, compensation, benefits and employee services, employee and organization development, staff relations, and information systems. This year Human Resources expanded services in several areas: the Career Center, formal brokering, the RESUMIX applicant tracking system, performance management, information technologies, and employee wellness and fitness.

Career Center

As the Laboratory reshapes its programs and redirects work assignments, the skill sets needed within the workforce are changing. The Career Center helps facilitate these changes by providing resources for employees engaged in setting goals, understanding options, and planning the development of their own careers.

Unique to the Career Center is its focus on employability and movement within the Laboratory. Ongoing workshops are offered in resume writing, interviewing, career assessment, and career development.

RESUMIX

RESUMIX, an artificial-intelligence-based optical scanning and skill extraction application, continues to form the basis of the employment applicant process. This base has become a rich pool of potential internal and external candidates to fill existing vacancies and to staff new programs at the Laboratory.

Table 3.2-1. Laboratory staff composition as of March 31, 1996.[a]

	Ph.D.	M.S./M.A.	B.S./B.A.	Other	Total
Scientists	883	369	341	12	1607
Engineers	257	429	240	19	949
Managers and administrators	32	202	303	478	1015
Technicians	1	29	315	1553	1898
All others	1	4	92	1468	1565
Total	1174	1033	1291	3530	7034

[a]Excludes summer hires and temporary program participants; may include indefinite employees.

With RESUMIX technology, managers can fill current vacant assignments, or can strategically develop sourcing pools of highly qualified potential applicants for future programmatic needs. Although this tool has been used primarily within the Recruiting and Employment Division, this year management in the Defense and Nuclear Technologies Directorate has established a local RESUMIX site to better serve its strategic planning needs.

Workforce and strategic planning models are designed and developed by staff of the Recruiting and Employment Division to assist management decision making and planning.

Back-trending, profiling, and demographic analysis are provided as background for institutional and organizational efforts. Pilot design of a skill base using RESUMIX artificial intelligence technology is under way. This application will provide in-depth analysis of Laboratory skill sets by individual, group, or organization as well as identify skill gaps, training deficiencies, and recruitment targeting.

Formal Brokering

The formal brokering process is in its second year. Representatives from each directorate identify potential jobs and existing vacancies. Employees currently between assignments or whose funding is uncertain are matched to employment opportunities in other areas of the Laboratory.

Use of Competencies in Workforce and Performance Management

LLNL is exploring an integrated workforce and performance management model that focuses on the employee competencies critical to the organization's success. Initial steps during FY 1996 include:

- Training employees how to assess their competencies and manage their career development plans.
- Revising the retention policy for scientists and engineers to a competency emphasis.
- Training managers in competency-based decision-making for selection, development, retention, and performance management.
- Piloting a competency-based performance management system for a trial in FY 1996.

The last initiative envisions using multisource assessments to drive performance, development planning and evaluation, and possibly compensation decisions.

Information Technology

A major effort is under way to build a sound, integrated information infrastructure. A commercial software product, PeopleSoft, is being implemented to replace the Laboratory's current corporate Human Resources and Payroll systems. This integrated solution is the cornerstone for building a single source of "people" information at the Laboratory.

As the infrastructure is being built, other projects that address data access are also in progress. The primary goal is to leverage the Internet for external interactions and the Laboratory's intranet to disseminate information internally. A suite of employment processes—such as job listings, staffing resources, foreign national visitor procedures, process information, and links to external employment resources—are currently available to all employees from the Recruiting and Employment (RED) and Career Center home pages. Tools such as a "Resume Builder" and electronic submission of resumes to RESUMIX are also available from RED's home page. Links are provided to worldwide career resources and employment opportunities including all University of California Campuses and other Department of Energy contract laboratories. Other information, such LLNL's *Course Catalog* and basic Laboratory demographic information, are available from LLNL's internal home page. A variety of new capabilities is in development. For example, an electronic process for employees to change their benefit enrollment information will be available in FY 1997.

Employee Wellness and Fitness

The Laboratory continues to provide employee services to increase job focus, save time and money, reduce stress and anxiety, promote fitness and wellness, and allow employees to get to know one another.

Using an employee association as the delivery model, LLNL employees have many wellness and fitness opportunities including exercise, child care, sport leagues, 60 employee activity groups, special events, and an employee store. In March 1996, the Laboratory consolidated many of its indoor exercise options into one exercise space and program called Fit For Business (FFB). The Employee Association manages the program and made the exercise space safe and

appropriate for exercise by donating resilient flooring, wall mirrors, a sound system, and a computerized monitoring and fitness information program. The Laboratory continues to encourage its employees to take responsibility for meeting their stress reduction, time-saving, and diversity needs.

All of these services are managed by the Lab's nonprofit Employee Services Association on a self-sustaining basis.

Diversity and Affirmative Action

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. With leadership provided by the Director's Office, we aim to become the model for diversity among the national laboratories (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.

Building Diversity

Our ongoing goals in achieving a diverse workforce include:

- Recruit and hire outstanding performers from diverse backgrounds.
- Design and implement leading educational and community outreach programs.
- Communicate technical and human resource achievements.
- Assure the continued excellence and diversity of our current workforce.

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 activities and speakers to promote greater cultural understanding. A Diversity Speaker Series was introduced this year and met with great success. This program highlights the benefits of diversity by featuring individuals from diverse backgrounds who are nationally recognized for their achievements in the areas of science, industry, or academia.
- 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 continues to

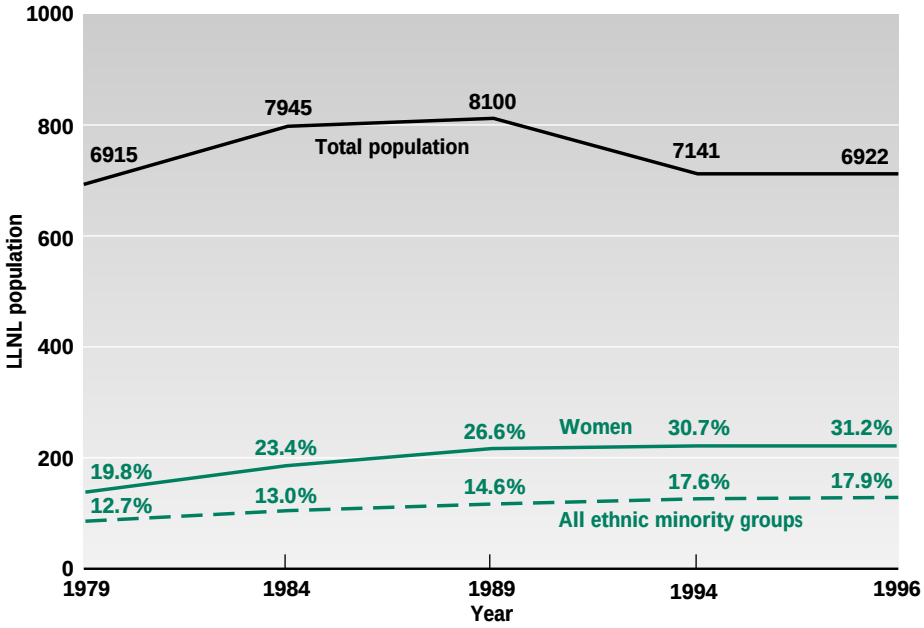


Figure 3.2-1. Increase in minorities and women employees at the Laboratory from 1979 to 1996, during declining overall population.

shift from promoting diversity training among managers and supervisors to greater inclusion of the entire workforce in Laboratory diversity activities.

Diversity dialogue groups and cross-cultural mentoring programs continue to play a major role in engaging nonmanagerial employees, as well as managers in diversity-related discussions and activities.

Diversity Survey and the Diversity Action Steering Committee

Results of the Laboratory's first-ever, all-employee diversity survey have been received, analyzed, and to reviewed with employees. The survey results (Figure 3.2-2) reveal that, overall, employees rate the Lab relatively high as a place to work, although approval ratings by women and minorities were lower than the Laboratory average.

In response to the survey, Diversity Action teams were constituted to develop findings and propose recommendations in the areas of job opportunity, performance management, career development, and employee empowerment. The teams reported to the Diversity Action Steering Committee (DASC), which issued a report with findings and recommendations. The Laboratory is taking responsive actions:

• **Career development.** The DASC identified a need for improved individual development planning by both employees and supervisors. All employees are responsible for managing their career development. For its part, the Laboratory is committed to providing opportunities for employees to develop and use their technical and behavioral competencies. Individual career development plans are now included in the annual performance appraisal.

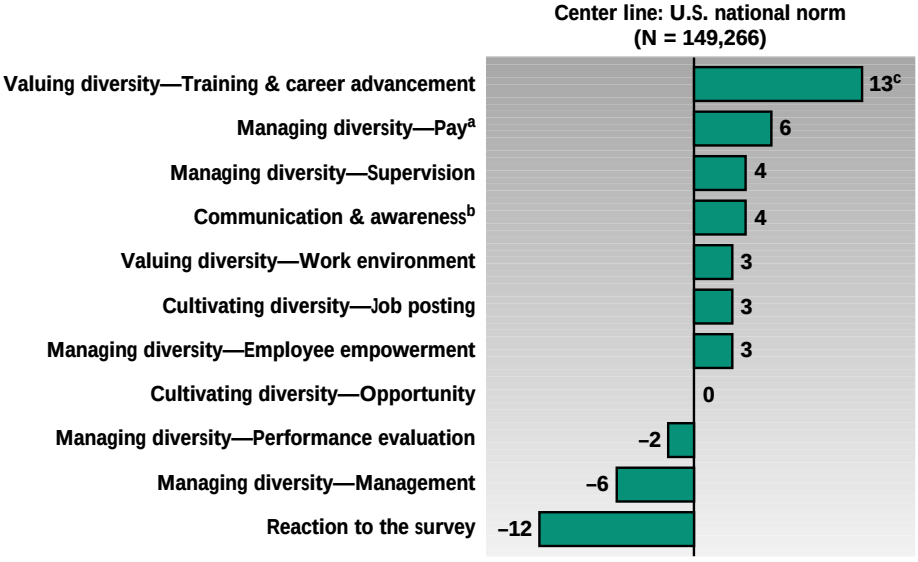
• **Mentoring.** Mentoring is important to the growth and effectiveness of employees. A number of Lab organizations have used formal mentoring programs as a supplement to informal mentoring. Our target is to assure that all Lab employees have access to mentoring if they so desire. As a first step, we are assessing current mentoring efforts around the Laboratory and working with the directorates to review and expand their own activities.

• **Job posting.** Measures will be taken to make job posting information more widely available to employees. In addition, job posting language will be revised to acknowledge cases in which there are strong internal candidates for jobs, while still ensuring the process fairly considers all candidates.

• **Supervisor/management training.** We are establishing a mandatory training program for supervisors and managers to expand and deepen necessary skills in areas such as personnel management, finances, safety, and policy implementation.

• **Management accountability.** In a pilot basis, we are implementing multi-source assessments for the appraisal of associate directors at the Laboratory to gain more complete information about their personnel management performance. The intent is to expand to other levels of management if and as appropriate.

• **Conflict resolution.** Many Lab organizations have highly successful ombuds programs. Their goal is to resolve issues as early and informally as possible. Our target is that by next



[a]Category average based on 2 items only
[b]Score based on 1 item only
[c]Colored bars indicate a statistically significant comparison

Figure 3.2-2. 1995 diversity survey (N = 5,557); percent deviation from the U.S. national norm.

year, every employee will have access to ombuds-like assistance.

Affirmative Action

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.

Our annual *Affirmative Action Plan* documents the goals and efforts of each Laboratory organization and the Laboratory-wide activities that ensure 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 for submission to the Department of Labor, Office of Federal Contract Compliance Programs.

Affirmative action activities include:

• Increasing 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.
• Providing technical expertise in employment law and affirmative action to organizations within LLNL.
• Improving opportunities for minorities, covered veterans, individuals with disabilities, and women within the Laboratory and at the local community, state, and national levels.
• Helping women and minorities develop the skills for future employment needs.
• Maintaining liaisons with and providing support for programs that assist in the skill development of women, minorities, covered veterans, and individuals with disabilities to meet utilization goals.

Accomplishments during the past year include:

Table 3.2-2. Population of Laboratory career employees as of March 31, 1991 (by number and percentage).

		Officials & Managers		Scientists & Engineers		Administrative		Technicians		All Others		Totals	
White	M	960	73.8%	1708	75.5%	175	30.2%	1324	70.8%	567	34.6%	4734	61.9%
	F	214	16.4%	265	11.7%	310	53.4%	225	12.0%	683	41.6%	1697	22.2%
Black	M	22	1.7%	22	1.0%	12	2.1%	56	3.0%	62	3.8%	174	2.3%
	F	4	0.3%	8	0.4%	21	3.6%	20	1.1	46	2.8%	99	1.3%
Hispanic	M	35	2.7%	45	2.0%	9	1.6%	108	5.8%	87	5.3%	284	3.7%
	F	14	1.1%	7	0.3%	25	4.3%	18	1.0%	97	5.9%	161	2.1%
Native American	M	9	0.7%	5	0.2%	0	0.0%	19	1.0%	9	0.5%	42	0.5%
	F	4	0.3%	1	0.0%	4	0.7%	5	0.3%	18	1.1%	32	0.4%
Asian	M	30	2.3%	156	6.9%	9	1.6%	75	4.0%	29	1.8%	299	3.9%
	F	9	0.7%	44	1.9%	15	2.6%	21	1.1%	42	2.6%	131	1.7%
Total Minorities	M	96	7.4%	228	10.1%	30	5.2%	258	13.8%	187	11.4%	799	10.4%
	F	31	2.4%	60	2.7%	65	11.2%	64	3.4	203	12.4%	423	5.5%
Totals	M	1056	81.2%	1936	85.6%	205	35.3%	1582	84.6%	754	46.0%	5533	72.3%
	F	245	18.8%	325	14.4%	375	64.7%	289	15.4%	886	54.0%	2120	27.7%

Table 3.2-3. Population of Laboratory career employees as of March 31, 1996 (by number and percentage).

		Officials & Managers		Scientists & Engineers		Administrative		Technicians		All Others		Totals	
White	M	869	67.4%	1373	72.1%	178	26.4%	1098	68.0%	477	33.1%	3995	57.7%
	F	251	19.5%	248	13.0%	361	53.5	240	14.9%	590	41.0%	1690	24.4%
Black	M	34	2.6%	26	1.4%	10	1.5%	48	3.0%	50	3.5%	168	2.4%
	F	7	0.5%	12	0.6%	28	4.1%	18	1.1%	42	2.9%	107	1.5%
Hispanic	M	43	3.3%	40	2.1%	11	1.6%	91	5.6%	77	5.3%	262	3.8%
	F	24	1.9%	7	0.4%	31	4.6%	13	0.8%	100	6.9%	175	2.5%
Native American	M	14	1.1%	9	0.5%	3	0.4%	19	1.2%	15	1.0%	60	0.9%
	F	3	0.2%	0	0.0%	12	1.8%	8	0.5%	20	1.4%	43	0.6%
Asian	M	25	1.9%	148	7.8%	16	2.4%	61	3.8%	27	1.9%	277	4.0%
	F	19	1.5%	40	2.1%	25	3.7%	19	1.2%	43	2.9%	145	2.1%
Total Minorities	M	116	9.0%	223	11.7%	40	5.9%	219	13.6%	169	11.7%	767	11.1%
	F	53	4.1%	59	3.1	86	14.2%	58	3.6%	204	14.2%	470	6.8%
Totals	M	985	76.4%	1596	83.9%	218	32.3%	1317	81.5%	646	44.9%	4762	68.8%
	F	304	23.6%	307	16.1%	457	67.7%	298	18.5%	794	55.1%	2160	31.1%

• Broader dissemination of the Affirmative Action Plan through electronic posting on LLNL's Technical Information Department server.
• Placement of over 50 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 and with positions ranging from clerk-typist trainees to post-doctoral physicists.
• Continued increase in use of sign language interpreters for deaf employees, resulting from the Affirmative Action and Diversity Program absorbing the costs of these services.
• Ongoing research and development collaborations with LLNL scientists and HBCU faculty and students. Current activities include projects with Howard University, Morehouse College, Spelman College, Fisk University, North Carolina A&T University, Florida A&M University, and the Science and Engineering Alliance (Southern University, Jackson State University, Prairie View A&M University, and Alabama A&M University).

