LBL-PUB-5422
June 1996

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Institutional Plan
FY 1997–2002

PUB-5422

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 1997–2002

June 1996

Ernest Orlando Lawrence
Berkeley National Laboratory
University of California
Berkeley, California 94720

This plan is available on the World Wide Web at
www.lbl.gov/LBL-Publications/Institutional-Plan/

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

PREFACE

The FY 1997–2002 Institutional Plan provides an overview of the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) mission, strategic plan, core business areas, critical success factors, and the resource requirements to fulfill its mission in support of national needs in fundamental science and technology, energy resources, and environmental quality. Of particular significance this year is the role of computing sciences in supporting a broad range of research activities, at Berkeley Lab in particular and throughout the entire Department of Energy system in general.

The Laboratory Strategic Plan section identifies long-range conditions that will influence the Laboratory, as well as potential research trends and management implications. The Core Business Areas section identifies those initiatives that are potential new research programs representing major long-term opportunities for the Laboratory, and the resources required for their implementation. It also summarizes current programs and potential changes in research program activity, science and technology partnerships, and university and science education. The Critical Success Factors section reviews human resources; work force diversity; environment, safety, and health programs; management practices; site and facility needs; and communications and trust. The Resource Projections are estimates of required budgetary authority for the Laboratory's ongoing research programs.

The Institutional Plan is a management report for integration with the Department of Energy's mission and programs and is an element of Department of Energy 's strategic management planning activities, developed through an annual planning process. The plan identifies technical and administrative directions in the context of the national energy policy and research needs and the Department of Energy's program planning initiatives. Preparation of the plan is coordinated by the Office of Planning and Communications from information contributed by the Laboratory's scientific and support divisions.

TABLE OF CONTENTS

I. DIRECTOR'S STATEMENT

Extending a tradition of 65 years of science leadership for America, the Ernest Orlando Lawrence Berkeley National Laboratory performs forefront research to address major national and global challenges. The Berkeley Lab has maintained its institutional distinction based upon our close partnership with the University of California, the size and scale of our research programs, and our accomplishments in computational, energy, life, and general sciences. Our location provides a rich environment, with an outstanding scientific and engineering staff and with joint faculty appointments, graduate students, and postdoctoral associates. We are proud of our 9 Nobel Laureates and 58 members of the National Academies of Science, Engineering, and Medicine. Our site is ideal for research facilities such as the Advanced Light Source, the National Energy Research Scientific Computing (NERSC) Division, the National Center for Electron Microscopy, the 88-Inch Cyclotron and Gammasphere, and the Human Genome Laboratory, to be completed in the first quarter of next fiscal year (FY 1998).

At this time, the nation is challenged by inadequate understanding of the basis of human diseases, limited materials capabilities, widespread environmental remediation needs, and an incomplete understanding of our universe. The long-term vitality of the nation rests on the depth of its understanding and scientific capability. The Department of Energy (DOE) is deploying its scientific resources — with increasing efficiency and effectiveness, to address the nation's pressing scientific challenges.

Berkeley Lab's Vision 2000, which advances DOE's energy research, efficiency, and environmental missions, began a strategic planning effort to define the Laboratory's major objectives and to provide the Laboratory, its employees, and the Department of Energy with goals and direction for the future. The Laboratory's current planning activities support DOE's Strategic Laboratory Mission's Plan, reaffirm Vision 2000 and places key emphasis on the importance of computing and the Advanced Light Source to the Laboratory's scientific programs. This FY 1997–2002 Institutional Plan describes our research initiatives and the progress toward realizing the vision as a key element of a strategically-managed national laboratory system.

Today, we are applying our fundamental capabilities in computing and computational sciences to new challenges, including the new paradigm of data demands for the future of high energy and nuclear physics, modeling combustion and turbulent systems, understanding quantum chemistry, simulating the energy performance of buildings, and solving the molecular structure of cancer-causing proteins. These capabilities are integral with the Laboratory's scientific divisions and focused through the NERSC, the Energy Sciences Network (ESnet), and Computational Sciences and Engineering Programs.

The Advanced Light Source (ALS) is implementing the DOE Research Facilities Initiative to achieve full utilization and is proceeding to expand on the existing complement of beamlines. With performance exceeding project specifications, the ALS is establishing a record at the forefront of materials research, chemical dynamics, and x-ray science. We have prepared a roadmap for the complete buildout of the ALS that supports DOE's strategic plans. For example, a new x-ray crystallography wiggler has been installed, and the beamline is being completed this year. The Laboratory's structural biology beamline is also adding user capabilities for studies in biological microscopy and spectroscopy. This program combines the capabilities of our Laboratory with university resources to address national needs for instrumentation in macromolecular and subcellular structure determination.

Our advances in genome sequencing hold special promise for improvements in health and new biological understanding. Berkeley Lab's Human Genome Center, delivering the highest levels of sequencing productivity in the world, now supports a partnership with the National Institutes of Health to solve the genetic code of *Drosophila*, a model research organism whose code is undetermined. The information generated at the Human Genome Center has already contributed to the development of improved methods for screening genetic abnormalities, locating cancer genes, and diagnosing solid tumors.

To meet the nation's need for a long-term energy supply, Berkeley Lab continues research at the forefront of inertial confinement fusion science. To this end, we are defining with the research community, the scientific questions that must be addressed for developing heavy-ion accelerators as fusion energy

drivers. Understanding this science opens the prospect for efficient and reliable pellet ignition for civilian power production for the 21st century.

In materials research, the Laboratory is addressing the national need for an effective and definitive molecular basis for materials design. For example, our combinatorial synthesis of materials has demonstrated new classes of materials with colossal magneto resistance, and we have developed atomic wires to precisely-sized nanocrystals, demonstrating quantum-size effects. An upgrade to the National Center for Electron Microscopy that will provide one Angstrom resolution for both static and dynamic studies will provide the U.S. scientists with leadership capabilities in materials research.

Berkeley Lab has maintained its historic strengths in high-energy and nuclear physics, providing leadership for the B Factory at the Stanford Linear Accelerator Center (SLAC) and the STAR detector at the Relativistic Heavy-Ion Collider (RHIC). The Laboratory is helping to design and fabricate key detector and accelerator systems at the Large Hadron Collider in Europe. The 88-Inch Cyclotron continues its leadership as a low-energy nuclear physics accelerator. The Cyclotron hosts the Gammasphere, the world's highest resolution gamma-ray spectrometer, which provides insights into nuclear structure, and offers the prospect of a new gamma-ray spectrometer with 1000 times the resolving power of even the latest generation of detectors.