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 direct 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.

Table 3.2-4. Minority and women diversity statistics as of March 31, 1996 (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	243	19	26	73.1%	12	28	42.9%
AB	Management Administrative	104	38	38	100.0%	16	16	100.0%
AC	Supervisor Technical	571	62	67	92.5%	69	67	103.0%
AD	Supervisor Clerical	158	148	135	109.6%	30	33	90.9%
AE	Supervisor Non-clerical	84	29	57	50.9%	21	14	150.0%
AF	Supervisor Blue Collar	83	1	4	25.0%	11	22	50.0%
AG	Supervisor Service	46	7	6	116.7%	10	15	66.7%
Total Officials & Managers		1289	304	333	91.3%	169	195	86.7%
BA	Administrator	627	430	359	119.8%	129	141	91.5%
BB	Physicist	531	41	58	70.7%	54	59	91.5%
BC	Chemist/Metallurgist	175	46	46	100.0%	28	35	80.0%
BD	Life Scientist	34	20	14	142.9%	7	7	100.0%
BE	Computer Scientist	400	117	118	99.2%	59	80	73.8%
BG	Engineer Mechanical	238	24	14	171.4%	45	37	121.6%
BH	Engineer Electronics	244	17	24	70.8%	35	45	77.8%
BJ	Engineer Miscellaneous	223	19	19	100.0%	48	43	111.6%
BK	Tech. Info. Editor	48	27	19	142.1%	7	4	175.0%
BZ	Environmental Scientist	58	23	10	230.0%	6	5	120.0%
Total Professionals		2578	764	681	112.2%	418	456	91.7%
Total Scientific Professionals[c]		1903	307	303	101.3%	282	311	90.7%
CA	Mechanical Technician	45	7	5	140.0%	10	11	90.9%
CB	Mechanical Tech. Specialist	257	17	33	51.5%	38	61	62.3%
CC	Electronics Technician	33	6	5	120.0%	7	10	70.0%
CD	Electronics Tech. Specialist	156	4	29	13.8%	25	57	43.9%
CE	Electronic Fabrication Technician	27	8	3	266.7%	7	7	100.0%
CI	Chemical Technician	72	19	15	126.7%	18	32	56.3%
CJ	Engineering & Science Technician	104	37	58	63.8%	18	36	50.0%
CL	Assistant Technical Coordinator	87	26	41	63.4%	14	15	93.3%
CM	Tech-Scientific Coordinator	76	6	24	25.0%	8	15	53.3%
CN	Technical Associate/Non-Engineering	155	44	55	80.0%	21	31	67.7%
CO	Drafter/Designer	124	12	50	24.0%	29	33	87.9%
CP	Technical Associate/Engineering	272	6	11	54.5%	23	36	63.9%
CQ	Computer Programming Technician	153	83	48	172.9%	42	41	102.4%
CS	Medical Technologist	5	4	4	100.0%	3	2	150.0%
CT	Technical Illustrator	49	19	17	111.8%	14	17	82.4%
Total Technicians		1615	298	398	74.9%	277	404	68.6%

[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, 1996 (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	72	71	67	106.0%	22	21	104.8%
DB	Administrative Support II	524	523	508	103.0%	133	125	106.4%
DC	Resource Management Support	42	40	36	111.1%	11	12	91.7%
DD	Info./Computer Service Support	89	79	60	131.7%	29	31	93.5%
Total Office & Clerical		727	713	671	106.3%	195	189	103.2%
EA	Miscellaneous Crafts	172	6	8	75.0%	35	49	71.4%
EC	Maintenance Mechanic	46	1	3	33.3%	16	17	94.1%
EJ	Machinist	105	4	4	100.0%	17	35	48.6%
EK	Assembly Specialist	24	0	1	0.0%	4	3	133.3%
Total Crafts		347	11	16	68.8%	72	104	69.2%
FD	Printer	4	4	1	400.0%	0	1	0.0%
FF	Warehouse Worker	56	12	20	60.0%	14	21	66.7%
FG	Photographic Specialist	36	12	13	92.3%	12	10	120.0%
FH	Vehicle Driver	26	1	2	50.0%	8	8	100.0%
Total Operators		122	29	36	80.6%	34	40	85.0%
GA	Laborer Gardener	36	2	7	28.6%	9	15	60.0%
Total Laborers		36	2	7	28.6%	9	15	60.0%
HA	Firefighters	29	3	3	100.0%	9	7	128.6%
HB	Protective Service Officers	123	14	21	66.7%	37	52	71.2%
HC	Custodian	56	22	19	115.8%	17	27	63.0%
Total Services		208	39	43	90.7%	63	86	73.3%
Laboratory Total Population		6922	2160	2185	98.9%	1237	1489	83.1%

[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.

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 laws, 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.

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 and the Livermore Site.

In support of the DOE's compliance with the National Environmental Policy Act (NEPA), and the UC's Compliance with the California Environmental Quality Act (CEQA) the Laboratory continues to make extensive use of information contained in the LLNL 1992 site-wide EIS/EIR. The 1992 EIS/EIR has served both DOE and State of California regulatory agencies as an adequate assessment of the potential impact for certain proposed projects and process decisions, thus reducing administrative effort and costs. We have also worked with DOE to ensure that Laboratory documents are suitable in format and content for incorporation either completely or by reference into DOE NEPA documents, such as DOE Programmatic Impact Statements. The Laboratory has also worked with DOE to suggest changes to DOE Orders, DOE's NEPA regulations, and DOE and LLNL NEPA compliance procedures so as to improve efficiency and reduce costs.

Indirect costs for ES&H, paid through overhead, are shown in Table 3.3-1. These costs include DOE order-related compliance and self-assessment activities. Table 3.3-2 shows direct funding levels.

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 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002 and beyond
ES&H	45.2	42.9	41.3	41.3	42.4	43.5	44.7	45.9
FTEs	380	370	379	375	370	365	365	364

Table 3.3-2. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives (in millions of dollars), including capital funding.

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002 and beyond
Waste Minimization	0.9	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Environmental Restoration	26.0	23.5	21.6	19.3	20.6	20.6	20.5	20.4
Waste Management	35.5	36.6	33.0	31.1	28.7	24.5	25.0	21.5

Current Conditions

LLNL is subject to numerous environmental laws and regulations covering all activities that may impact the environment, such as storm water discharges, air emissions, hazardous waste treatment and storage, and radionuclide emissions. Two other factors influence operations and environmental activities:

• 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.

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.

• Surveys proposed ground disturbance areas for sensitive, natural, cultural, and paleontological resources.

• 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 services and support for the handling, storage, treatment, disposal, and minimization of hazardous, radioactive and mixed wastes.

• Operates the Treatment and Storage Facility at the main site and a storage facility at Site 300 in accordance with state and federal requirements.

The Environmental Restoration Division:

• Designs and applies cost-effective technologies for site restoration and remediation.

• Develops and applies needed computer and analytical models.

• Determines contaminant fate and transport mechanisms.

• Tests and implements innovative technologies for environmentally responsible cleanup.

• Optimizes hydraulic control and contaminant removal.

Air Emission Standards

A change in the California Clean Air Act of 1987 required that the geographical areas not meeting ambient air-emission standards must implement strategies to reach these standards. Both the San Francisco Bay and San Joaquin Valley areas are nonattainment areas for state ozone and particulate standards. Therefore, the local air-quality management districts adopted rules to implement strategies for meeting the air-emission standards. New rules are proposed in five-year air-quality plans.

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 California 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.

Waste Water Discharges

LLNL water discharge to the sanitary sewer from the Livermore Site is permitted by the Livermore Water Reclamation Plant. LLNL renews the permit annually. In addition, both LLNL sites discharge other wastewater and wastes under National Pollutant Discharge Elimination System (NPDES) permits and waste discharge requirements issued by the Regional Water Quality Control Boards. These permits expire every five years, or as necessary. In 1996, LLNL is working on permit renewals for wastewater discharges at Site 300.

Storm-Water Discharges

The Environmental Protection Agency issued a rule in October 1990 that requires NPDES permits for storm-water discharges from industrial activities. In California, the State Water Resources Control Board adopted two general permits that cover the majority of California industrial and construction activities. The regional water quality control boards implement the general permits.

The Laboratory operated under the general permits for the first three years of California's storm-water program. Currently, LLNL holds NPDES permits specifically tailored to the operations at each site; they incorporate requirements patterned after the general permits. These permits authorize certain discharges of nonstorm water to the surface and storm drains that will have no environmental impact from discharges such as irrigation water, emergency shower and eyewash test water, and air conditioner condensate. Nonpermitted discharges, identified in an earlier investigation, were repaired or rerouted. LLNL's storm-water pollution prevention plans identify practices to assure that activities other than storm water are controlled and to assure the quality of storm-water runoff. LLNL continues to obtain coverage of construction projects that impact areas five acres or larger under the general construction storm-water permit.

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 for tanks and equipment containing oil. We have issued plans for the Livermore and Site 300 facilities and are continuing to implement line-item-funded improvements.

Hazardous Waste Operations

Many facets of LLNL's hazardous waste management operations participate in permit activities.

The Resource Conservation and Recovery Act Main Site Part B permit will be issued by the California Department of Toxic Substances Control. The permit, including both existing and proposed operations, is expected to be issued in FY 1997.

The draft permit for the Site 300 Building 883 container storage facility and the proposed Explosives Waste Storage Facility was issued for public comment beginning in March 1996. The final permit is expected by early summer 1996.

The proposed Explosives Waste Treatment Facility permit application, under review by the Department of Toxic Substances Control, is expected to be issued in FY 1997. Although current methods for treating explosive waste by burning are allowed, future regulations may require advanced handling and treatment technology and facilities.

Methods of managing mixed waste (waste that contains both radioactive and hazardous constituents) generated by LLNL operations are presented in the *Federal Facility Compliance Act Site Treatment Plan*. This document was prepared and negotiated by the DOE with the California Department of Toxic Substances Control in 1995 and 1996. The document describes the backlog of mixed waste, the proposed treatment, and planned schedule for treatment. Excellent progress has been made in immobilizing the hazardous portion of the mixed waste residue from aqueous waste treatment. This stabilized low-level radioactive waste will be shipped to the Nevada Test Site (NTS) for disposal. We have disposed of mixed waste soil at a permitted commercial facility.

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 significant 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 that are being implemented 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.
• Compensating for 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.

In addition, the impact of newly proposed LLNL projects are assessed by applying the provisions of DOE's April 1992 NEPA regulations.

Sensitive Species Protection and Management

As a result of our need to implement environmental impact mitigation measures related to protection of sensitive animal species at our Site 300 Experimental Test Facility, we have developed a miniaturized infrared camera system mounted on a tracked chassis that can be used to explore the narrow, twisting dens of burrowing animal species and record their images. This 5-inch-long system, the Mobile Optical Lair Explorer (MOLE), has sparked wide international interest and will be further developed and considered for commercialization.

Radionuclide Emission Sources

LLNL is in compliance with EPA's Subparts A and H National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities. This order requires the Laboratory to evaluate all potential sources of radionuclide emissions.

Based on a conservative model, as required by the Environmental Protection Agency, the 1995 effective dose equivalents to the hypothetical site-wide maximally exposed individuals are 0.41% and 0.23% of the 10 mrem/yr standard for the Livermore site and Site 300, respectively.

Waste Minimization

The Laboratory has established and is implementing a waste-minimization program. During FY 1996, Quarterly Waste Generation Reports 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 to generate funds for implementing pollution prevention.

DOE is currently re-evaluating how the cost might be paid by the waste generators. Pilot recharge programs at other sites are currently being reviewed.

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 computerized chemical inventory system, ChemTrack, greatly enhances the Laboratory's ability to track chemicals and improve its chemical management practices. This system uses bar code scanners and customized software to enter and track chemical inventory information. 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 (WCP)

The Waste Certification Program is developing the necessary documents and characterization systems to allow the shipment of treated low-level radioactive waste (formerly mixed waste) to the Nevada Test Site for disposal; mixed low-level radioactive waste to Envirocare for disposal; mixed low-level radioactive waste to commercial treatment facilities; and mixed transuranic waste to the Waste Isolation Pilot Plant in New Mexico. To be initiated in FY 1996 are the development of certification programs for the Idaho National Engineering Laboratory and Hanford.

LLNL currently has 21 low-level radioactive waste streams certified and approved for disposal at the Nevada Test Site; an additional 3 waste streams are conditionally approved and waiting for review of analytical data.

The certification process will continue until all newly generated radioactive waste is certified for disposal. In addition, DOE is using our waste certification and waste management expertise to assist them in managing waste from facility shutdowns.

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 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 online 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 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, and radioactive waste certification.

Resource Conservation and Recovery Act Training

This year we trained about 1,800 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.

This year we implemented an RCRA tank management course and a land disposal restriction course.

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 (UC) to provide training for approximately 400 personnel on site.

Department of Transportation Training

Personnel involved with the shipment of hazardous materials are required to take Department of Transportation training. This year we provided about 70 personnel with classroom and on-the-job training, which took about 40 hours for each person to complete.

Radioactive Waste Certification Program

Approximately 300 LLNL personnel and personnel from Oak Ridge, Tennessee, were trained in the requirements for the certification of low-level radioactive waste. Because our personnel are properly trained, the Laboratory is able to ship low-level radioactive waste to the Nevada Test Site.

Environmental and Waste Management Education

The Laboratory offers courses—Air Source Management, National Environmental Policy Act Compliance, Spill Prevention Control and Countermeasures, and Tank Management—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, the management of petroleum products, and the management of storage tanks.

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 pollution prevention.

The Environmental Training Section participates as LLNL's representative to PETE (Partnership for Environmental Technology Education). Additionally, a section member is serving as the chair of the Environmental Management Special Interest Group of the DOE-sponsored Training and Resources Data Exchange (TRADE).

Safety and Health

Our safety and health staff 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.

In 1995, we implemented an electronic version of the *Health and Safety Manual* (hyper-linked to the *Environmental Compliance Manual*) to make it easier for Laboratory employees to consult and review ES&H subjects online. By doing this, we have saved an estimated $1.8 million that would have been required to develop and publish a combined ES&H manual. Because subject matter in the electronic ES&H manual is linked to OSHA, DOE, and other documents, users can access the original source of the regulations. Besides helping LLNL employees, the electronic ES&H manual is used by other DOE Laboratories and outside organizations.

We also spearheaded an effort with support from the UC, LANL, and LBNL to convert the DOE RadCon Manual from a compliance document to a guidance document. This allows the RadCon Manual to be implemented in a cost-effective manner at LLNL and at other DOE Contractor sites, thus saving an estimated $2 million per year at Livermore alone.

Industrial Hygiene

LLNL operates DOE's Industrial Hygiene Technical Center of Excellence for Assessment of Biological and Chemical Hazards. The Center brings together technical resources for DOE's expanded worker exposure assessment program.

Radiation Protection

Because of decreased workload and dose-reduction procedures implemented during the inventory-reduction effort in the Plutonium Facility, the person-rem doses have decreased from 30 person-rem to 11 person-rem, well below the background exposure experienced by all people worldwide.

Industrial Safety

In 1993 Hazards Control identified the top three types of injury to UC and LLNL management to be used as a contract performance measure. The three types were repetitive-motion injuries at workstations, overexertion injury to backs, and other overexertion injuries. Through ergonomics safety training classes, *Newsline* articles, and new ergonomic equipment, we have cut the severity rates of repetitive-motion injuries in half.

Although the total number of reported electrical shocks has been decreasing for the past few years, the number of serious electrical shocks has increased during the past two years. In curbing this trend, we have developed new electrical safety awareness briefings, lessons-learned publications, a draft electrical safety training policy, and a new Web-based electrical safety

training course; and we have established a new electrical safety review committee.

Case Management

Health Services provide on-site medical treatment of work-related injuries and illnesses, and work collaboratively with Risk Management and Applied Risk Management in comprehensive case management that is directed at a timely return to work of injured employees. The result is a decrease of lost and restricted work days.

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, San Francisco. This program provides consultation and training in ergonomics for Laboratory employees, as well as prevention of and early intervention to correct repetitive-motion injuries and other health problems related to work routines.

Employee Assistance and Other Health Programs

We are working to increase the awareness of the Laboratory's Employee Assistance Program (EAP), and Recovery Assistance Program (RAP). The EAP brochure was updated this year, and the Alcohol and Substance Abuse Prevention (ASAP) training was provided to all Laboratory managers and supervisors. Annual employee health events include the "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 counseling services with off-site counseling resources.

Health Promotion

Health Services is identifying personal health issues that impair the efficiency of the LLNL workforce. Services have been set up to prevent debilitating diseases. The Health Promotion Partnership Program is available to working groups to facilitate health improvement initiatives within LLNL organizations. Tailored health awareness, assessment, counseling, education, and intervention are available to individuals and groups.

Stockpile Dismantlement Health and Safety Effects

We have provided information on all existing LLNL-designed weapons, including chemical and physical properties and hazards, in terms of toxic, flammable, radioactive and explosive hazards, and recommended personal protection for the Stockpile Dismantlement Database (SDDB) designed by Sandia.

In addition, have fabricated a mobile laboratory that is designed to monitor radiation from an accident, should one occur involving dismantlement of nuclear weapons. It is deployed in Belarus. The laboratory contains a liquid scintillation counter, low- and high-energy gamma detector systems, and an alpha-beta gas proportional counter; and it is equipped with portable radiation measurement equipment designed for field measurements of contaminated areas.

JIGSAW-95

We developed the Hazards Analysis and Safety Assessment (HA&SA) for the 1995 Nuclear Emergency Search Team (NEST) Training Drill (JIGSAW-95). The drill, which was conducted as a readiness activity by Nevada Test Operations and the NAI Directorate, was conducted during the week of December 4, 1995, at Area 27 at the Nevada Test Site.

Emergency Medical Services

The Fire Department Emergency Services Program now provides advanced life support, or paramedic, level services. Prior service was at a basic life support level. Since the program began in September 1994, LLNL paramedics have saved five lives—three in the first four months of the service. The Fire Department strives to respond to calls on-site in 5 minutes for 95% of its calls, which is one-half to one-third the response time in the community.

Communication and Information 3.4

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

Our principal product is scientific and technical information, which we must disseminate as widely as possible. We also generate significant administrative information in managing our programs. Improved management of information internal to the Laboratory can help reduce costs. We are using the current explosion in communications technology to assist us in reaching our goals.

Chief Information Officer

The Cost-Cutting Initiative (CCI) identified internal Laboratory information management as an area where significant cost savings are possible through standardization of desktop systems, software, and databases. Many programs at the Laboratory have set up their own information systems suited to their needs, but often they are not well integrated with other on-site systems. A lack of Laboratory-wide standards for software and hardware have resulted in systems that are not "user-friendly," accessible, or "scalable," that is, easily expanded to accommodate more data and additional users.

The Laboratory's first chief information officer (CIO) was named in October 1996 to deal with these issues. The CIO's job is to provide the vision and leadership for the development of an information system architecture for the future, to propose and implement standards for hardware and software, and to develop information system strategies that balance cost, technology, and service.

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.

A major task is implementing a new computing environment, which includes efforts to reduce costs, improve cycle times, and improve quality by using information technology more effectively and re-engineering business processes. Administrative applications software will be set up on a RESC/UNIX-based open system. Information services will be available via:

- Web browsers.
- Electronic forms.
- Workflow automation.
- Digital signature and public-key infrastructure.
- Advanced object-oriented software.

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. The Institutional Business Systems Implementation Team is responsible for the overall integrated deployment of Laboratory business systems.

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 main 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.

Building on its achievements for last

year, the Library of the Future has accomplished the following:
• Made LLNL documents available through the Internet as well as through an internal home page. Since the Library of the Future home page was placed on the Internet, the number of accesses from external locations has averaged some 6,500 per month, a clear indication of ongoing interest.
• Completed scanning of more than 15,000 of the 77,000 documents in the archival document collection. These documents will be released to the external Library of the Future home page as they are converted to proper format. Scanning and release will continue until all archival documents are publicly available.
• Continued review of text-search technologies for added value compared to cost.
• Continued to make current documents available electronically as they come to the Technical Information Department. The inventory of current documents was more than 700 in February 1996.
• Added electronic journals to the Library of the Future home page, so customers can browse, search, and order relevant articles.
• Added an electronic order form to the Library's home page that allows users to order various hardcopy library materials for their own use.

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.

Information Archive

The Office of History and Historical Records reports to the head of the Technical Information Department. This office has two major functions:
• Acquiring, cataloging, and maintaining pertinent historical records.
• 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 14 volumes covering 410,000 items to date. Of these items, about 15% are classified.

Information to Employees and the Public

The Laboratory has strengthened internal and external communication 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 publishes the Laboratory newspaper, *Newsline*, once a week.
• For faster-breaking news, an electronic "*E-line*" gets vital messages to some 6,000 online employees within two to three hours. An electronic newsletter, *News-on-Line*, was launched in early 1996.
• 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.
• The Area Relations Group operates the Visitors Center, arranges for Lab tours, takes community "hotline" calls, and provides Lab speakers to community organizations. About 9,000 people toured the Visitors Center in 1995; 2,000 took escorted tours of the Laboratoy;, and the Speakers Bureau reached 2,500 people in the local community. Approximately 800 "hotline" calls were answered.
• With the support and encouragement of local schools, we have designed a program called The Learning Playground, which supplements science learning and promotes science careers.
• Area Relations coordinates employee-volunteer efforts for several charity events held in the Tri-Valley area, as well as Lab-sponsored events such as the Brighter Christmas food-basket collection.

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 making extensive use of the electronic distribution systems.

• We offered special services such as placements for editorial articles, comprehensive planning, 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 assistant 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.

The Laboratory actively participates in the Livermore, San Ramon, Pleasanton, and Tracy Chambers of Commerce, the Tri-Valley Business Council and with several area science museums.

Laboratory employees contributed over $700,000 to local and national charities, through the Helping Others More Effectively (HOME) campaign and Daffodil Days. In addition, approximately 2,500 employees volunteered for all types of community activities that help students, seniors, and the needy of all ages.

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 $1.8 billion in personal property and land value (see Table 3.5-1).

Stewardship of DOE lands and facilities at Livermore is an important responsibility. It is also an area identified by the Cost-Cutting Initiative as an area where steps to standardize definitions and policies and to centralize management can lead to greater efficiency and lower costs. We have changing requirements for space as program needs change, and there are legacy facilities that must be dealt with. The Council on Strategic Operations, identifying facilities as a high-priority issue, is revising policies and priorities regarding space utilization at the Laboratory as it updates the institutional space plan.

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 1996, the Laboratory population numbered 9,626, including 307 at off-site leased facilities and 256 at Site 300. The Livermore site has 170 permanent and 331 temporary structures, housing a population of 9,063 in a total (gross) of 537,863 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 44% 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 during 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 34,008 m^2 of facilities. The site consists of two remote firing areas, supported by a chemistry and

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	537,353	34,008	11,355
Net square meters	369,106	25,497	8,937
Number of permanent buildings	170	66	9
Number of trailers	231 (1075 units)	7 (21 units)	0
Number of modulars	76	3	0
Number of utility facilities	36	24	0
Number of WWII buildings	20	0	0
LLNL population	7,924	241	62
Other population	991	15	244
DOE and other federal employees	148	0	1
Total population	9,063	256	307

Table 3.5-3. Facilities owned and leased (in gross square meters).

Livermore Main Site	
Owned	537,353
Leased	510
Total	527,863
Site 300	
Owned	34,008
Leased	0
Total	32,008
Off-site	
Owned	0
Leased	11,355
Total	11,355

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 the most significant infrastructure problem. Revitalization 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.

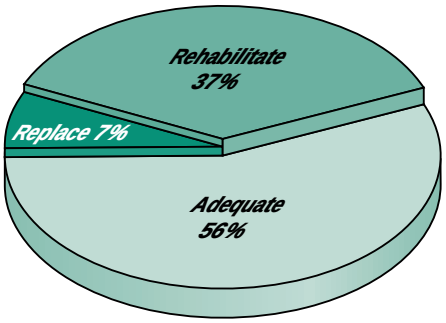


Figure 3.5-1. The condition of building structures at LLNL and Site 300.

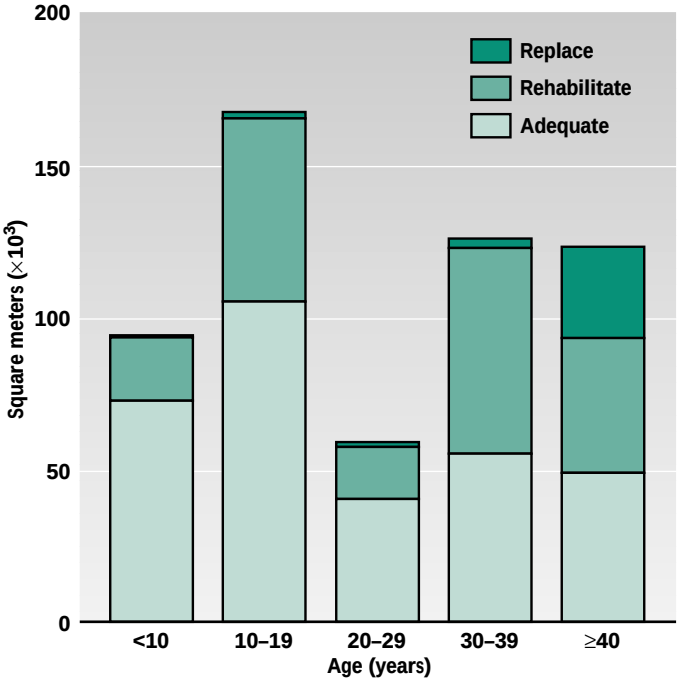


Figure 3.5-2. The age distribution of buildings.

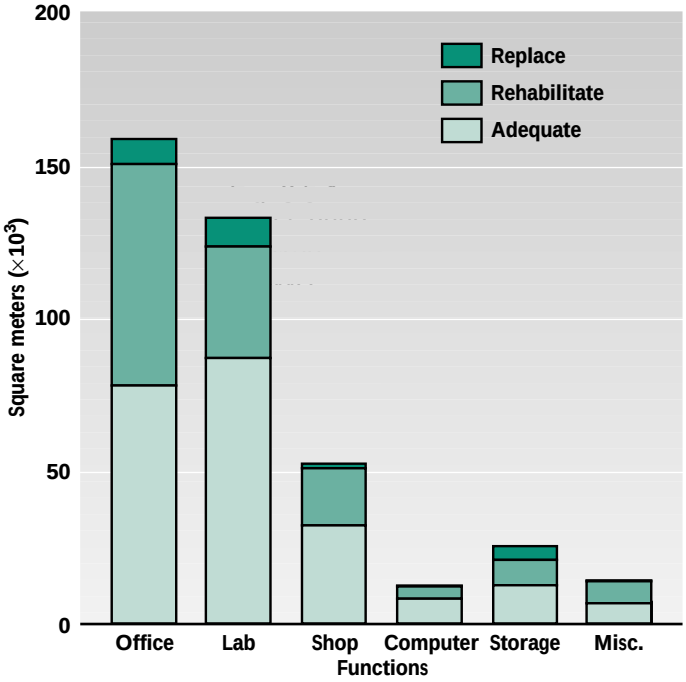


Figure 3.5-3. The appropriateness of facilities for their current uses.

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.

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 stakeholder participation in the planning process.

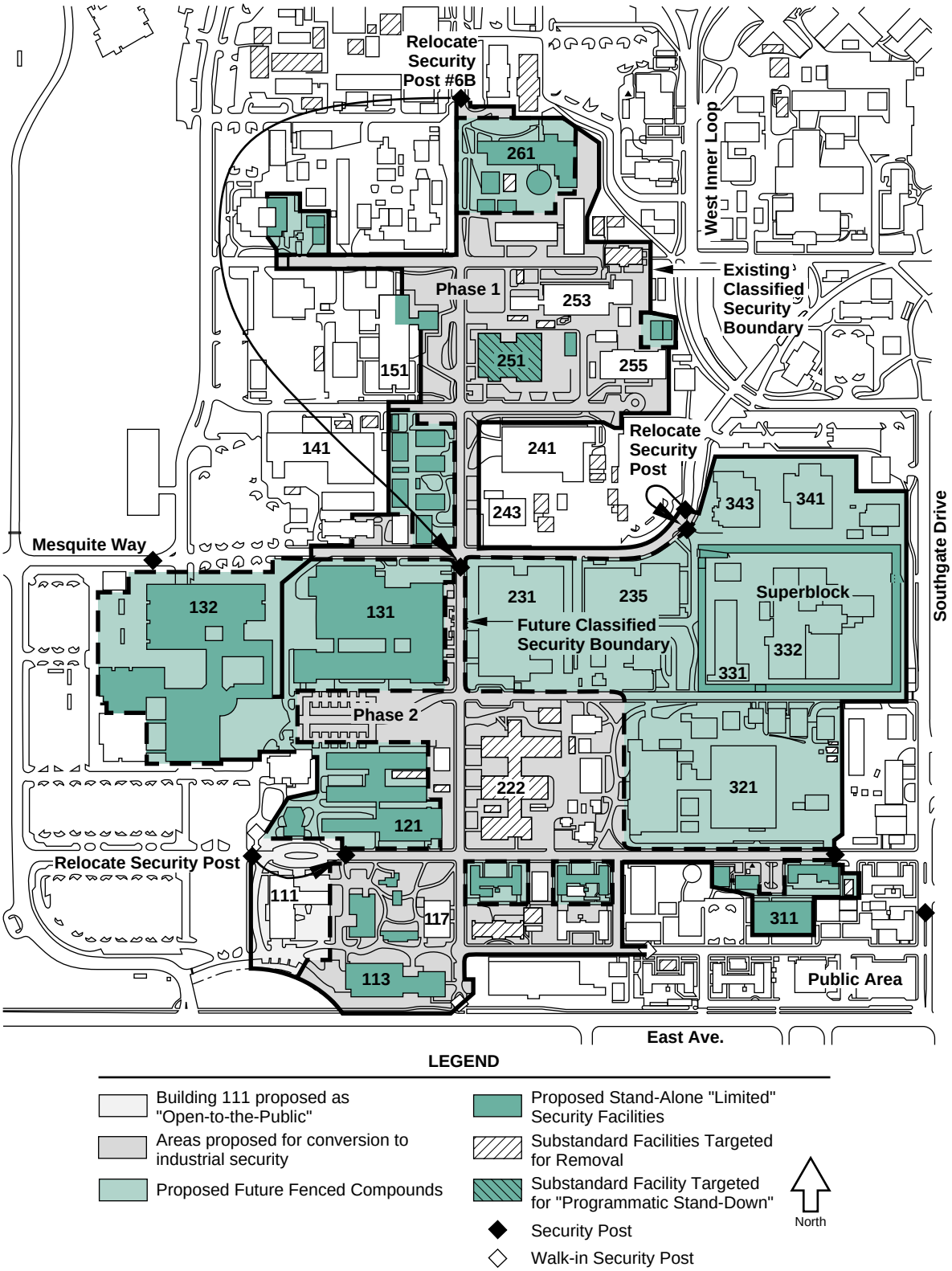
The continuing long-range planning process at LLNL is an integrated effort with inputs from capital asset management and prioritization, condition assessment survey, and Program Area Plan projections of facility requirements for the next 20 years. The Comprehensive Site Plan (CSP), prepared in compliance with the new DOE Life Cycle Asset Management Order, documents this planning process. The CSP, as with its predecessor, the Site Development Plan (SDP), updates trends and land-use options in response to the Laboratory's facility and mission resource projections.