The Laboratory's geoscience capabilities also position us for leadership in environmental remediation technologies, with research programs in improved subsurface characterization methods, development of predictive models, and risk-assessment methodologies, including the development of techniques to isolate and clean up sites contaminated by radioactive materials and toxic chemical wastes, with an emphasis on bioremediation techniques. We host the Natural and Accelerated Bioremediation Program Office as a service to this critically important DOE national program.

To address the national need for improved energy efficiency, our leadership in advanced building technologies and electrochemical research is being applied to creating computational codes for building design, new lighting systems, and superwindow technology. These advances can restructure the way innovative building systems can be incorporated into residential and commercial designs. We also serve as an international resource for energy efficiency technologies and provide technical assistance on energy supply and demand to developing nations. To improve the detection and recovery of oil and gas, Berkeley Lab also continues to pioneer advances in electromagnetic and seismic methods for imaging subsurface resources.

We have made significant progress on our management goal to deliver the best research support services at the lowest cost. We have achieved a fifteen percent reduction in core administrative overhead costs through the consolidation of administrative departments and staffing and by removing non-value-added work. The administrative savings have lowered overhead and are also being reinvested in necessary maintenance of our research infrastructure. We also have sustained our commitment to the environment and to safety in day-to-day operations. We have established new outreach and retention programs to ensure an ethic that fully respects diversity and encourages excellence through the Office of Work Force Diversity. We have initiated performance-based management in all scientific and management activities, including pilot joint peer reviews of scientific programs in conjunction with DOE.

Our collaborations with universities, other national laboratories, and industry contribute to understanding our world, improving the environment and health, and creating long-term value for the economy. We are setting a scientific agenda for the next ten years that reflects both the critical scientific needs of the nation and the Laboratory's distinctive capabilities that will address those needs.

As Ernest Orlando Lawrence Berkeley National Laboratory charts its course into the 21st century, we will continue to refine our strategic objectives and articulate clearly this institution's strategic contribution to the Department of Energy's missions and its national Laboratory System. Our ultimate goal is to see that our people and our programs continue to serve as unique and valuable resources for the Department of Energy and the nation.

Charles V. Shank
Director

II. THE LABORATORY MISSION

Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multiprogram national research facility operated by the University of California for the Department of Energy (DOE). Its fundamental mission is to provide national scientific leadership and technological innovation to support the DOE's objectives. Berkeley Lab's mission addresses four distinct goals:

- To perform leading multidisciplinary research in the energy sciences, general sciences, and biosciences in a manner that ensures employee and public safety and protection of the environment.
- To develop and operate unique national experimental facilities that are available to qualified investigators: the Advanced Light Source, National Energy Research Scientific Computing Center, Energy Sciences Network (ESnet), National Center for Electron Microscopy, 88-Inch Cyclotron, Biomedical Isotope Facility, and National Tritium Labeling Facility.
- To educate and train future generations of scientists and engineers to promote national science and education goals.
- To transfer knowledge and technological innovations and foster productive relationships among Berkeley Lab research programs, universities, and industry to promote national economic competitiveness.

CORE COMPETENCIES AND FOUNDATIONS

The ability of the Laboratory to advance its mission depends upon its "core competencies." These are an integration of research disciplines, personnel, skills, technologies, and facilities that produces valuable results for our sponsors and customers. The core competencies can be applied to rapidly changing national needs and new research problems while, at the same time, undergoing evolution themselves.

Underlying many of our core competencies in specific technical areas are fundamental capabilities, or "foundations." Berkeley Lab has identified seven core competencies and four foundations as follows.

Core Competencies

- **Bioscience and Biotechnology:** Structural biology; genome research; bioinstrumentation; molecular cytogenetics; medical imaging; biology of human diseases; biomolecular design.
- **Particle and Photon Beams:** Analysis and design of accelerators; beam dynamics; high-brightness ion, electron, and photon sources; advanced magnet design and R&D; high-frequency rf technology; x-ray optics and lithography; induction linacs and neutral beams for fusion energy.
- **Characterization and Synthesis of Materials:** Advanced spectroscopies and microscopies based on photons, electrons, and scanning probes; ceramics; alloys; heterostructures; superconducting, magnetic, and atomically structured materials; bio-organic synthesis.
- **Advanced Technologies for Energy Supply and Energy Efficiency:** Subsurface resources and processes; building technologies; electrochemistry; fossil fuel technologies; energy analysis.
- **Chemical Dynamics, Catalysis, and Surface Science:** Reaction dynamics; photochemistry of molecules and free radicals; surface structures and functions; heterogeneous, homogeneous, and enzymatic catalysis.
- **Advanced Detector Systems:** Major detectors for high-energy physics, nuclear science, and astrophysics; scientific conception and project leadership; advances in particle and photon detection; implementation of new concepts in detector technology.

- **Environmental Assessment and Remediation:** Advanced instrumentation and methods for environmental characterization and monitoring; human health and ecological risk assessment; indoor air quality; subsurface remediation of contaminants; geologic isolation of high-level nuclear waste; actinide chemistry.
- **Computational Science and Engineering:** Computational fluid dynamics; applied mathematics; computational chemical sciences; algorithms for scalable systems; discretization algorithms for partial differential equations; distributed memory; visualization techniques.

Foundations

- **National Research Facilities:** Advanced Light Source; National Energy Research Scientific Computing Division; ESnet; National Center for Electron Microscopy; 88-Inch Cyclotron and Gammasphere; Biomedical Isotope Facility; National Tritium Labeling Facility.
- **Information Management:** High-speed networking and distributed computing, including network congestion studies and remote experiment control; processing and analysis of scientific images; visualization and virtual reality; data-acquisition and analysis systems; mass storage and scientific data management.
- **Engineering Design and Fabrication Technologies:** Custom integrated circuits; integrated accelerator systems; superconducting magnet assemblies; insertion devices for synchrotron radiation; large-volume semiconductor detector technology; laboratory automation; advanced CAD/CAM facilities for large systems; facilities for materials processing and fabrication.
- **Education of Future Scientists and Engineers:** Undergraduate, graduate, postdoctoral, and faculty involvement in scientific and engineering research through close ties with the University of California system; educational programs for elementary schools, high schools, and colleges.