Site development goals have been set to direct the planning effort. These goals and the basis for them can be found in the CSP. Additionally, the CSP outlines future land-use plans for both the Livermore site and Site 300, and presents implementation strategies to reach the stated goals.

Workforce migrations are significant in shaping the future of the site. Primarily because of 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.

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. The Facility Assessment & Ranking System (FAaRS), which was developed last year, will continue to be updated for assisting LLNL planners to identify and rank substandard facilities. 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.

Figure 3.5-4. Classified Core Contraction Plan.



Additional analyses are being conducted to determine the best secondary and tertiary moves into the vacated spaces. Ensuing decisions are aimed at optimizing space use and operating efficiency.

Facilities Resource Requirements

The following construction project summaries describe proposed facilities for FY 1997 through 1999 and for the National Ignition Facility and Contained Firing Facility in 1996. The fiscal years are the years that construction begins. Tables 3.5-4 and 3.5-5 present the requirements for funded and proposed construction, respectively. 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 and Management 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 ($36 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 several phases: Phase I in FY 1997 at $7.8 million; Phase II in FY 1999 at $19.9 million; Phase III in FY 2002 at $8.3 million.

FY 1998

Site 300 Fire Station/Medical Facility ($5.4 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.

Sensitive Compartmented Information Facility (SCIF) ($6.5 million)

The planned SCIF will be housed in Building 132 North. This facility will complete the migration of the Nonproliferation Arms Control and International Security (NAI) Directorate, which until 1995 was scattered throughout the LLNL site. By relocating Z Division and other elements working on SCI (with the

(Continued on page 146)

Table 3.5-4. Funded construction (in millions of dollars).

Sponsor	Type of Facility[a]	Total Estimated Cost	Prior Years Total	FY 1995 BO	FY 1996 BA	FY 1997 BA	FY 1998 BA	FY 1999 BA	FY 2000 BA	FY 2001 BA	FY 2002 BA[b]
Defense Programs											
GB-01 Stockpile Stewardship											
Site 300 Contained Firing Facility	PR	49.7	0.0	0.0	6.6	17.1	19.3	6.7	0.0	0.0	0.0
Defense Programs Research Facility	PR	72.7	67.2	4.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Site 300 Facilities Revitalization – Part 1	PR	27.4	21.2	0.9	5.3	0.0	0.0	0.0	0.0	0.0	0.0
Electrical Power System Upgrade	GPF	28.4	28.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Fiber Optics Communication	GPF	1.8	1.1	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
GB-01 Total		151.6	89.5	4.9	14.3	17.1	19.3	6.7	0.0	0.0	0.0
GB-02 Intertial Confinement Fusion											
National Ignition Facility	PR	842.6	0.0	0.0	37.4	131.9	197.8	198.8	191.3	75.4	10.0
GB-02 Total		842.6	0.0	0.0	37.4	131.9	197.8	198.8	191.3	75.4	10.0
Total Defense Programs		1022.6	117.7	4.9	51.7	149.0	217.1	205.5	191.3	75.4	0.0
Energy Research											
KA-00 High Energy Physics											
B-Factory (SLAC Site)	PR	24.4	2.5	6.7	8.0	6.0	1.2	0.0	0.0	0.0	0.0
KA Total		24.4	2.5	6.7	8.0	6.0	1.2	0.0	0.0	0.0	0.0
Total Energy Research		24.4	2.5	6.7	8.0	6.0	1.2	0.0	0.0	0.0	0.0
Environmental Restoration and Waste Management											
EW-31 Waste Management											
Decontamination/Waste											
Treatment Facility	GPF	68.0	19.8	4.5	8.9	11.0	12.5	11.0	0.3	0.0	0.0
EW-31 Total		68.0	19.8	4.5	8.9	11.0	12.5	11.0	0.3	0.0	0.0
Total Environmental Restoration and											
Waste Management		68.0	19.5	4.5	8.9	11.0	12.5	11.0	0.3	0.0	0.0
Field Management											
WB In-House Energy Management											
Energy Conservation Retrofits	GPF	23.4	20.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WB Total		23.4	20.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Field Management		23.4	20.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Funded Projects		1138.3	160.4	19.1	68.6	166.0	230.8	216.5	191.6	75.4	10.0

[a] PR = program related; GPF = general purpose facility/utility.
[b] Includes projected construction beyond FY 2002.

Table 3.5-5. Proposed construction (requirement case; in millions of dollars).

Sponsor	Type of Facility[a]	Total Estimated Cost[b]	FY 1995 BO	FY 1996 BA	FY 1997 BA	FY 1998 BA	FY 1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY 2002[b,c] BA
Defense Program										
GB-01 Stockpile Stewardship										
Protection of Real Property (roofs) Phase 1	GPF	7.8	0.0	0.0	3.0	4.8	0.0	0.0	0.0	0.0
Site 300 Fire Station and Medical Facility	GPF	5.4	0.0	0.0	0.0	0.9	3.4	1.1	0.0	0.0
Storm Drain Sitewide Rehabilitation	GPF	7.6	0.0	0.0	0.0	2.0	3.0	2.6	0.0	0.0
Protection of Real Property (roofs) Phase 2	GPF	19.9	0.0	0.0	0.0	0.0	7.3	6.4	6.3	0.0
B-511 Renovation Project	GPF	8.0	0.0	0.0	0.0	0.0	2.0	3.0	3.0	0.0
Adaptive Re-Use for Office Space	GPF	20.0	0.0	0.0	0.0	0.0	4.0	13.0	3.0	0.0
B-151 Plant and Seismic Upgrade	PR	17.0	0.0	0.0	0.0	0.0	4.0	5.0	5.0	3.0
B-321 General Upgrade	PR	11.0	0.0	0.0	0.0	0.0	0.0	2.0	5.5	3.5
NW LCW Station	GPF	6.5	0.0	0.0	0.0	0.0	0.0	0.0	2.1	4.4
Tank Upgrades Project Phase 2	GPF	5.1	0.0	0.0	0.0	0.0	0.0	0.0	2.0	3.1
Replace Deteriorating Physics Offices	PR	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5
Building Renovation Project	GPF	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0
Protection of Real Property (roofs) Phase 2	GPF	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3
GB Total		148.0	0.0	0.0	3.0	7.7	23.7	33.0	26.9	53.7
GC Verification and Control Technologies										
SCIF Area for NAI		6.5	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0
GC Total		6.5	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0
Energy Research										
KP-04 General Life Sciences										
Genomics and Structural Biology Research Facility	PR	40.5	0.0	0.0	0.0	0.0	4.0	12.0	20.0	4.5
KP Total		40.5	0.0	0.0	0.0	0.0	4.0	12.0	20.0	4.5
Total Energy Research		40.5	0.0	0.0	0.0	0.0	4.0	12.0	20.0	4.5
Magnetic Fusion										
B-543 Addition	PR	18.2	0.0	0.0	0.0	0.0	0.0	3.5	10.7	4.0
Energy Program Office Building	PR	20.4	0.0	0.0	0.0	0.0	0.0	0.0	5.5	14.9
Total Magnetic Fusion		38.6	0.0	0.0	0.0	0.0	0.0	3.5	16.2	18.9
Environmental Restoration and Waste Management										
B-222 Chemistry Building Decontamination/ Demolition	PR	23.2	0.0	0.0	0.0	0.0	0.0	0.0	2.9	20.3
Total ERWM		23.2	0.0	0.0	0.0	0.0	0.0	0.0	2.9	20.3
Total LLNL Proposed Projects		256.8	0.0	0.0	3.0	14.2	27.7	48.5	66.0	97.4

[a] PR = program related; GPF = general purpose facility/utility.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

exception of the Forensic Science Center), NAI will have all its components located in one building. This move will remove the need to make extensive modifications to the 35-year-old SCIF in Building 261.

FY 1999

Site-wide Storm Drain Rehabilitation ($7.6 million)

This new project will provide investigation, rehabilitation, proper reconnection, and other infrastructure improvements to storm drain, channels, and sewer lines in the 50-year-old system, thus keeping the sewer system in compliance with California's Porter-Cologne Water Quality Control Act, San Francisco Bay Regional Water Quality Control Board Quality Control Basin Plan, and other federal, state, and local regulatory requirements.

Building 511 Renovation Project ($8.0 million)

The proposed project renovates this World War II-vintage building for adaptive reuse instead of demolition and replacement. The structural integrity of this building offers a cost-effective opportunity for renewal. The renovation will include code-compliant upgrades in plumbing, fiber-optic communication, electrical, and seismic standards, hazardous material removal, personnel accessibility, and energy-efficient lighting and heating, ventilating, and air conditioning (HVAC) systems.

Building 151 Plant/Seismic Upgrade and Office Modification ($17.0 million)

With special emphasis on enhanced structural integrity, this project upgrades Building 151 to currently required seismic and safety standards. The project also provides a 2,050-m^2 office space and storage area. Plant upgrade includes installation of exhaust systems allowing continuous monitoring of emissions, integration of exhaust systems into the central HVAC control system, and replacement of two boilers with more energy-efficient units.

Office of Energy Research

FY 1999

Genomics and Structural Biology Research Facility ($40.5 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.

Section 4

Appendices

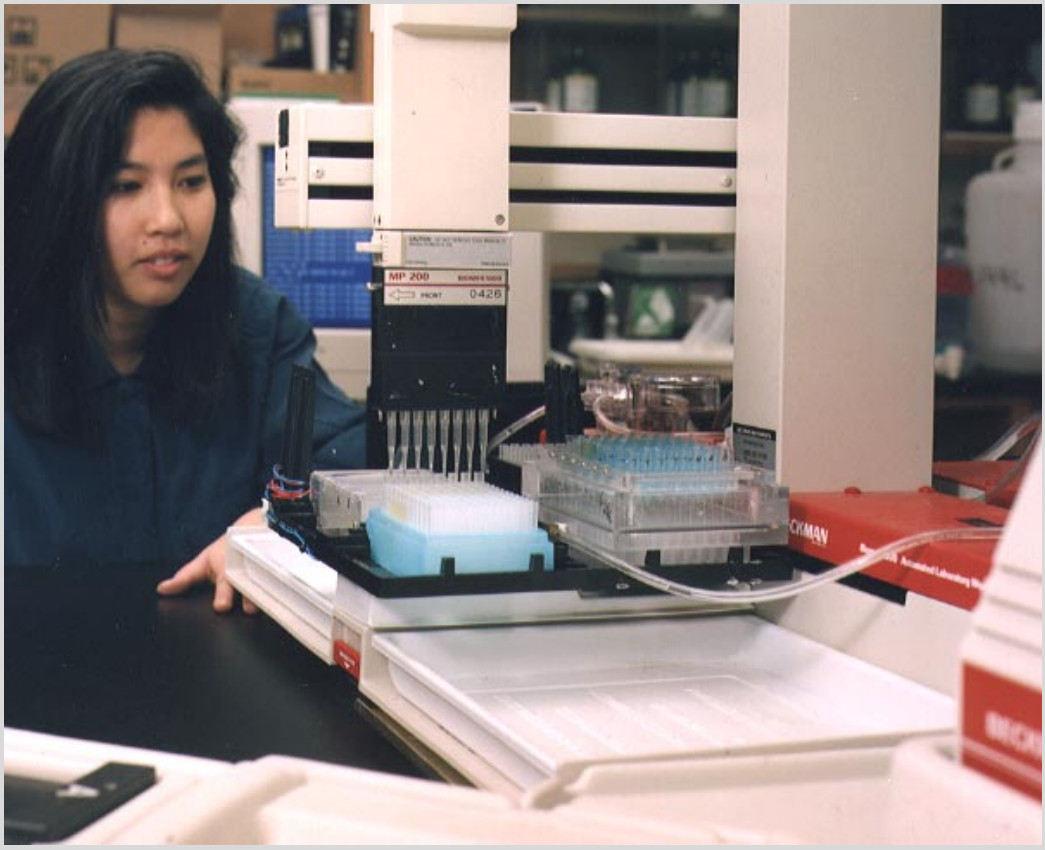


Photo: Manual pipetting is a time-consuming task of the past, thanks to automated workstations like the one pictured with biomedical scientist Maria De Guzman. Before these machines were available, it took one person all day to process 48 DNA samples for sequencing. Using the Genome Center's three workstations, one person can now process up to 1,000 samples a day.

Program Resource Requirement Projections 4.1

Data for FY 1995 is taken from the FY 1995 *LLNL Budget Office Annual Report.* Data for FY 1996 through FY 1998 represent a combination of the FY 1998 Field Budget Submission and the FY 1998–1999 Defense Programs Field Budget Estimates (April 1996). The guidance case is used for all programs. The resource data for FY 1995 through 2002 are based on the following:

- FY 1995 through 1996, actual budget obligations and authority.
- FY 1997 through 2002, Program Managers' estimates of resource requirements.
- Inflation factor: from FY 1996 through 1998, inflation is 2.7%; from FY 1998 through 2002, inflation is expressed in constant FY 1998 dollars, except where a project budget plan extends into this period, in which case the project numbers are used.
- Personnel figures do not always add correctly because the numbers have been rounded to whole numbers.

The program resource projections are shown as follows:

- Table 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.
- Tables 4.1-5 through 4.1-16. Detailed resource breakouts by DOE sponsors.

Table 4.1-1. Laboratory funding summary (in millions of dollars).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Sponsor-Funded Operating								
DOE Direct	593.2	573.5	569.4	635.5	640.0	639.9	639.9	659.9
DOE Other	96.3	87.7	97.1	102.9	102.9	102.9	102.9	102.9
Non-DOE	163.7	211.0	250.0	203.1	163.1	153.1	153.1	143.1
Total Operating	853.2	872.2	916.5	941.5	906.0	895.9	895.9	905.9
DOE Capital								
Capital Equipment	40.5	34.2	37.3	35.6	42.6	42.6	42.6	42.6
Facility Construction	51.3	79.4	40.9	45.1	49.5	49.5	49.5	49.5
Total Capital	91.8	113.6	78.2	80.7	92.1	92.1	92.1	92.1
Total Laboratory	945.0	985.8	994.7	1022.2	998.1	988.0	988.0	998.0
NIF-TEC[d]	0.0	37.4	131.9	197.8	198.8	191.3	75.4	10.0
NIF-OPC[d]	6.0	23.6	59.2	31.3	11.6	31.7	37.5	17.9

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.
[d] National Ignition Facility funding reflects total appropriation distributed nationally, pending site selection.

Table 4.1-2. Laboratory personnel summary (in full-time employee equivalent).

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Sponsor Funded Operating								
DOE	2490	2400	2378	2478	2478	2478	2478	2478
Non-DOE	500	674	719	660	507	472	472	432
Total Operating	2990	3074	3097	3138	2985	2950	2950	2910
DOE Capital	73	42	53	43	43	43	43	43
Construction	79	162	60	30	30	30	30	30
Total Sponsor Funded	3141	3278	3210	3211	3058	3023	3023	2983
Distributed	4182	4071	3882	3826	3826	3826	3826	3826
Total Laboratory	7323	7349	7092	7037	6884	6849	6849	6809

Table 4.1-3. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999b BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Defense Programs								
Operating Costs	347.4	371.4	338.5	404.3	408.8	408.7	408.7	428.7
Capital Equipment	23.2	16.5	20.7	21.8	28.8	28.8	28.8	28.8
Construction[d]	33.6	54.2	22.6	29.0	33.4	33.4	33.4	33.4
Total Cost/Funding	404.2	442.1	381.8	445.1	471.0	470.9	470.9	490.9
Direct Personnel	1298	1532	1339	1408	1408	1408	1408	1408
Nonproliferation & National Security								
Operating Costs	69.0	65.0	83.3	84.4	84.4	84.4	84.4	84.4
Capital Equipment	4.3	5.2	3.3	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	73.3	70.2	86.6	87.8	87.8	87.8	87.8	87.8
Direct Personnel	232	206	276	282	282	282	282	282
Fissile Materials Disposition								
Operating Costs	8.6	7.5	10.5	10.8	10.8	10.8	10.8	10.8
Capital Equipment	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.6	8.5	11.5	11.8	11.8	11.8	11.8	11.8
Direct Personnel	34	26	40	40	40	40	40	40
Energy Research								
Operating Costs	81.0	52.2	47.3	50.1	50.1	50.1	50.1	50.1
Capital Equipment	4.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3
Construction	6.8	9.1	6.8	3.2	3.2	3.2	3.2	3.2
Total Cost/Funding	92.2	63.7	56.5	55.6	55.6	55.6	55.6	55.6
Direct Personnel	216	252	213	221	221	221	221	221

Table 4.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Environmental Restoration & Waste Management								
Operating Costs	61.5	57.6	61.5	57.2	57.2	57.2	57.2	57.2
Capital Equipment	8.1	8.8	9.2	6.3	6.3	6.3	6.3	6.3
Construction	6.8	16.1	11.5	12.9	12.9	12.9	12.9	12.9
Total Cost/Funding	76.4	82.5	82.2	76.4	76.4	76.4	76.4	76.4
Direct Personnel	244	261	282	252	252	252	252	252
Environmental, Safety & Health								
Operating Costs	8.4	6.7	8.0	7.7	7.7	7.7	7.7	7.7
Capital Equipment	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.6	6.7	8.3	8.0	8.0	8.0	8.0	8.0
Direct Personnel	30	21	20	17	17	17	17	17
Nuclear Energy								
Operating Costs	9.7	7.0	11.4	10.9	10.9	10.9	10.9	10.9
Capital Equipment	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	11.8	7.1	11.5	11.0	11.0	11.0	11.0	11.0
Direct Personnel	27	22	26	24	24	24	24	24
Fossil Energy								
Operating Costs	2.7	1.7	3.9	3.9	3.9	3.9	3.9	3.9
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	2.7	1.7	3.9	3.9	3.9	3.9	3.9	3.9
Direct Personnel	6	4	10	10	10	10	10	10
Energy Efficiency & Renewable Energy								
Operating Costs	3.0	3.2	3.6	4.7	4.7	4.7	4.7	4.7
Capital Equipment	0.0	0.2	0.3	0.4	0.4	0.4	0.4	0.4
Construction	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.3	3.4	3.9	5.1	5.1	5.1	5.1	5.1
Direct Personnel	10	11	11	13	13	13	13	13
Human Resources & Administration								
WM General Administration-Contractual Services								
Operating Costs	0.7	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.7	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	2	3	3	3	3	3	3	3

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.
[d] Includes General Plant Projects.

Table 4.1-3, continued. Resources by major program (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Science Education & Technical Information								
Operating Costs	1.2	0.7	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	1.2	0.7	0.7	0.8	0.8	0.8	0.8	0.8
Direct Personnel	3	3	3	3	3	3	3	3
Total DOE Direct								
Operating Costs	593.2	573.5	569.4	635.5	640.0	639.9	639.9	659.9
Capital Equipment	40.5	34.2	37.3	35.6	42.6	42.6	42.6	42.6
Construction	51.3	79.4	40.9	45.1	49.5	49.5	49.5	49.5
Total Cost/Funding	685.0	687.1	647.6	716.2	732.1	732.0	732.0	732.0
Direct Personnel	2101	2341	2223	2273	2273	2273	2273	2273
Total DOE Other								
Operating Costs	96.3	87.7	97.1	102.9	102.9	102.9	102.9	102.9
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	96.3	87.7	97.1	102.9	102.9	102.9	102.9	102.9
Direct Personnel	332	263	268	278	278	278	278	278
Total All DOE								
Operating Costs	689.5	661.2	666.5	738.4	742.9	742.8	742.8	762.8
Capital Equipment	40.5	34.2	37.3	35.6	42.6	42.6	42.6	42.6
Construction[d]	51.3	79.4	40.9	45.1	49.5	49.5	49.5	49.5
Total Cost/Funding	781.3	774.8	744.7	819.1	835.0	834.9	834.9	854.9
Direct Personnel	2433	2604	2491	2551	2551	2551	2551	2551

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.
[d] Includes General Plant Projects.

Table 4.1-4. Resource projections by sponsor for non-DOE reimbursable programs (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Department of Defense								
Operating Costs	63.8	63.1	96.4	83.3	83.3	83.3	83.3	83.3
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	63.8	63.1	96.4	83.3	83.3	83.3	83.3	83.3
Direct Personnel	196	195	213	219	219	219	219	219
NASA								
Operating Costs	3.5	1.6	3.6	1.6	1.6	1.6	1.6	1.6
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	3.5	1.6	3.6	1.6	1.6	1.6	1.6	1.6
Direct Personnel	10	4	11	6	6	6	6	6
U.S. Enrichment Corporation								
Operating Costs	45.5	87.0	90.0	80.0	40.0	30.0	30.0	20.0
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	45.5	87.0	90.0	80.0	40.0	30.0	30.0	20.0
Direct Personnel	195	330	340	303	150	115	115	75
Other Federal Agencies								
Operating Costs	13.4	18.8	20.2	17.2	17.2	17.2	17.2	17.2
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	13.4	18.8	20.2	17.2	17.2	17.2	17.2	17.2
Direct Personnel	41	50	55	58	58	58	58	58
Non-Federal Agencies								
Operating Costs	37.5	40.5	39.8	21.0	21.0	21.0	21.0	21.0
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	37.5	40.5	39.8	21.0	21.0	21.0	21.0	21.0
Direct Personnel	114	95	100	74	74	74	74	74
Total Non-DOE								
Operating Costs	163.7	211.0	250.0	203.1	163.1	153.1	153.1	143.1
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	163.7	211.0	250.0	203.1	163.1	153.1	153.1	143.1
Direct Personnel	556	674	719	660	507	472	472	472

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-5. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Core Stockpile and Stewardship-DP0101								
Operating Costs	197.1	196.2	203.9	246.2	246.2	246.2	246.2	246.2
Capital Equipment	18.2	12.2	16.3	16.6	16.6	16.6	16.6	16.6
Construction[d]	33.6	16.8	22.6	29.0	33.4	33.4	33.4	33.4
Total Cost/Funding	248.9	225.2	242.8	291.8	296.2	296.2	296.2	296.2
Direct Personnel	745	785	823	876	876	876	876	876
Inertial Confinement Fusion-DP02								
Operating Costs[e]	71.9	83.8	83.4	95.5	100.0	100.0	100.0	120.0
Capital Equipment	4.6	3.0	3.0	3.0	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	76.5	86.8	86.4	98.5	110.0	110.0	110.0	130.0
Direct Personnel	296	363	304	311	311	311	311	311
National Ignition Facility-DP0207[f]								
Operating Costs	3.9	20.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	37.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.9	57.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	17	72	0	0	0	0	0	0
Technology Transfer and Education-DP03								
Operating Costs	57.6	43.8	17.7	3.0	3.0	3.0	3.0	3.0
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	58.0	43.8	17.7	3.0	3.0	3.0	3.0	3.0
Direct Personnel	198	181	64	12	12	12	12	12
Weapons Stockpile Management-DP04								
Operating Costs	9.5	27.6	25.0	50.9	50.9	50.8	50.8	50.8
Capital Equipment	0.0	1.0	1.4	2.2	2.2	2.2	2.2	2.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	9.5	28.6	26.4	53.1	53.1	53.0	53.0	53.0
Direct Personnel	35	126	116	178	178	178	178	178
Program Direction-DP05								
Operating Costs	6.1	0.0	8.5	8.7	8.7	8.7	8.7	8.7
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	6.1	0.0	8.5	8.7	8.7	8.7	8.7	8.7
Direct Personnel	20	3	31	31	31	31	31	31
Indust Partnering NIS, former Soviet Union-GB0107								
Operating Costs	1.3	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	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	4	2	1	0	0	0	0	0

Table 4.1-5, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BA	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BO
Total Defense Programs								
Operating Costs	347.4	371.4	338.5	404.3	408.8	408.7	408.7	428.7
Capital Equipment	23.2	16.5	20.7	21.8	28.8	28.8	28.8	28.8
Construction[d]	33.6	54.2	22.6	29.0	33.4	33.4	33.4	33.4
Total Cost/Funding	404.2	442.1	381.8	455.1	471.0	470.9	470.9	490.9
Direct Personnel	1298	1532	1339	1408	1408	1408	1408	1408

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.
[d] Includes General Plant Projects.
[e] For FY 1998 and beyond, CRADAS are integrated into the operating.
[f] National Ignition Facility funding reflects total appropriation distributed nationally, pending site selection.

Table 4.1-6. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Nonprolif & Verif Res & Develop-GC00								
Operating Costs	36.5	34.3	32.0	33.0	33.0	33.0	33.0	33.0
Capital Equipment	0.0	2.6	2.5	2.6	2.6	2.6	2.6	2.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	36.5	36.9	34.5	35.6	35.6	35.6	35.6	35.6
Direct Personnel	141	99	93	98	98	98	98	98
Arms Export Control & Nonproliferation-GJ								
Operating Costs	16.4	15.5	21.0	22.5	22.5	22.5	22.5	22.5
Capital Equipment	4.2	2.5	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	20.6	18.0	21.1	22.6	22.6	22.6	22.6	22.6
Direct Personnel	36	46	57	60	60	60	60	60
Emergency Management Program-ND02								
Operating Costs	0.0	0.6	0.5	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	0.0	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	0	2	1	2	2	2	2	2

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Analytical Support-NT01								
Operating Costs	7.0	5.5	5.4	5.3	5.3	5.3	5.3	5.3
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	7.0	5.5	5.4	5.3	5.3	5.3	5.3	5.3
Direct Personnel	31	23	23	23	23	23	23	23
Technical Support-NT04								
Operating Costs	0.4	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	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0	0
Classification Resources-GD03								
Operating Costs	0.6	1.0	0.9	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	0.6	1.0	0.9	0.6	0.6	0.6	0.6	0.6
Direct Personnel	2	3	3	3	3	3	3	3
Operational Support-GD05								
Operating Costs	0.3	0.5	1.2	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.5	1.2	0.9	0.9	0.9	0.9	0.9
Direct Personnel	1	1	3	3	3	3	3	3
Technology & Systems Development-GD06								
Operating Costs	3.7	3.3	19.2	20.0	20.0	20.0	20.0	20.0
Capital Equipment	0.1	0.1	0.7	0.7	0.7	0.7	0.7	0.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.8	3.4	19.9	20.7	20.7	20.7	20.7	20.7
Direct Personnel	14	17	86	87	87	87	87	87
Related Security Investigations Activity-GH03								
Operating Costs	4.1	4.3	3.1	1.6	1.6	1.6	1.6	1.6
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	4.1	4.3	3.1	1.6	1.6	1.6	1.6	1.6
Direct Personnel	7	15	10	7	7	7	7	7

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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Total Nonproliferation & National Security								
Operating Costs	69.0	65.0	83.3	84.4	84.4	84.4	84.4	84.4
Capital Equipment	4.3	5.2	3.3	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	73.3	70.2	86.6	87.8	87.8	87.8	87.8	87.8
Direct Personnel	232	206	276	282	282	282	282	282

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-7. Fissile Materials Disposition detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Storage and Disposition Options-GA01								
Operating Costs	8.6	7.5	10.5	10.8	10.8	10.8	10.8	10.8
Capital Equipment	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.6	8.5	11.5	11.8	11.8	11.8	11.8	11.8
Direct Personnel	34	26	40	40	40	40	40	40

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-8. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Biological and Environmental Res-KP00								
Operating Costs	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	1.1	0.8	0.9	0.9	0.9	0.9	0.9
Total Cost/Funding	0.0	1.1	0.8	0.9	0.9	0.9	0.9	0.9
Direct Personnel	0	0	0	0	0	0	0	0
Analytical Technology KP01								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Environmental Research-KP02								
Operating Costs	0.4	0.6	0.5	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	0.4	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1	3	3	3	3	3	3	3
Health Effects-KP03								
Operating Costs	1.0	0.5	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	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.0	0.5	0.7	0.5	0.5	0.5	0.5	0.5
Direct Personnel	4	2	7	13	13	13	13	13
General Life Sciences-KP04								
Operating Costs	12.0	11.4	11.6	11.3	11.3	11.3	11.3	11.3
Capital Equipment	1.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Construction	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	14.6	12.4	12.6	12.3	12.3	12.3	12.3	12.3
Direct Personnel	56	57	55	58	58	58	58	58
Carbon Dioxide Research-KP05								
Operating Costs	6.1	5.7	5.6	5.6	5.6	5.6	5.6	5.6
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	6.1	5.8	5.7	5.7	5.7	5.7	5.7	5.7
Direct Personnel	28	27	17	19	19	19	19	19
Magnetic Fusion-AT00								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	1.1	1.1	1.1	1.1	1.1
Total Cost/Funding	0.3	0.0	0.0	1.1	1.1	1.1	1.1	1.1
Direct Personnel	1	0	0	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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Applied Plasma Physics-AT05								
Operating Costs	11.9	9.3	6.5	7.2	7.2	7.2	7.2	7.2
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	11.9	9.3	6.5	7.2	7.2	7.2	7.2	7.2
Direct Personnel	40	35	24	24	24	24	24	24
Confinement Systems-AT10								
Operating Costs	4.7	3.2	3.8	3.6	3.6	3.6	3.6	3.6
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	4.7	3.2	3.8	3.6	3.6	3.6	3.6	3.6
Direct Personnel	10	12	12	18	18	18	18	18
Development and Technology-AT15								
Operating Costs	6.4	3.3	5.4	5.8	5.8	5.8	5.8	5.8
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	6.4	3.3	5.4	5.8	5.8	5.8	5.8	5.8
Direct Personnel	20	13	14	16	16	16	16	16
Inertial Fusion Energy-AT25								
Operating Costs	1.4	1.8	2.2	4.5	4.5	4.5	4.5	4.5
Capital Equipment	0.0	0.1	0.1	0.4	0.4	0.4	0.4	0.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.4	1.9	2.3	4.9	4.9	4.9	4.9	4.9
Direct Personnel	3	7	7	8	8	8	8	8
Materials Sciences-KC02								
Operating Costs	3.0	3.2	3.7	4.3	4.3	4.3	4.3	4.3
Capital Equipment	0.0	0.2	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	3.0	3.4	3.9	4.7	4.7	4.7	4.7	4.7
Direct Personnel	2	13	13	17	17	17	17	17
Chemical Sciences-KC03								
Operating Costs	0.4	0.3	2.0	0.8	0.8	0.8	0.8	0.8
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	0.4	0.3	2.1	0.8	0.8	0.8	0.8	0.8
Direct Personnel	0	0	4	3	3	3	3	3