DIVISION STRENGTHS

Berkeley Lab benefits from its close working relationship with the University of California at Berkeley, as well as other universities, laboratories, and industrial institutions. As indicated in the organization chart (p. 2-4), the Laboratory is structured to integrate these relationships with its mission in the most effective way possible. The core research strengths of each of the Berkeley Lab divisions are as follows:

Energy Sciences

- **Chemical Sciences:** Chemical physics and the dynamics of chemical reactions; structure and reactivity of transient species; electron spectroscopy; surface chemistry and catalysis; electrochemistry; chemistry of the actinide elements and their relationship to environmental issues; atomic physics.
- **Earth Sciences:** Structure, composition, and dynamics of the earth's subsurface; geophysical imaging methods; chemical and physical transport in geologic systems; isotopic geochemistry; physicochemical process investigations.
- **Energy and Environment:** Building energy efficiency; environmental effects of technology; energy storage and distribution; fossil-energy conversion; industry, transportation, and utility energy use; national and international energy policy studies.
- **Materials Sciences:** Advanced ceramic, metallic, polymeric, magnetic, biological, and semi- and superconducting materials for catalytic, electronic, optical, magnetic, structural, and specialty applications; exploration of low-dimensional materials; development and use of instrumentation,

including spectroscopies, electron microscopy, x-ray optics, nuclear magnetic resonance, and analytical tools for ultrafast processes and surface analysis.

General Sciences

- **Accelerator and Fusion Research:** Fundamental accelerator physics research; accelerator design and operation; advanced accelerator technology development for high-energy and nuclear physics; accelerator and beam physics research for heavy-ion fusion; beam and plasma tools for materials sciences and engineering; operation of the Advanced Light Source.
- **Nuclear Science:** Relativistic heavy-ion physics; medium- and low-energy nuclear physics; nuclear structure; nuclear theory; nuclear astrophysics; weak interactions; nuclear chemistry; studies of transuranium elements; nuclear-data evaluation; detector development; operation of the 88-Inch Cyclotron.
- **Physics:** Experimental and theoretical particle physics; advanced detector development; particle database for the high-energy physics community; astrophysics; applied mathematics; innovative educational programs for high schools.

Biosciences

- **Life Sciences:** Gene expression; molecular genetics; genome sequencing studies; cellular differentiation and carcinogenesis; hematopoiesis; macromolecular structure; DNA repair; diagnostic and functional imaging; innovative microscopies; radiation biology; animal models of disease.
- **Structural Biology:** Structural and molecular biology of nucleic acids and proteins; genetics and mechanisms of photosynthesis; photochemistry; computational biology.

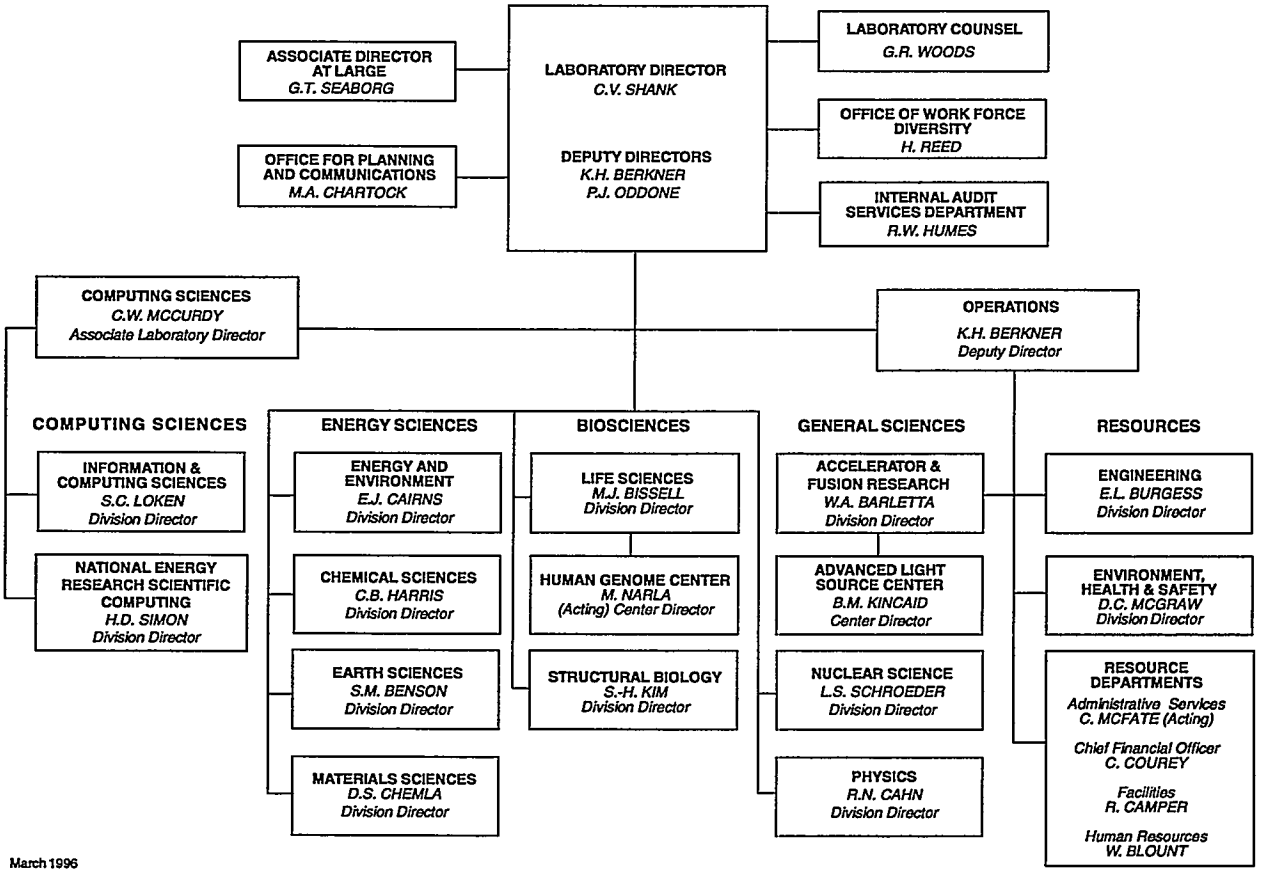
Computing Sciences

- **Information and Computing Sciences:** Advanced software engineering; information management; network development; scientific imaging and visualization tools; computation tools for the Human Genome Project; biostatistics; distributed control of applications.
- **National Energy Research Scientific Computing (NERSC) Center:** Unsurpassed high-end computing services to the ER user community; access to state-of-the-art computers, including the Cray C90 and Cray J90/T3E, scalable, high-performance computing systems; collaboration and support for external users and computational scientists for mathematical modeling, algorithmic design, software implementation, and system architecture, as well as science-of-scale projects; access to high performance (terabyte) storage systems; large-scale parallel applications; collaboration with industry and other institutions.
- **Energy Sciences Network (ESnet):** Nationwide computer data-communications network supporting multiple-program, open scientific research. Supports multiple protocols, such as DOD Internet, DECnet Phase IV, Open Systems Interconnection ConnectionLess Network Protocol. Connects more than 30 sites at up to 45 Mbps; DOE contribution to National Research and Education Network (NREN); provides access for data exchange with ARPA, DOD, NASA, NSF, plus international connections.
- **Center for Computational Science and Engineering (CCSE):** High-resolution numerical methods for partial differential equations; adaptive methodologies; computational fluid dynamics; algorithms for parallel architectures, scientific visualizations.