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-8, continued. Energy Research detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Engineering and Geosciences-KC04								
Operating Costs	1.5	1.9	3.0	3.4	3.4	3.4	3.4	3.4
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	1.5	2.0	3.1	3.5	3.5	3.5	3.5	3.5
Direct Personnel	1	7	10	16	16	16	16	16
Advanced Energy Projects-KC05								
Operating Costs	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	3	0	0	0	0	0	0
Applied Mathematical Sciences-KC07								
Operating Costs	28.7	9.2	1.0	1.1	1.1	1.1	1.1	1.1
Capital Equipment	2.7	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	31.4	9.2	1.0	1.1	1.1	1.1	1.1	1.1
Direct Personnel	45	15	5	5	5	5	5	5
High Energy Physics-KA00								
Operating Costs	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	8.0	6.0	1.2	1.2	1.2	1.2	1.2
Total Cost/Funding	0.0	8.0	6.0	1.2	1.2	1.2	1.2	1.2
Direct Personnel	0	47	32	11	11	11	11	1
Facility Operations-KA02								
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.9	0.7	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	0.1	0.9	0.7	0.2	0.2	0.2	0.2	0.2
Direct Personnel	1	0	0	0	0	0	0	0
High Energy Technology-KA03								
Operating Costs	1.0	0.5	0.5	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	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	6.6	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Direct Personnel	1	4	4	4	4	4	4	4
Medium Energy Physics-KB01								
Operating Costs	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	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	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1	0	0	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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Heavy Ion Physics-KB02								
Operating Costs	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
Direct Personnel	1	2	3	3	3	3	3	3
Nuclear Theory-KB03								
Operating Costs	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
Direct Personnel	1	0	0	0	0	0	0	0
Low Energy Physics-KB04								
Operating Costs	0.3	0.3	0.5	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	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1	4	4	4	4	4	4	4
Total Energy Research								
Operating Costs	81.0	52.2	47.3	50.1	50.1	50.1	50.1	50.1
Capital Equipment	4.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3
Construction	6.8	9.1	6.8	3.2	3.2	3.2	3.2	3.2
Total Cost/Funding	92.2	63.7	56.5	55.6	55.6	55.6	55.6	55.6
Direct Personnel	216	252	213	221	221	221	221	221

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Corrective Activities (Defense)-EW11								
Operating Costs	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	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0	0
Environmental Restoration-EW20								
Operating Costs	24.9	23.5	21.6	19.3	19.3	19.3	19.3	19.3
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	24.9	23.5	21.6	19.3	19.3	19.3	19.3	19.3
Direct Personnel	98	90	81	72	72	72	72	72
Waste Management (Defense)-EW31								
Operating Costs	29.5	29.7	34.6	33.3	33.3	33.3	33.3	33.3
Capital Equipment	7.5	8.6	8.9	6.0	6.0	6.0	6.0	6.0
Construction	0.0	16.1	11.5	12.9	12.9	12.9	12.9	12.9
Total Cost/Funding	37.0	54.4	55.0	52.2	52.2	52.2	52.2	52.2
Direct Personnel	118	154	181	163	163	163	163	163
Technology Development-EW40								
Operating Costs	6.5	4.3	4.9	4.2	4.2	4.2	4.2	4.2
Capital Equipment	0.6	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Construction	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.9	4.5	5.2	4.5	4.5	4.5	4.5	4.5
Direct Personnel	26	17	18	16	16	16	16	16
Program Dir Def(ense) Nonenv Advise Comm-EW60								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Facility Transition & Management-EW70								
Operating Costs	0.3	0.1	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	0.3	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	1	0	2	1	1	1	1	1

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 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Total Environmental Restoration and Waste Management								
Operating Costs	61.5	57.6	61.5	57.2	57.2	57.2	57.2	57.2
Capital Equipment	8.1	8.8	9.2	6.3	6.3	6.3	6.3	6.3
Construction	6.8	16.1	11.5	12.9	12.9	12.9	12.9	12.9
Total Cost/Funding	76.4	82.5	82.2	76.4	76.4	76.4	76.4	76.4
Direct Personnel	244	261	282	252	252	252	252	252

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-10. Environment, Safety, and Health detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Environment, Safety and Health-HA01								
Operating Costs	4.3	2.2	3.1	2.8	2.8	2.8	2.8	2.8
Capital Equipment	0.0	0.0	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	4.3	2.2	3.3	3.0	3.0	3.0	3.0	3.0
Direct Personnel	18	8	8	5	5	5	5	5
Nuclear Safety Policy Contractor Support-HP01								
Operating Costs	0.7	0.7	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	2	2	2	2	2	2	2	2
Office of Security Evaluations-HS01								
Operating Costs	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
Direct Personnel	1	3	2	2	2	2	2	2
Emergency Management Program-NS02								
Operating Costs	0.0	0.3	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	0.0	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	0.0	1	1	1	1	1	1	1
Marshall Island Program-HR0115								
Operating Costs	2.1	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Capital Equipment	0.2	0.0	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	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4
Direct Personnel	9	7	7	7	7	7	7	7
Total Environmental Safety & Health								
Operating Costs	8.4	6.7	8.0	7.7	7.7	7.7	7.7	7.7
Capital Equipment	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.6	6.7	8.3	8.0	8.0	8.0	8.0	8.0
Direct Personnel	30	21	20	17	17	17	17	17

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-11. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Light Water Reactors-AF1210								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Naval Reactors Development-AJ05								
Operating Costs	0.3	0.3	0.3	0.3	0.3	0.3	0.3	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	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0	0	0	0	0	0	0	0
Highly Enrich Uran Eqp Shut & Inv Dis-CD1004								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.3	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
Direct Personnel	1	1	0	0	0	0	0	0
Nuclear Safety CD1006								
Operating Costs	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
Direct Personnel	1	0	0	0	0	0	0	0
Maint of Leased & Non-Leased Fac-CD1007								
Operating Costs	0.0	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	0.0	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0	1	1	1	1	1	1	1
Atomic Vapor Laser Isotope Separation-CD1008								
Operating Costs	0.8	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	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	1	1	0	0	0	0	0

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-11, continued. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Technology Partnerships-CD1009								
Operating Costs	0.5	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.5	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	2	0	1	1	1	1	1	1
Program Management Services-CD1012								
Operating Costs	2.0	1.0	1.3	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	2.0	1.0	1.3	1.1	1.1	1.1	1.1	1.1
Direct Personnel	3	4	3	3	3	3	3	3
Transparency Measures-CD1013								
Operating Costs	3.2	3.2	7.0	7.0	7.0	7.0	7.0	7.0
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	3.2	3.3	7.1	7.1	7.1	7.1	7.1	7.1
Direct Personnel	10	8	16	16	16	16	16	16
Depleted Uran Hexaflour Cyl & Mntc-CD1015								
Operating Costs	2.5	2.2	2.3	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	2.5	2.2	2.3	2.0	2.0	2.0	2.0	2.0
Direct Personnel	8	7	5	4	4	4	4	4
Total Nuclear Energy								
Operating Costs	9.7	7.0	11.4	10.9	10.9	10.9	10.9	10.9
Capital Equipment	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	11.8	7.1	11.5	11.0	11.0	11.0	11.0	11.0
Direct Personnel	27	22	26	24	24	24	24	24

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-12. Fossil Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Advanced Research and Technology Develop-AA15								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Natural Gas Research-AB05								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Oil Technology-AC10								
Operating Costs	2.3	1.6	3.9	3.9	3.9	3.9	3.9	3.9
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	2.3	1.6	3.9	3.9	3.9	3.9	3.9	3.9
Direct Personnel	6	4	10	10	10	10	10	10
Naval Petroleum Reserves Nos 1 & 2-CB01								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Total Fossil Energy								
Operating Costs	2.7	1.7	3.9	3.9	3.9	3.9	3.9	3.9
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	2.7	1.7	3.9	3.9	3.9	3.9	3.9	3.9
Direct Personnel	6	4	10	10	10	10	10	10

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-13. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Systems and Materials Research-AK06								
Operating Costs	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
Direct Personnel	1	0	0	0	0	0	0	0
Geothermal Technology Development-AM10								
Operating Costs	0.0	1.0	0.8	0.9	0.9	0.9	0.9	0.9
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	1.1	0.9	1.0	1.0	1.0	1.0	1.0
Direct Personnel	0	3	1	1	1	1	1	1
Hydrogen Research-AR00								
Operating Costs	1.4	1.4	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	1.4	1.4	2.0	2.0	2.0	2.0	2.0	2.0
Direct Personnel	4	4	4	4	4	4	4	4
Process Heating and Cooling-ED21								
Operating Costs	0.2	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	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	0	0	0	0	0	0
Materials & Metals Processing-ED22								
Operating Costs	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
Direct Personnel	0	0	0	0	0	0	0	0
Alternative Fuels Utilization-EE50								
Operating Costs	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
Direct Personnel	0	0	0	1	1	1	1	1
Materials Technology-EE51								
Operating Costs	0.1	0.2	0.4	1.3	1.3	1.3	1.3	1.3
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	0.1	0.3	0.6	1.6	1.6	1.6	1.6	1.6
Direct Personnel	0	1	3	5	5	5	5	5

Table 4.1-13, continued. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Electric & Hybrid Propulsion Development-EE53								
Operating Costs	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.3	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	1	0	0	0	0	0
In-House Energy Management-WB00								
Operating Costs	0.9	0.0	0.1	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	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.2	0.0	0.1	0.5	0.5	0.5	0.5	0.5
Direct Personnel	3	1	2	2	2	2	2	2
Total Energy Efficiency & Renewable Energy								
Operating Costs	3.0	3.2	3.6	4.7	4.7	4.7	4.7	4.7
Capital Equipment	0.0	0.2	0.3	0.4	0.4	0.4	0.4	0.4
Construction	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.3	3.4	3.9	5.1	5.1	5.1	5.1	5.1
Direct Personnel	10	11	11	13	13	13	13	13

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-14. Human Resources and Administration detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Human Resource & Admin-WM10								
Operating Costs	0.7	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.7	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	2	3	3	3	3	3	3	3

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-15. Science Education and Technical Information detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Laboratory Coop Science Ed Center-KT01								
Operating Costs	1.2	0.7	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	1.2	0.7	0.7	0.8	0.8	0.8	0.8	0.8
Direct Personnel	3	3	3	3	3	3	3	3

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

Table 4.1-16. Other DOE detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

	FY 1995 BO	FY 1996 BA	FY 1997[a] BA	FY 1998[a] BA	FY1999[b] BA	FY 2000[b] BA	FY 2001[b] BA	FY2002[b,c] BA
Work for DOE Integrated Contractors								
Operating Costs	42.4	35.6	23.9	20.4	20.4	20.4	20.4	20.4
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	42.4	35.6	23.9	20.4	20.4	20.4	20.4	20.4
Direct Personnel	140	107	67	55	55	55	55	55
Work for Other DOE Installations								
Operating Costs	53.9	52.1	73.2	82.5	82.5	82.5	82.5	82.5
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	53.9	52.1	73.2	82.5	82.5	82.5	82.5	82.5
Direct Personnel	192	156	201	223	223	223	223	223
Total Other DOE								
Operating Costs	96.3	87.7	97.1	102.9	102.9	102.9	102.9	102.9
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	96.3	87.7	97.1	102.9	102.9	102.9	102.9	102.9
Direct Personnel	332	263	268	278	278	278	278	278

[a] 2.7% Escalation FY 1997 and FY 1998.
[b] FY 1999–2002 in constant FY 1998 dollars.
[c] BA includes projected construction beyond FY 2002.

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The following publications are listed here to aid readers in accessing information about the Laboratory's plans and programs. Electronic information about the Laboratory's work may be found with the Laboratory's Home Page at http://www.llnl.gov; specific electronic information may be accessed at the addresses below. Please direct requests for hard copies to Ellen Shorr, Off-Site Requests Coordinator, LLNL, P.O. Box 808, L-658, Livermore, CA 94551; phone 510-422-5820.

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Acronyms 4.3

ACDA	Arms Control & Disarmament Agency
ACET	Alameda Center for Environmental Technology
ACRS	Arms Control and Regional Security
ADaPT	Advanced Design & Production Technologies
AETB	Airborne Experimental Test Bed
AMIP	Atmospheric Model Intercomparison Project
APT	Accelerator Production of Tritium
ARAC	Atmospheric Release Advisory Capability
ARIES	Advanced Recovery & Integrated Extraction System
ARM	Atmospheric Radiation Measurement
ARNet	Acquisition Reform Network
ASAP	Alcohol and 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
Caltrans	California Department of Transportation
CCI	Cost-Cutting Iniative
CCD	charged-coupled device
CDR	Conceptual Design Report
CEA	Commissariat a l'Energie Atomique
CEL-V	Centre d'Etudes de Lameil-Valenton
CEQA	California Environmental Quality Act
CFC	chlorofluorocarbon
CGRO	Compton Gamma Ray Observatory
CIAC	Computer Incident Advisory Capability
CLC	Campus Laboratory Collaborations
CRADAs	cooperative research & development agreements
CSP	Comprehensive Site Plan
CSTC	Computer Security Technology Center
CTBT	Comprehensive Test-Ban Treaty
CWC	Chemical Weapons Convention
DARPA	Defense Advanced Research Projects Agency
DASP	Diversity Action Steering Committee
DBE	small disadvantaged business
DNA	Defense Nuclear Agency
DNA	deoxyribonucleic acid
DoD	Department of Defense
DOE	Department of Energy
DOE/EE	DOE/Energy Efficiency & Renewable Energy
DOE/FE	DOE/Fossil Energy
DOE/OAK	Department of Energy/Oakland
DP	Defense Programs
DS	Defense Sciences
DWTF	Decontamination & Waste Treatment Facility
EAP	Employee Assistance Program
EBIT	Electron Beam Ion Traps
EDAB	Economic Development Advisory Board
EDI	Electronic Data Interchange
EIR	environmental impact report
EIS	environmental impact statement
EM	Environmental Management
EMATT	Energy, Manufacturing, & Transportation Technologies
EPA	Environmental Protection Agency
ES&H	Environmental, Safety, & Health
ESNet	Energy Sciences Network
EUVE	*Extreme Ultraviolet Explorer*
EW	Explosive Waste
EYH	Expanding Your Horizons
FAA	Federal Aviation Agency
FAaRS	Facility Assessment & Ranking System
FBI	Federal Bureau of Investigation
FFB	Fit For Business
FHWA	Federal Highway Administration
FXR	flash x-radiography
GEM	Graduate Degrees for Minorities in Engineering & Science, Inc.
GPIR	ground penetrating imaging radar
GROSCE	Gamma-Ray Optical Counterpart Search Experiment
H4P	High Performance Parallel Processing Project
HA&SA	Hazards Analysis &Safety Assessment
HBCU	Historically Black Colleges & Universities
HEU	highly enriched uranium
HIF	Heavy Ion Fusion
HOME	Help Others More Efficiency
HPSS	High Performance Storage System
HR	Human Resources
HRA	Health Risk Assessment
HVAC	Heating, ventilating & air conditioning
HYDOX	hydride, dehydride, oxide
I/O	input/output
IAEA	International Atomic Energy Agency
ICF	inertial confinement fusion
IFE	inertial fusion energy
IGPP	Institute of Geophysics & Planetary Physics
IP&C	Industrial Partnerships & Commercialization
IPC	Industrial Partnerships & Commercialization
ISCR	Institute for Scientific Computing Research
ITER	International Thermonuclear Experimental Reactor
JCM	Joint Conflict Model
JTS	Joint Tactical Simulations
LANL	Los Alamos National Laboratory

4.3 Acronyms

LBNL	Lawrence Berkeley National Laboratory
LC	Livermore Computing
LDRD	Laboratory Directed Research & Development Program (at LLNL)
LIPS	Laboratory Integrated Prioritization System
LLNL	Lawrence Livermore National Laboratory
MFE	Magnetic Fusion Energy
MIR	Micropower Impulse Radar
MOLE	Mobile Optical Lair Explorer
MOU	Memorandum of Understanding
MPC&A	material protection, control, & accountability
MPPs	massively parallel processing
MRI	Mutual Reciprocal Inspections
MSW	municipal solid waste
MWMF	Mixed Waste Management Facility
NAI	Nonproliferation, Arms Control, & International Security
NAPL	nonaqueous phase liquid
NASA	National Aeronautical & Space Administration
NEPA	National Environmental Policy Act
NESP	National Education Supercomputer Program
NEST	Nuclear Emergency Search Team
NIF	National Ignition Facility
NIH	National Institutes of Health
NIS	Newly Independent States
NIS	New Independent States
NLC	Next Linear Collider
NOAA	National Oceanographic Atmospheric Administration
NOD	Notice of Deficiency
NO_x	neutrons oxide
NPDES	National Pollutant Discharge Elimination System
NPSC	National Physical Science Consortium
NPT	Non-Proliferation Treaty
NRC	Nuclear Regulatory Commission
NSSC	Nuclear Systems Safety Center
NTS	Nevada Test Site
OFCCP	Office of Federal Contract Compliance Program
OHER	Office of Health & Environmental Research
OPC	Other Project Cost
ORR	Operational Readiness Review
OSHA	Occupational Safety & Health Administration
OSIA	On-Site Inspection Agency
PAH	polycyclic aromatic hydrocarbons
PAO	Public Affairs Office
PCMDI	Program for Climate Model Diagnosis & Intercomparison
PCR	polymerase chain reaction
PDSIP	Process Development & Surveillance Implementation Plan
PDSP	Process Development & Surveillance Program
PEIS	Programmatic Environmental Impact Statement
PETE	Partnerships for Environmental Technology Education
PRISM	Property Information System
QED	quantum electrodynamics
R&D	Research & Development
RAP	Radiological Assistance Program
RCRA	Resource Conservation & Recovery Act
RED	Recruiting & Employment
Sandia	Sandia National Laboratories
SAR	synthetic aperture radar
SBE	small business
SBS	stimulated Brillouin scattering
SDDB	Stockpile Dismantlement Database
SDP	Site Development Plan
SERDP	Strategic Environmental Research & Development Program
SLAC	Stanford Linear Accelerator Center
SMPs	symmetric multiprocessors
SNM	special nuclear material
SRS	stimulated Raman scattering
SSDS	Secure Software Distribution System
SSM	Stockpile Stewardship & Management
START	Strategic Arms Reduction Treaty
STJ	superconducting tunnel junction
TCE	trichlorethylene
TEAM	Technologies Enabling Agile Manufacturing
TICAS	Tactical Imaging Constellation Architecture Study
TID	Technical Information Department
TISP	Technology Information Systems Program
TOWER	Lab Technology Resource Center
TPC	Total Project Cost
TPX	Tokamak Physics Experiment
TRADE	Training and Resources Data Exchange
TTI	Technology Transfer Initiatives
UC	University of California
UCOTT	UC Office of Technology Transfer
USEC	U.S. Enrichment Corporation
UV	ultraviolet
VA	Veterans Administration
VSIP	Voluntary Separation Insentive Plan
VOC	volatile organic compound
WAC	waste-acceptance criteria
WBE	small women-owned business
WCP	Waste Certification Program
WMD	weapons of mass destruction

Index 4.4

A

academia 13
Accelerated Strategic Computing Initiative (ASCI) 18, 25, 26, 29, 33, 34, 44, 45, 56
Accelerator Production of Tritium 29
accelerator mass spectrometry 98
accessibility 40
actinide chemistry 30
administrative information systems 39, 135
Advanced Design and Production Technologies (ADaPT) 18, 25, 26, 45, 60
Advanced Hydrotest Facility 58
advanced conventional defense 10, 20, 89
advanced energy projects 74
advanced fusion assessment 69
advanced laser materials-processing 46
advanced materials 90
advanced recovery and integrated extraction system 61
advanced sensors 9
advanced vehicles 24
advanced waste treatment 25
aerocapacitors 101
aerogels 26, 27, 30, 81, 86, 101
Affirmative Action Plan 123, 124
agile manufacturing practices 46
air emission standards 128
Air Force 89, 91
Airborne Experimental Test Bed 86
Alameda Center for Environmental Technology (ACET) 137
Alameda County Economic Development Advisory Board 137
Alameda Naval Air Station FastTrack Project 90
Albuquerque Operations Office 83
all-optical network testbed 101
alternating gradient synchrotron 70
alternative and advanced energy programs 24
American Indian Program 110
American Petroleum Institute 80
analytical chemistry 30
archeology 141
Argentina 64
Argonne National Laboratory (ANL) 72
Argus security system 83, 89
Arms Control and Disarmament Agency 19, 66, 93
arms control 18
Army 89, 90
Assessments of the Potential of Energy Technologies 82
Assistant Secretary for Defense Programs 43, 53, 143
Assistant Secretary for Energy Efficiency and Renewable Energy 49, 79
Assistant Secretary for Environment, Safety, and Health 77
Assistant Secretary for Environmental Restoration and Waste Management 74
Assistant Secretary for Fossil Energy 79
Assistant Secretary for Human Resources and Administration 82
Assistant Secretary for Policy and International Programs 82
Assistant Secretary of Defense for Atomic Energy 85
Associated Western Universities 109
assurance 113
atmospheric measurement 72
Atmospheric Model Intercomparison Project (AMIP) 106
Atmospheric Release Advisory Capability (ARAC) 86
atmospheric and geologic test 54
atmospheric boundary layer 24
Atomic Energy Act of 1954 20
Atomic Vapor Laser Isotope Separation (AVLIS) 11, 23, 97, 98
audit and oversight 113
Australia 98

B

B-factory 70
Ballistic Missile Defense Organization (BMDO) 88
basic energy sciences (BES) 27, 34, 73, 74
battery technology 27, 74
Bay Area Economic Forum 137
Bay Area Regional Technology Alliance (BARTA) 137
Beckman Laser Institute and Medical Clinic 100
Belarus 77
Big Explosives Experimental Facility 58
bioinstrumentation 12
biology 27, 141
biomedical sciences 5, 6, 9, 11, 27, 105
bioremediation 146
biosciences 5, 6, 27
biotechnology 11
biotechnology 27, 28, 107
biotechnology and health 27
bridge deck inspection 95
brokering 120
Brookhaven National Laboratory (BNL) 46, 72
Brown and Caldwell Inc 75
buckyballs 103
budget, finance, and resource information and analysis 114
building renovations 146
buried interfaces 27
business affirmative action and vendor assessments 115
business goals 14

C

California 76, 79, 129
California Clean Air Act of 1987 128
California Department of Toxic Substance Control 76, 98
California Department of Transportation (Caltrans) 95
California State Historic Preservation Officer 141
California State Water Resources Control Board 129
Caltrans 95
Campus–Laboratory Collaborations 34
Canada 98
Cape Canaveral 75
carbon-aerogel-based supercapacitors 24
carcinogens 96
Career Center 119
carpal tunnel syndrome 48
Case Western Reserve University 101
case management 133
casting 61
cathodes 88
Center for Accelerator Mass Spectrometry 98
Center for Advanced Manufacturing and Productivity 110
Center for Healthcare Technologies 48, 72, 102
Center for Microelectronics and Optoelectronics 101
Centre d'Etudes de Limeil-Valenton 59
ceramics 73
CHEETAH 90
Chemical Weapons Convention (CWC) 65, 66
chemical carcinogens 97
chemical engineering 30
chemical kinetic modeling of hydrogen applications 81
chemical kinetics 73

chemical tracking 130
chemistry 27, 30, 73
chemistry and materials science 30
Chernobyl 77
chief information officer 40
chromosome 19 47, 71
Cincinnati Milacron 101
classified core contraction plan 116, 141
Clean Air Act 81
cleanup 75, 76, 103
Clementine 2 88, 107
climate 24
climate and atmospheric sciences 72
climate modeling 93, 106
Cold War 20
collaborations 13, 29, 30, 32, 33, 34, 68, 101, 103, 104, 105, 146
Columbia University 101
commercialization 24, 137
Commissariat a l'Energie Atomique 59
communication networks 32
communications 32
community involvement 137
compensation 120
composite materials 98
Comprehensive Site Plan 141
Comprehensive Test Ban Treaty (CTBT) 65
Compton Gamma Ray Observatory (CGRO) satellite 95
computational mechanics 31
computations 27, 32
computations and modeling 56
Computer Incident Advisory Capability (CIAC) 82
computer modeling 27
computer networking 31
computer security 66
computer simulation 9
computer systems security 74
computing 101, 105
conceptual design report (CDR) 43
condensed matter 29
Conference on Disarmament 65
conflict simulation 63, 86
construction 143
Contained Firing Facility 43, 143
Contract 48 38, 115
contract administration 114
control of nuclear material 65
cooperative research and development agreement (CRADA) 33, 34, 99, 110
core competencies 29, 35, 54
core values 5
corrective actions 131
cost-cutting initiative 36, 119
councils 17
counterproliferation 53, 85
Cray Research 57, 100
curriculum improvement 106

D

dark matter 103, 105
education outreach 109
DEC 57
Decontamination and Waste Treatment Facility (DWTF) 76
deepwater technologies 26
Defense Advanced Research Projects Agency (DARPA) 87, 89
Defense Conversion Workshops 93
Defense Nuclear Agency (DNA) 85, 89
Defense Programs (DP) 17, 18, 26, 35, 43, 44, 46, 53, 56, 58, 100, 106, 107
defense technology 62
demilitarization 63
demilitarization for molten-salt destruction 90
Denmark 98
Department of Applied Science Student Employer Program 104
Department of Defense (DoD) 6, 14, 21, 62, 63, 85
Department of Energy (DOE) 12, 13, 14, 33, 37, 43, 44, 53, 55, 59, 66, 93, 99, 102, 113, 114, 116, 127, 130, 110
Department of Justice 19
Department of Labor 123
Department of the Air Force 89, 91
Department of the Army 89, 90
Department of the Navy 62, 89, 90
Department of Transportation 14, 131
Deputy Assistant Secretary for Military Applications 64
Deputy Assistant Secretary for Nuclear Facility Safety 78
Deputy Assistant Secretary for Safety and Quality Assurance 78
desalinization 103
detecting and monitoring nuclear weapon activities 64
diamond cold cathode technology 87
diamond-turned optics 88
digital mammography 48
DIII-D tokamak 21, 22, 68
disarmament 66
disassembly 61
disease susceptibility 12
dismantlement 10, 20, 53, 61, 64
dismantlement and long-term storage 61
disposition of fissile material 67
distributed control systems 31
diversity 29, 36, 37, 38, 109, 121, 125, 126
Diversity Action Steering Committee 36
diversity and affirmative action 121
DNA 12, 28, 47, 71, 87, 96, 97, 146
DOE Field Offices 83
DOE Human Genome Centers 71
DOE Office of Civilian Radioactive Waste Management 96
DOE Technology Development 77
DOE Threat Credibility Assessment Program 64
DOE/Albuquerque 60
DOE/Oakland Office 41, 136
dosimetry 24
dual revalidation 17
DYNA3D 60, 101

E

East Bay Conversion and Reinvestment Commission 137
ecology 141
economic development 137
economic impact 141
ecosystem management 141
educational technology 109
electric power 22
electric power generation 58
electromagnetics 31
electromechanical batteries 24, 26
electron beam ion trap (EBIT) 26, 56, 73, 105
electron-beam melting of uranium alloys 60
electronic commerce 91, 93
electronic data interchange 117
electronic security systems 66, 83
electronics 31
Emergency Management Center 137
emergency preparedness 64
emergency response 19, 62, 64
emissions 26
Employee Services Association 121
employee assistance 133
employee wellness and fitness 120
Energetic Materials Center 105
energetic materials 30, 62, 105
energy 11, 17, 22, 25, 26, 69
energy and environmental science 6, 10
energy and environmental systems 5, 21, 26

energy efficiency and renewable energy 27
energy security 24
energy storage 81
energy storage devices 26
energy systems 24
energy technologies 82
Energy, Manufacturing, and Transportation Technology (EMATT) 25, 26, 101
Engineering Test Facility 22
engineering 31
England 14
enhanced stockpile surveillance 54, 60
environment 11, 28, 38
Environmental Protection Agency (EPA) 14, 25, 75, 93, 101, 129, 130
Environmental Quality Act 127
environmental and waste management 131, 132
environmental cleanup 25
environmental monitoring 107
environmental programs 24
environmental protection 77
environmental remediation 11
environmental research 25
environmental restoration 74
environmental training 131
environmental, safety, and health (ES&H) 14, 38, 40, 62, 127, 132, 141
equal employment opportunity 121
ergonomics 133
ETA-II 58
Europe 49, 67, 68
excellence 30
Expanding Your Horizons 109
explosive waste storage facility 76
extreme ultraviolet explorer 94

F

facilities 40, 57, 62
facilities maintenance 141
facilities plans and options 141
facilities resource requirements 143
Facility Assessment and Ranking System (FAaRS) 41, 143
facility construction 141
Federal Aviation Agency (FAA) 95
Federal Facility Agreement 76
Federal Highway Administration (FHWA) 95
Federal Laboratory Consortium 102
Federal Radiological Management Assessment Center 64
Fermi National Accelerator Laboratory 70, 105
Fissile Material Cutoff Treaty, 65
fissile materials 67
fission energy and systems safety 22
Fit For Business 120
flash x-radiography (FXR) 43, 57, 58
flat-panel display technology 87, 101
flywheel battery 102
forensic analysis 65
former Soviet Union 20, 78, 105
fossil energy 79
fossil fuels 24, 49
fracture permeability 73
France 14, 59
fuel cells 49, 81
Fun With Science 109
fusion 11, 68, 69, 143
fusion plasmas 22

G

gamma-ray camera 57
gamma-ray optical counterpart search experiment 95
GAMMASPHERE 70
General Atomic Inc. 21, 68, 69
General Motors 102
genome 146
Genomics and Structural Biology Research Facility 47, 146
genomics 12, 71
geochemistry 24
geology 141
geophysics 24
geosciences 27, 73
geothermal energy 24
global concerns 107
global security 107
groundwater 75

H

Harvard–Smithsonian 95
hazardous waste 129
health 9, 28, 71, 72, 133
health-care technology 12
heavy-ion fusion 69
Herculis 94
Hewlett Packard 102
high-energy and nuclear physics 70
high-energy-density physics 54
high explosives 46, 90
High Explosives Application Facility (HEAF) 46, 57, 105
high performance parallel processing 57, 100
high performance storage system 32, 56
high-power radiofrequency countermeasure 89
highway design 95
Historically Black Colleges and Universities (HBCU) 124
HOME campaign 137
Hughes 101
human factors in security 95
Human Genome Project 28, 32, 47
human resources 37, 119
hybrid-electric vehicle 26, 81
HYDOX 67
hydrocarbon combustion modeling 81
hydrocarbon fuels 27, 73
hydrodynamic test facilities 54, 57
hydrodynamics 18, 29, 56, 63
hydrogen 24, 48, 80, 81
hydrogen-powered vehicles 24
hydrogen production 80
hydrogen storage in engineered microspheres 81

I

IBM 56, 77
Idaho National Engineering Laboratory 83
image processing 31, 48, 105
India 63
induction Linac systems experiment 22
industrial consortium 87
industrial hygiene 132
industrial partnering 59, 65, 99, 100, 103
industrial partnering and commercialization (IPC) 33, 34
industrial safety 132
industry 13, 33, 53,
inertial confinement fusion (ICF) 22, 43, 58, 143
inertial fusion energy (IFE) 22, 58, 69, 70
information archive 136
information storage 32
information technology 31, 96, 120
information to employees and the public 136
infrastructure 54
Institute for Nuclear Research, Moscow 105
Institute of Geophysics and Planetary Physics (IGPP) 104
Institutional Business Council 135
Institutional Collaborative Research Program 106
Intel 102
intelligence agencies 19
intelligence assessments 63
International Atomic Energy Agency (IAEA) 64, 65

International Thermonuclear Experimental Reactor (ITER) 22, 68, 69
international security 18
ion beam sciences 24
Iraq 64
isotope sciences 30
Italy 98

J

Janus laser 56
Japan 49, 67, 68, 94, 98
Joint Chiefs of Staff 86
joint conflict model 86
joint tactical simulations 86

K

Kara Sea/Russian Naval Waste Assessment 91
Kazakhstan 63
Key Decision One 43
Korea 98