Resources and Operations

- **Engineering:** Engineering design, planning, and concept development; advanced accelerator components; electronic and mechanical instrumentation; scientific applications software development; laboratory automation; fabrication of detectors and experimental systems; shops and technical support for scientific programs and research facilities.
- **Environment, Health and Safety:** Technical support for safety and environmental protection; radiation safety associated with accelerator technology; advanced dosimeters; dispersion of radionuclides; waste management.
- **Resources Departments:** Administrative, financial, human resources, and facilities support for research and Laboratory management.

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY • UNIVERSITY OF CALIFORNIA



March 1996

III. LABORATORY STRATEGIC PLAN

BERKELEY LAB'S VISION AND STRATEGIC OBJECTIVES

Berkeley Lab's Strategic Plan and Vision 2000 support DOE's missions and the Laboratory's national role within the DOE system of laboratories, the most distinguished system of its kind in the world and an essential and major element of the nation's scientific infrastructure. The Laboratory's Vision focuses on our performance as a multiprogram laboratory that addresses scientific challenges of national significance. The four major goals of Vision 2000 are as follows:

> ***Distinguish ourselves as a premier DOE multiprogram national laboratory by performing research of the highest scientific quality. Build on our educational and technical resources to gain a competitive advantage for addressing problems of national significance and advancing the mission of the DOE.***
>
> ***Create value for the economy, enhance education, and contribute to the community through partnerships with industry, universities, and other laboratories.***
>
> ***Make Berkeley Lab the location of choice for facilities and programs. Our operational, administrative, and technical resources will integrate seamlessly with research and engineering programs to make a laboratory that works. All of our activities will be conducted with full regard for the environment, health, and safety.***
>
> ***Commit to developing our people to their fullest potential. We value and seek diversity in our work force. We will create an environment that respects the individual, encourages leadership, stimulates innovation, fosters integrity, and demands excellence.***

To achieve these goals effectively and efficiently, Berkeley Lab's research programs are strategically planned and conducted to achieve our national science and technology mission. These efforts are managed as an essential and complementary element with other parts of DOE's Laboratory system.

SITUATION ANALYSIS

As recognized in DOE's Strategic Laboratory Missions Plan, Berkeley Lab has a principal role in fundamental sciences, a major contributing role to DOE energy resource mission, and its specialized and distinctive capabilities in earth, environmental, and biotechnology sciences that provide a valuable resource to DOE's environmental quality mission. This Institutional Plan describes the roles and activities of the Laboratory that supports this strategic position that advances DOE national missions. We support these DOE missions efficiently and in a manner that incorporates the highest standards for health, safety, and environmental protection. Examples of Laboratory research efforts that support DOE's missions are:

Science and Technology

- **Networking, computation, and information management.** These efforts are focused primarily on providing the supercomputing capabilities for the nation's energy research programs, computational sciences and engineering, advanced high-speed networking, distributed computing, and advanced computing systems. The next generation of processing and high-performance, network-mediated collaborative computing is vital to the success of complex scientific endeavors and innovations. Our

DOE role demands continuous development of hardware, software, and network technology, and is vital to the nation's economic future.

- **Fundamental Sciences.** Basic science is the foundation for our understanding of nature and the universe and is the cornerstone for future technology development. This effort encompasses a range of theoretical, experimental, and computational studies in the physical sciences, including research in the properties of matter, high-energy and nuclear physics, and astrophysics. Such research demands continuing development of investigative tools, including new computational modeling capabilities, advanced accelerator/detector facilities, and space technologies. Basic science studies span the entire scientific spectrum, including chemical, materials, geosciences, and biophysical research. Key to the success of these efforts with be the utilization of the new high-performance computing facilities at Berkeley Lab, with the development of computational algorithms in many new areas of study. Broadly based fundamental research is the ultimate source of long-term technological advancement for DOE's mission.
- **Structural biology, biotechnology, and the human genome.** These efforts include research underlying the development of new medical treatments, including such modern techniques as genetic probes of disease, the use of monoclonal antibodies; and structural studies based on x-ray diffraction and spectroscopy, and magnetic resonance imaging. Sophisticated computational algorithms will support investigations in new areas such as the interface between structural biology and the Human and Drosophila Genome Projects. These activities demand continuing development of instrumentation and computation, and form the basis of the nation's biotechnology industry.
- **Advanced Materials.** R&D efforts are needed for the development of superconducting, catalytic, polymeric, magnetic, biological, and tribiological materials, as well as materials for electronic applications that will have long-term national economic benefits. A number of research efforts span several program areas, including the development of nanometer-scale, artificially structured materials; materials for harsh chemical environments; and techniques for synthesis, processing, and characterization. Creating materials by design demands continuous development of advanced facilities, computational algorithms, and instrumentation with the highest resolving power and sensitivity.

Energy Resources

- **Energy supply and resource development technology.** Energy supply research is needed to assure long-term energy supplies and to improve the performance, economics, and environmental effects of technologies. An active fusion and plasma science program is needed to address the long-term technical needs that may underpin future energy supplies for America and the world. Sustainable resources, including inertial fusion energy, are key to the nation's R&D program portfolio if energy security and environmental quality are to be preserved. Required research activities include research on inertial fusion accelerators and the physics of inertially driven plasmas.
- **Technologies to increase the efficiency of energy use.** These include fundamental research in chemical and combustion dynamics as well as development of more energy-efficient building technologies, industrial processes, and transportation systems. They encompass research on energy-efficient windows; lighting; heating, ventilating, and air-conditioning (HVAC) systems for buildings; and the development of zero-emissions vehicles. This research also includes development of improved methods for analyzing policies to increase energy efficiency, assessment of alternative strategies for R&D investment and energy supply, analysis of policy responses to mitigate global climate change, and understanding of the consequences of transferring better energy technology to the former Soviet Union and the developing world.

Environmental Quality

- **Understanding and controlling environmental risks.** Needed areas of R&D include geological and biological research on environmental response to pollution. Environmental contamination mitigation requires research on improved characterization methods, development of predictive models and risk-assessment methodologies, and development of techniques, including bioremediation, to isolate and clean up sites contaminated by toxic chemical wastes and radioactive materials.