L

Laboratory Directed Research and Development (LDRD) 17, 28, 29, 34, 47, 48, 102, 103
Laboratory for Experimental Astrophysics (LEA) 105
laboratory integrated prioritization system 62
LAM Research 102
large optics diamond turning machine 88
laser 22, 43, 54, 55, 58, 73, 90, 110, 102
laser guide star 98
laser megajoule project 59
laser radar 90
laser welding 60
lasers and electro-optics 7
Lawrence Berkeley National Laboratory (LBNL) 22, 69, 70, 72, 90 105
Library of the Future 39, 135
licenses 137
LINAC 46
Livermore Center for Microelectronics and Optoelectronics 88
Livermore computing 56
Livermore site 139
Livermore User Facility for Inspection and Characterization 110
long-term storage 61
Los Alamos National Laboratory (LANL) 17, 19, 22, 35, 45, 46, 56, 57, 59, 61, 62, 65, 66, 72, 100, 105, 106
low-temperature solid oxide fuel cell 81

M

magnetic fusion energy (MFE) 21, 69
magnetic properties 27
magnetic storage 101
maintenance and operations 141
mammalian and microbial genomes 47
man-portable land-mine detector 89
management practices 14, 39
manufacturing 25, 26, 60, 101
manufacturing technology 9
Marshall Islands 77
Massachusetts Institute of Technology (MIT) 105
massively parallel computers 32, 72, 100
massively parallel processing 56
materials 26, 27, 29, 30, 54, 63, 80
materials characterization 30
materials chemistry 73
materials sciences 73
materials theory 30
mathematical models 79
Mayak Complex 78
medicine 28
mentors 36
Metal Finishers Association 101
metallurgy 30, 73
Mexico 98
microfabrication 31, 87
microminiaturization 31
micropower impulse radar (MIR) 13, 89, 95
microspheres 81
minimum-waste processes 46
minorities 123
minorities and women 38
mission 5
modeling 22, 24, 26, 29, 32, 44, 55, 72, 73, 80, 101, 102
modular armor 90
Morocco 64
multidisciplinary 7, 29, 64
multilayers 30, 81
municipal solid waste (MSW) 80
mutagens 96
mutual reciprocal inspections 65

N

nanostructure 26, 27, 30
National Aeronautical and Space Administration (NASA) 14, 25, 75, 93, 94
National Atmospheric Release Advisory Capability 11, 62
National Defense Authorization Act 119
National Education Supercomputer Program (NESP) 109
National Environmental Policy Act (NEPA) 127, 132
National Ignition Facility (NIF) 18, 22, 29, 31, 32, 34, 43, 54, 55, 58, 70, 104, 143
National Information Infrastructure 60
National Institutes of Health (NIH) 13, 71, 96, 97
National Oceanographic Atmospheric Administration 25
National Performance Review 115
National Petroleum Refinery Association 80
National Priorities List 75, 76
national security 5, 6, 9, 17, 19, 20, 53
National Storage Laboratory 32
National Test Facility 89
National Transparent Optical Networking Consortium 101
Natural Gas and Oil Technology Partnership 26
natural phenomena hazards policy and standards 78
Navajo Community College 110
naval research 90
Navy 62, 89, 90
network security 82
networks 96, 101
neural network 86
Nevada Operations Office 76
Nevada Test Site 58, 77, 116, 131, 132
Newly Independent States 14, 19, 65
News-on-Line 136
Newsline 136
Next Linear Collider 70
night-ellipse project: backlash 91
non-nuclear tests 55
Non-Proliferation Treaty 63
nondestructive evaluation 31, 101
nondestructive test 54
nonhazardous wastes 77
nonproliferation 6, 10, 18, 53, 105
nonproliferation, arms control, and international security 18
North American Free Trade Agreement 14
Northern Telecom 101
Northridge, California, earthquake 73
Nova 54, 56, 58, 59, 70
novel materials 30
nuclear criticality safety 83
Nuclear Emergency Search Team (NEST) 64, 65, 133

nuclear materials 10
nuclear physics 70
nuclear power 22
Nuclear Regulatory Commission (NRC) 23, 62, 79, 96, 97
nuclear safety 62, 78
nuclear science and technology 7, 29
nuclear smuggling 64
nuclear stockpile 17
Nuclear Systems Safety Center (NSSC) 96
nuclear waste repository 23
nuclear weapon 17, 18, 44, 53, 59
numerical simulation 54

O

Oak Ridge Field Office 83
Oak Ridge National Laboratory (ORNL) 68
Oakland Operations Office 114
Office of Civilian Radioactive Waste Management 78
Office of Emergency Operations 64
Office of Energy Research 47, 49, 68, 146
Office of Environmental Management 75
Office of Federal Contract Compliance Programs 123
Office of Fissile Materials Disposition 67
Office of Health and Environmental Research 27, 72
Office of Nonproliferation and National Security 63, 64
Office of Nuclear Energy 78
Office of Nuclear Materials Safety and Safeguards 96
Office of Nuclear Reactor Regulation 96
Office of Nuclear Regulatory Research 96
Office of Nuclear Safety Policy and Standards 78
Office of Personnel Management 66
Office of Research and Development 64
Office of Scientific and Technical Information 136
Office of the Secretary of Defense 85, 89
Office of Uranium Programs 78
oil pollution prevention 129
On-Site Inspection Agency 66
Open Computing Facility 106
operations 36, 130
optical computer interconnects 87
optics 59
optics engineering 31
optimized hydrogen-fueled internal combustion engine 80
optoelectronic device packaging 87
Optoelectronic Technology Consortium 102
Oregon Department of Transportation 95
osteoporosis 103

P

Pacific Bell 101
Pacific Northwest National Laboratory (PNNL) 72
packaging certification and training 78
Pantex Plant 20, 61, 83
Partnering 12, 13, 15, 24, 26, 32, 33, 34, 87, 99, 101, 109, 114
Partnership for a New Generation of Vehicles 102
Partnership for Environmental Education 107
PEREGRINE 72
performance-based contract 114
performance management 120
performance measures 38, 114
Phebus 59
PHENIX 70
Phillips Laboratory's 91
physics 27, 29, 143
physics and space technology 29, 30
pit processing 61
plutonium
pollution prevention 76, 77
polymerase chain reaction 87
Portsmouth Diffusion Plant 83
Power One (and PolyStar) 101
power conversion 31
precision engineering 46
President Clinton 65
Presidential Decision Directive-13 67
ProCard 115
procurement 37, 93
procurement and materiel 115
Program for Climate Model Diagnosis and Intercomparability 72, 106
programmatic environmental impact statement (PEIS) 18, 43, 60, 67, 68
proliferation 18
property information 116
property management 115
proteins 96
Public Affairs Office 136
pulsed power 56

Q

quality 31
quality management 14

R

radar 86
radar-based technology 100
radar ocean imaging 86
radiation 29
radiation effects 59
radiation oncology 72
radiation protection 132
radioactive waste certification 132
radiological assistance program 64
radionuclide emission sources 130
rapid prototyping and multilayer Coating 81
rational device design 48
reactor safety 23
Refinery of the Future 79
Regents of the University of California 130
remediation 25
remediation technology 74
remote monitoring 64
repository 79
research 34
research internships 109
Resource Conservation and Recovery Act 76, 131
resource information 114
resource recovery 82
RESUMIX 119, 120
retired warheads 20
revitalization 140
risk analysis 24
risk-assessment 23
road reconstruction 146
robotic handling systems 77
Rockwell 101
Russia 19, 20, 62, 64, 65, 67, 68, 77, 86, 91

S

safeguards and security 66, 68, 83, 116
safety 38
safety analysis reports 78
safety and health 132
San Jose State University 109
Sandia National Laboratories (SNL) 17, 19, 35, 45, 46, 56, 59, 61, 66, 69, 80, 81, 105, 130
satellite imaging 91
Saturn 59
Savannah River National Laboratories (SRNL) 46, 67, 116
Savannah River Operations Office 83
science and engineering 109, 124

science and mathematics 106
science and technology 7, 28, 103, 107
science-based stockpile stewardship 25, 29, 104
science education 35
scientific computing 32, 33, 68
Secretary of Energy 43
secure communications network 46
Secure Software Distribution System (SSDS) 74
security 40, 66, 74
security systems 83
seismic 24
self-assessment 113
Sematech 102
semiconductor 101
Semiconductor Research Corporation 102
sensitive species protection and management 130
sensor 20, 64
Silicon Video Corp. 102
simulation 44, 100
Site 300 46, 57, 58, 75, 76, 105, 128, 139, 141
Site 300 Contained Firing Facility 143
Site 300 Fire Station/Medical Facility 143
site development Plan 141
site master planning 40
site restoration 75
small business 34, 99, 115
small disadvantaged business 115
small women owned businesses 115
solid oxide fuel cell 81
South Africa 63
space science 29
spectroscopic modeling 94
spent nuclear fuels 96
Stanford Linear Accelerator Center (SLAC) 70
Stanford University 72
START I and II 20
State Department 19
State of California 76, 79, 129
stockpile 17, 18, 20, 44, 53, 59, 61
stockpile stewardship and management 6, 9, 13, 17, 29, 31, 43, 45, 54, 60, 143
stormwater discharges 129
stormwater pollution prevention plans 129
Strategic Command 17
strategic environmental R&D 86
strategic operations 5
strategic science and technology 5
structural biology 47
structure-function analysis 71
student science research associates 107
student support 109
substandard facilities 139, 141
supercapacitors 81
supercomputing 102
superconducting x-ray and UV spectrometers 94
Superfund 131
superplastic 102
surveillance 18, 60
Sweden 98
synchrotron radiation 27, 73
synthetic aperture radar 86
systems engineering 31

T

tactical imaging constellation architecture study 91
target physics 58
teacher certification program 109
teacher enhancement 107
teacher research internship 107
technology 20
Technology Resource Center 109
Technology Transfer Initiatives (TTI) 26
Texaco 80
Texas 79
Texas Instruments 102
The Geysers, California 82
thermoelectric devices 27
TIGER 90
tissue welding 48
tokamak 21, 69
transparency 64
transportation 25, 27, 48, 78, 80
transportation and advanced manufacturing 11
transportation of radioactive materials 83
travel service 117
TRW 89

U

U.S. Enrichment Corporation (USEC) 11, 23, 32, 97
U.S. Marine Corps 89
UC Contract Appendix F 39
Ukraine 63, 77, 96
Ultratech Stepper 102
undergraduate summer institute 109
United Kingdom 86, 98
United Nation's World Climate Research Program 106
university collaborations 34, 104, 105
University of California 14, 35, 37, 98, 101, 104, 105, 113, 114, 116, 132, 137
University of California, Berkeley 90, 105
University of California, Davis 13, 34, 104, 106
University of California, Irvine 106
University of California, San Diego 101
University of California, San Francisco 133
University of Florida 105
University of Rochester 22
university relations 35
UNIX 106
uranium feed preparation 97
uranium handling 78

V

vapor phase manufacturing 87
vehicles 26, 80, 103
Veterans Administration 93
virtual laboratory testbed 110
vision and goals 6
Visitors Center 136
volatile organic compound 75
voluntary separation incentive program 37, 119

W

wall surveyor 90
warhead design technology 90
warhead dismantlement 20
waste certification 131
Waste Isolation Pilot Plant 131
waste management 23, 76, 130, 131
waste minimization 77, 127, 130
waste treatment 77
waste water discharges 129
weapon physics 55, 143
weapons complex 60
weapons of mass destruction 10, 19, 85
wide-area nuclear detection 85
work for others 98
workforce 14, 28, 37, 120, 121
workforce migrations 141
workforce restructuring plan 36
Wright Laboratories 90

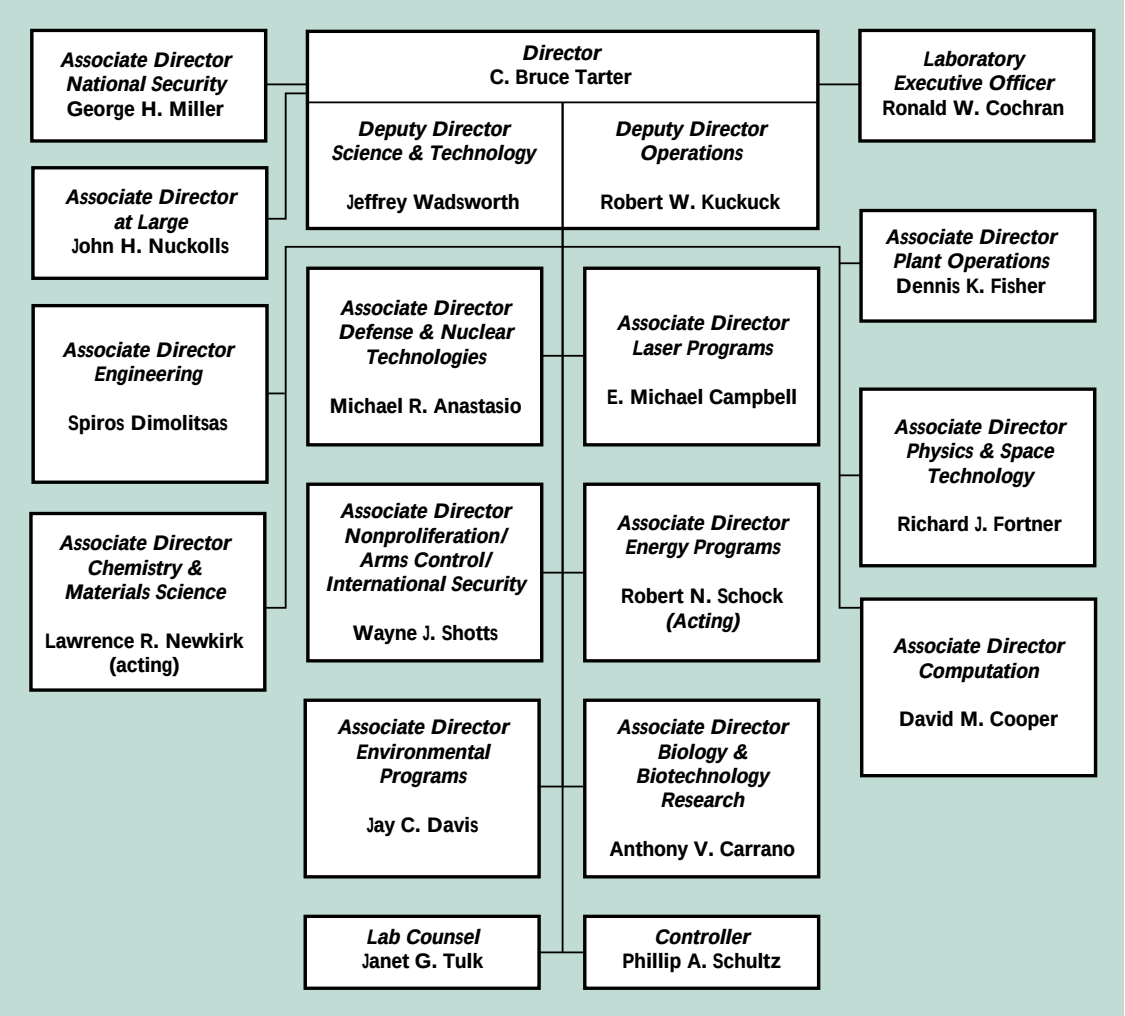
Y

Y-12 116
Yucca Mountain 78
Yucca Mountain Repository 11

Z

zinc/air fuel cell 26, 101
zoology 141

Organization Chart 4.5



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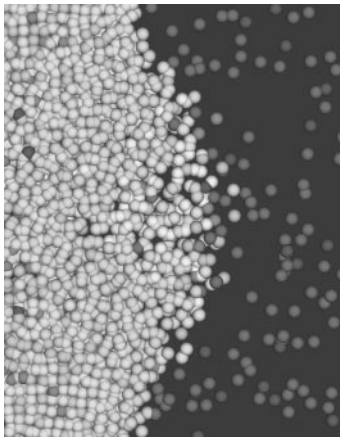

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