STRATEGIC ISSUES

Scientific and technological advances are critical if we are to achieve the nation's scientific, energy, and environmental objectives. It is essential that initiatives be well coordinated with DOE's and national long-range plans and managed and involve effective scientific review. Setting priorities, integrating them with DOE's programs, and improving cost effectiveness will be essential to initiating and sustaining programs.

Berkeley Lab's support for its scientists and engineers and its performance contract with DOE address the expectations for efficient performance of our scientific programs and administrative and health and safety operations. Quality services and their delivery at all levels are now being achieved at roughly 15% lower costs for core services than in prior years. New efforts with DOE, such as the Necessary and Sufficient Pilot and Business Management Oversight Pilots, offer the potential for further improvements in efficiency while assuring high standards of performance. Process improvements in support of Laboratory and DOE quality improvement programs have helped to remove the barriers to research cooperation and assure efficient management with cost controls.

STRATEGIES

Berkeley Lab has a distinguished history of scientific discovery, grounded in a spirit of multidisciplinary teamwork. Many available measures, such as program and divisional peer reviews corroborate the Laboratory's scientific performance. The Laboratory focuses on providing core competencies that enable DOE's missions—science and technology, energy resources, environmental quality—to succeed. In carrying out this enabling research, both basic and applied, the Lab has developed internationally recognized programs and facilities. As indicated in the Strategic Laboratory Missions Plan, Berkeley Lab has a principal role in fundamental sciences, a major contributing role to DOE energy resource, and its specialized and distinctive capabilities for DOE's environmental quality mission. We are committed to adding value to society by advancing these roles for the national laboratory system through strategies that emphasize scientific excellence, by being partners of choice, optimizing the way we work, and empowering our people. It is in this context that Berkeley Lab's agenda for the future takes shape.

Maintaining Scientific Excellence

The first part of Vision 2000, "to distinguish ourselves as a premier DOE multiprogram national laboratory by performing research of the highest scientific quality," is a primary objective that underpins our corollary strategic goals. The scientific agenda for the next decade reflects both the research needs of the nation and the Laboratory's ability to contribute to those needs:

- **Computational sciences are at the core of our scientific capabilities and impact all programs for the Office of Energy Research.** Advanced computing and networking capability are essential for achieving DOE's research and development objectives. Further advances in computing and networking performance are integral to advances in energy-research activities, such as high-energy and nuclear physics, fluid mechanics and combustion sciences, mathematics, engineering, materials,

and the life and environmental sciences. In addition, the Energy Sciences Network (ESnet) provides nationwide and international connectivity for the entire DOE community.

- **The Advanced Light Source (ALS) provides an instrumentation centerpiece for DOE research programs, giving scientists new probes and realms of sensitivity, resolving power.** As a tool for the characterization of advanced materials, development of x-ray lithographic techniques, study of chemical dynamics, and pursuit of structural biology research, the ALS has a central role in some of the Laboratory's most important research thrusts, at the same time providing great opportunities for researchers across the country. The Scientific Facilities Initiative is enabling new levels of service to users.
- **The Biosciences at Berkeley Lab is achieving success through integrating capabilities in genomics, ALS structural biology, and computation with cell and molecular biology.** Prospects include a much deeper understanding of the origins and intervention in disease, custom-tailored pharmaceuticals and materials, and microbial engineering to eliminate contaminants from the soil.
- **Berkeley Lab forefront role in high-energy and nuclear physics and astrophysics will continue to provide leadership for national and international programs.** New Laboratory resources in computation will enable the community of high-energy and nuclear physicists to address the new data and communications requirements for experimental programs at Brookhaven, Fermilab, and SLAC, and at the Large Hadron Collider at CERN.
- **Accelerator and detector technologies sustain central roles in the scientific future of the nation and the national laboratory system.** The ALS, and cutting-edge undulator magnet technology, are products of a research field that continues to flourish at Berkeley Lab. Of particular immediate interest is the heavy-ion fusion science effort, which holds the potential for developing the future means of fusion energy.
- **Berkeley Lab is at the forefront in providing the nation with key options to address both the need for energy and an increasing demand for minimizing the environmental impacts of its use.** A particularly important thrust for the Laboratory is research in heavy-ion fusion science, where Berkeley Lab continues to play a pioneering role. Berkeley Lab continues to make pioneering advances in the development of electromagnetic and seismic methods for imaging subsurface resources, development of advanced building technologies, studies of indoor air quality, and combustion research.
- **Berkeley Lab is providing leadership in environmental protection and remediation.** Programs include research innovations in chemistry to prevent pollution from industrial products and the manufacturing process; characterization methods; predictive models and risk-assessment methodologies; and environmental biotechnology methods to clean up sites contaminated by toxic chemical wastes. DOE's new Natural and Accelerated Bioremediation Research Program is strongly supported by the development efforts at Berkeley Lab.

New initiatives require that resources be mobilized throughout the Laboratory. Special emphasis is being given to support leadership in emerging areas of science. Berkeley Lab is working with the DOE to anticipate needs and develop proposals that address the nation's most pressing scientific, energy, and environmental needs. The Laboratory Directed Research and Development (LDRD) funds are vital for catalyzing and fostering new scientific directions and initiatives. Berkeley Lab is reviewing levels of funding for LDRD and assuring that the process supports the most promising strategic research directions.

Adding Value through Partnerships

The system of national laboratories provides the unique strength of a multidisciplinary collaboration for the tackling of some of nature's and society's most intractable puzzles. A central objective for the next decade is to enhance relationships with university, government, and industrial research communities, the underlying aims being those enunciated in Vision 2000: "to create value for the economy, enhance

education, and contribute to the community." Three strategies address the strengthening of Berkeley Lab's partnerships:

- **Develop partnerships with other laboratories, universities, and industry.** In order to benefit fully from the competencies of the national laboratory system, we must partner with industry, federal and state agencies, and universities to tackle problems of increasing complexity. Partnerships not only among different institutions, but also among different disciplines, will be increasingly productive arrangements with national user facilities such as the ALS and NERSC. These partnerships are essential to provide for the nation's needs in such areas as materials research and development, computing and networking, and biotechnology.
- **Strengthen partnerships with the University of California (UC).** One of the great strengths of the Laboratory is its close relationship with the UC Berkeley campus. Partnerships must fully join the multidisciplinary academic strengths on campus with the research facilities and technical infrastructure of the Laboratory. Because of the growing importance of interdisciplinary and facility-oriented research (such as computational sciences and the structural biology and genome sequencing projects), partnerships with the campus should be strengthened and broadened to address industrial and national R&D needs and promote leadership in science, computing, and engineering.

Optimizing the Way We Work

In an increasingly competitive national research environment, we are demonstrating to the DOE and other sponsors that we are spending their research dollars wisely and effectively. Emphasizing performance and sustained quality service, we are integrating administrative systems to deliver on our commitment for cost-effective services that support scientific and technological excellence. Key strategies address these challenges:

- **Streamlining.** The Laboratory has established performance improvements in concert with DOE to address streamlined, efficient, and cost-effective management systems. Berkeley Lab anticipated some recommendations of the 1995 Galvin report by initiating in 1994 an aggressive cost savings plan. These savings were accomplished through integration of management, halting peak load staffing, implementing cross-organizational work assignments, and more careful management of employee job performance. In two years, overhead staffing levels were reduced 15%, and the administrative support to technical support staffing ratios improved from 1:6 to 1:10.
- **Service Providers and Customers; Total Quality Management.** Satisfied research customers should be recognized as the main deliverable of our user facilities. Customer orientation is the watchword for management support areas. This strategy includes adequate technical resources, service close to the customer, skilled support staff, and expedited handling of scientists' needs ("one-stop shopping") and outside suppliers in areas where quality resides elsewhere. A new Administrative Services Department has been established that provides seamless institutional services, cross-functional infrastructure, and feedback on performance. We are promoting a culture in which we measure and analyze performance results and encourage greater communications to assure the development of quality and customer-focused programs. We are working in partnership with DOE and active in the "Quality Summit" to advance Department-wide quality programs and efficiencies.
- **Communications Excellence and On-line Systems for Administrative Functions.** Good communication plays a key role in working with the DOE, other agencies, industry, and key audiences. Berkeley Lab's Communications Plan advances our distinctive identity and visibility, strengthens relationships with constituencies, and builds the sense of community within the Laboratory. An essential tactic in implementing our strategies is a greater reliance on electronic communications and electronic information management. An attainable administrative objective is to replace virtually all of the Laboratory's paper transactions with on-line systems that update forms and procedures, make them accessible, and allow users to check the status of pending actions.

Respecting and Empowering Our People

This management objective is to develop our people to their fullest potential, value and seek diversity in our work force, and create an environment that respects the individual and fosters integrity. The objective is fundamental—to ensure a unity of purpose and a respectful sense of community without which our research objectives become unattainable. Key strategies include:

- **Diverse work force.** Although Laboratory programs related to diversity in the work force have been in place since the mid-1980s, the term "work force diversity" has come to have a much broader meaning than gender and racial balance. The challenge and the goal is to value diversity in the workplace, and to establish diversity as a permanent part of the Laboratory's institutional culture. We are committed to equal opportunity and affirmative action, and we recognize these policies as the first and most important steps to achieving diversity in our working community.
- **Career growth and training.** More educational opportunities and job-related training and a wider awareness of these opportunities are measures for addressing the professional development of Berkeley Lab employees. The new Administrative Services Department enables more consistent skill levels and expectations and provides improve opportunities for staff development, planning, and placement. The Berkeley Lab goal is the growth of all Berkeley Lab employees facilitated by a responsive management. Berkeley Lab has instituted a program of training for all managers through operational and scientific program divisions addressing a range of skills, including in communications, performance progress reviews, interpersonal relations and conflict resolution, and personnel development.

MANAGEMENT OPPORTUNITIES AND ISSUES

To maintain the Laboratory's scientific leadership and to ensure the full development of its capabilities and resources, Berkeley Lab has identified strategic management issues that it is addressing with DOE through institutional planning and other management forums. These issues, which continue to be developed as an ongoing process within Berkeley Lab's strategic planning activities, can be divided into five main categories: fulfilling our mission, implementing initiatives, modernizing our research facilities, further improving our ES&H performance, and improving efficiency in oversight and indirect costs.

Fulfilling Our Scientific, Energy, and Environmental Research Role

The Laboratory's initiatives support the effective deployment of the DOE national laboratory system. The Laboratory must demonstrate that its initiatives efficiently and effectively contribute to national needs and address problems of significance. The Laboratory is working with DOE, the scientific community, the state, and industry participants to establish priorities and to support initiatives that can best serve the nation under financial constraints. Examples from several key DOE program areas illustrate the Laboratory's priorities for initiatives.

- **Office of Computing and Technology Research.** To greatly enhance progress in the scientific programs of the Office of Energy Research (ER), Berkeley Lab is implementing a world-class advanced distributed supercomputer and network environment—the National Energy Research Scientific Computing Division, Energy Sciences Network, and Computational Sciences and Engineering programs. These programs encompass a broad range of computational and computer sciences activities to ensure that the production environment evolves to meet the changing needs of ER scientific research. This capability represents an opportunity for significant cost savings for DOE and is now fully operational.

- **Office of Basic Energy Sciences.** The Scientific Facilities Initiative is a key element to effective utilization of Berkeley Lab's major facilities, including the Advanced Light Source and National Center for Electron Microscopy. The Laboratory's progress on beamlines development and utilization, and the capital investments for completion of the second floor of the Advanced Light Source building for user offices and laboratories need continued support. The Laboratory can serve the broader national scientific communities through the facilities initiative and by other capital investments.
- **Office of Fusion Energy.** Heavy-ion fusion science is poised to advance our understanding of heavy-ion-based fusion plasmas and to evaluate the potential for developing intense and focused heavy-ion beams as drivers for inertial confinement fusion. The Laboratory is poised for construction of the necessary research facility, as well as contributing to scientific progress in other elements of the national fusion energy program.
- **Office of Health and Environmental Research.** Berkeley Lab's Human Genome Center, the Advanced Light Source, and National Energy Research Scientific Computing resources give biologists access to advanced technology needed to address fundamental life science challenges: to understand the genetic and structural basis of energy-derived and environmentally-derived health issues. Berkeley Lab is working with the Office of Health and Environmental Research to establish a scientific and management framework, including close collaborations with other DOE laboratories, that will ensure the success of these initiatives. The collaborations among DOE Genome Centers, for example, promise to significantly advance DOE's goals to fully sequence one-third of the human genome in the coming years.

Modernizing Facilities and Infrastructure

Berkeley Lab will continue to give priority to modernizing and restoring facilities to sustain national programs while also maintaining high standards in the areas of environment, health, and safety. The Laboratory closely coordinates its facilities and institutional planning, safety and health planning, and environmental restoration so that a safe working environment will be provided for implementation of DOE scientific programs. In this manner information on the program activities for DOE compliance with the National Environmental Policy Act is also fully sustained. Critical elements of Berkeley Lab capital resource and modernization planning are implemented through:

- **Multiprogram Energy Laboratories Facilities Support (MEL-FS).** This program has been vital for replacing electrical and mechanical utilities, and upgrading buildings at Berkeley Lab. A key element for the program will be the continued improvement of these systems and modernization of support buildings and infrastructure facilities. Recent reversals in the program's funding place the Laboratory infrastructure under severe stress.
- **General Plant Projects (GPP).** Small capital projects (up to $2.0 million) supported by GPP are essential for small modifications and additions; for compliance with environmental, health, and safety standards; and for upgrades of obsolete and deteriorated infrastructure such as transformers, switching stations, boilers, chillers, and roofs. At $3.4 million, the current annual budget for GPP projects is inadequate to make substantial progress in meeting identified needs.
- **General Purpose Equipment (GPE).** The Laboratory uses GPE funds to replace its essential support equipment. This equipment includes environmental, safety, and health equipment; mechanical and electrical engineering shop equipment; transportation vehicles, including shuttle vehicles; data processing and telecommunications equipment; and other equipment used by support divisions. In FY 1996, GPE funds were $1.9 million, but, compared with 1980, the purchasing power was equivalent to about $700,000, or one-half the 1980 funding. This level of need has resulted in equipment used beyond its normal lifetime, sustained high maintenance costs, and substandard equipment performance.

Performance-Based Management

Appendix F of the contract between the University of California Regents and the Department of Energy for the operation and management of Berkeley Lab (Contract 98) contains performance measures that are the components of the performance-based management system that the University and DOE utilize for Laboratory oversight. The DOE and the University have developed the measures as objective standards against which the University's overall performance under the prime contract are to be assessed. The performance measures are subject to annual review and may be modified by agreement of the parties. DOE appraisal of Berkeley Lab's performance establishes the positive trend in the contract measures as reported in DOE's "1995 Annual Summary Appraisal."

Science and technology performance assessment guidelines for UC's peer review process are summarized in the document "Laboratory Science and Technology Assessment Process and Criteria." In essence, these guidelines prescribe the use of outside peer review committees, which assess the Laboratory's science and technology programs according to four criteria: quality of science, relevance to national needs and agency missions, performance in the construction and operation of major research facilities, and programmatic performance and planning. The result of each review is an overall rating of outstanding, excellent, good, marginal, or unsatisfactory.

The long-term goal for Berkeley Lab's performance-based contracting is the integration of the measures, assessments, and reviews for an efficient and productive evaluation of Berkeley Lab's performance. The Laboratory and the University continue to work with DOE to optimize the performance evaluation process, eliminate redundancies, and develop a system that provides positive feedback for improved performance.

ES&H Performance

It is the policy of the Laboratory to integrate its performance in the areas of environment, safety, and health (ES&H) into the planning and implementation of all of its operations to protect the health of employees, the public, and the environment. Laboratory plans integrate ES&H requirements in a prioritized manner to assure that Berkeley Lab can meet DOE's Critical Success Factors for ES&H in the conduct of research. All Conceptual Design Reports and other supporting materials indicate ES&H requirements for program planning. Issues that continue to be addressed include:

- **Necessary and Sufficient Pilot.** Among the more significant joint DOE and Berkeley Lab management efforts has been to move from the order system to one of direct application of accepted legal codes and standards. Such an approach involves examination of work being conducted, evaluation of the hazards, and implementation of controls tailored to mitigate risks. A "Necessary and Sufficient" pilot was executed at Berkeley Lab's National Tritium Labeling Facility which meant significant cost savings compared to the alternative implementation of nuclear facility standards. This approach is now being applied to all Berkeley Lab facilities and activities with the promise that it will enhance hazard communication and consistent understanding of requirements, ensure a disciplined approach to performance-based management, result in a more rational and efficient management of laboratory operations, and increase line management involvement in implementation of the ES&H program.
- **Resources for environment, safety, and health plans.** Commitments must continue to support environmental management activities and for multiprogram facilities support to ensure that ongoing operations are maintained. The new Hazardous Waste Handling Facility will upgrade, consolidate, and relocate existing waste handling operations in FY 1996. Further infrastructure upgrades to plant or facilities are important to address other needs.

Improving Oversight and Administrative Efficiency

DOE, Berkeley Lab, and the UC Office of the President (UCOP) are working together to eliminate redundancy or impediments to efficient business transactions. New procedures for DOE's compliance with the National Environmental Protection Act (NEPA) have continued to streamline paperwork. Performance-based management and the Self-Assessment Program also contribute to improving the efficiency of Laboratory operations.

- **Paperwork reduction.** Paperwork required for NEPA compliance has been significantly reduced. In addition, the existing framework for Cooperative Research and Development Agreements (CRADA) has been streamlined and made more timely. Both of these actions can facilitate effective decision making and encourage industrial, government, and university partnerships.
- **Consolidating reviews.** Costly reviews require considerable time and effort by both the Laboratory and DOE. By implementing the Business Pilot program and emphasizing biennial and triennial reviews, DOE and the Laboratory are working together to streamline the review process, increase productivity, and reduce costs. The current performance-based contract between the University of California Regents and the Department of Energy contributes to the elimination of redundant oversight.

DOE, Berkeley Lab, and UCOP are taking steps through improved directives and are assessing mechanisms to control drivers of any unnecessary indirect costs. With DOE, Berkeley Lab has joined with LANL and LLNL in an Oversight Pilot that is significantly reducing the number of audits and appraisals.

IV. CORE BUSINESS AREAS

INITIATIVES

Berkeley Lab's mission to provide national scientific leadership and technological innovation is based on its ability to build and make available its unique resources. These resources allow Berkeley Lab, along with the other DOE laboratories, to maintain leadership in basic research, to focus on fundamental and applied research in support of the DOE and other federal and state agencies, and to maintain global technical leadership through science and mathematics education. Initiatives are provided for consideration by the Department of Energy. Inclusion in this plan does not imply DOE's approval of or intent to implement an initiative. The following key Berkeley Lab initiatives support the Laboratory's mission:

Basic Energy Sciences

- Advanced Light Source Roadmap
- Molecular Design Institute
- New Chemistry for the Environment
- Electron Beam Microcharacterization Facility

Computational and Technology Research

- High Energy and Nuclear Physics Computing
- Advanced Computational Testing and Simulation (ACTS)
- National Collaboratory
- Molecular Theory Center

High-Energy and Nuclear Physics

- Large Hadron Collider
- GRETA (Gamma-Ray Energy Tracking Array)
- Km-Scale Neutrino Observatory Design

Health and Environmental Research

- Genome Sequencing
- Transgenic Research
- Environmental Biotechnology
- Boron-Neutron Capture Therapy
- Computational Biology

Fusion Energy

- Heavy-Ion Fusion Science Facility

Energy Efficiency and Renewables

- Building Performance Assurance
- Energy Technologies for Developing Countries

Environmental Management

- SELECT: A Science-Based Framework for Cost-Effective Environmental Cleanup

Civilian Radioactive Waste Management

- Yucca Mountain Percolation Flux

Other Sponsors

- Advanced Lithography
- X-ray Etching of Microelectromechanical Systems

Basic Energy Sciences

Advanced Light Source Roadmap Initiative

The Advanced Light Source (ALS) produces the world's brightest light in the soft x-ray and vacuum ultraviolet range of the spectrum. This synchrotron radiation source is used for basic and industrial research and development across a broad spectrum of the physical, chemical, and life sciences, as well as such technological areas as materials analysis, microstructure fabrication, and macromolecular crystallography. To exploit fully the state-of-the-art capabilities of this newly constructed national user facility, the Laboratory has developed a roadmap that will provide for installation of the full complement of insertion devices (undulators and wigglers) in the ALS storage ring, full instrumentation of the insertion-device beamlines, and completion of the second floor of the ALS building with user offices and laboratories, thereby enhancing the ability of the ALS to expand the nation's scientific and technology base. The organization of the roadmap is structured around beamlines, primarily the insertion-device beamlines and continuing with the bend-magnet beamlines. Also included is the scientific and technological motivation for the particular beamlines. The intent is to arrive at a complete facility that can service a wide community over a broad spectral range and do it in a balanced way. No single scientific discipline can be completely serviced by only one beamline. Indeed, ease of transferability of end stations between beamlines is an important goal of this plan.

Nanoparticle Analysis (Beamline 10.0). Outreach efforts in the Bay Area semiconductor industry reveal a strong need for characterization of the chemical properties of the structures in microcircuits at a resolution less than the smallest feature size, as well as the identification of particulate contamination. The advantage of spectromicroscopy is that it provides not merely elemental composition but also (by use of microXANES and microESCA) the chemical binding nature of such particles. Trial experiments are presently being performed with Intel on Beamline 7.0, but it is already clear that our existing beamlines are not optimum for microscopy, since they have been designed with a strong emphasis on high-energy resolution. Spectromicroscopy for particle analysis is not demanding on energy resolution, and so a monochromator designed to match the desired energy dispersion with the desired spatial resolution would yield higher signals by a factor of 30 or more. The beamline will be illuminated by a short U5 undulator similar to the longer device already commissioned and demonstrating performance up to design level. The beamline is based on a spherical grating monochromator with moderate resolution. Experimental stations include an imaging photoelectron microscope for microXANES, a scanning photoemission microscope for microESCA, and a scanning transmission microscopy facility. Nanoparticle analysis will also be applicable to supported metal clusters that are crucial to heterogeneous catalysis, which plays an important role in the petrochemical industry and in the control of atmospheric pollution. Inhaleable carbonaceous clusters constitute a demonstrable mortality and morbidity health problem. The relevant length scale is 1–100 nm. The demand for nanoparticle analysis is expected to be sufficiently high that Beamline 6.0 is being reserved to accommodate the possible overflow.

High-Resolution EUV Spectroscopy (Beamline 6.0). The high brightness of undulator radiation permits the construction of monochromators with unprecedented resolving power. The spherical grating monochromator in Sector 9 has a demonstrated resolving power of 65,000, but is idle for 75% of the time since it shares the Sector 9 undulator with the beamlines of the Chemical Dynamics program. The plan is to acquire an undulator and front end so that this monochromator can be installed in Sector 6. There, it will service the existing Atomic and Molecular Physics community, as well as a new

Condensed Matter Physics community interested in the electron structure of high-temperature superconductors and other highly correlated materials. A key impediment to the theoretical understanding of such materials is the strong coulomb interaction, involving an interplay between the charge and spin degrees of freedom. A battery of powerful spectroscopic techniques, including angle-resolved photoemission, circular dichroism, and electron spin polarization analysis, will be targeted at this interplay.

Elliptically Polarizing Undulator Facility (Beamline 4.0). There is a growing demand for circularly polarized x-rays, and for studies of magnetic materials and organometallic molecules. Advances have been made recently in the design and manufacture of elliptically polarizing undulators (EPUs) that can deliver x-rays of any desired state of helicity. Two EPUs will be installed in Sector 4, each serving its own beamline: one optimized for microscopy on magnetic materials of interest to the magnetic recording industry; and one optimized for spectroscopy and circular dichroism studies of the spin states of organometallic molecules of biological importance. A third interchangeable EPU will eventually be added and the beamlines modified to permit fast switching between left and right helicity.

Superbends. The ALS storage ring, as originally configured, comprises a triple-bend achromat magnet lattice. Each of the 12 superperiods of the lattice contains three combined-function magnets (bend magnets) that are sources of synchrotron radiation. At the normal operating energy of 1.5 GeV, the critical photon energy of these magnets is 1.56 keV, which limits the useful photon flux from these sources to photon energies less than 8 keV. Replacement of the central bend magnet in a sector of the lattice with a high-field (nominally 4-Tesla) superconducting dipole magnet (superbend magnet) would extend the generation of high-flux, high-brightness x-rays to photon energies of up to at least 30 keV without the use of a high-field wiggler. The extended spectral range would enhance the utilization of the ALS by increasing the attractiveness of the bend-magnet sources to a broader range of users in the industrial, academic, and laboratory research communities. In addition, using superbends rather than wigglers to provide high-photon energies would preserve the ALS straight sections for the very-high-brightness undulators that make the best use of this scarce resource. An Accelerator and Reactor Improvement and Modification project is now underway to demonstrate a prototype magnet that might ultimately result in the replacement of bend magnets in three sectors with superconducting dipoles.

X-ray Microscopy (Beamline 7.3). The numerous spectromicroscopy techniques that form the backbone of the scientific programs associated with the previously described undulator beamlines do not invariably require the ultrahigh brightness of the undulator sources in all circumstances. In addition, there are numerous experiments for which preliminary measurements, development work, and rapid access on a bend-magnet beamline are advantageous before advancing to the undulator beamline. Beamline 7.3 will feature a monochromator explicitly designed for maximum performance in a spectromicroscopy environment. It will also have a circular polarization capability for magnetic contrast microscopy. This beamline is based on a spherical-grating monochromator with moderate resolution. In addition to spherical- and plane-mirror focusing and elliptical-mirror refocusing optics, there will be an aperture for circular polarization selection. The experimental stations comprise an imaging photoelectron microscope for microXANES and an electron spectrometer for microESCA with a 1-μm spot size. The facility will be designed for rapid, low-cost implementation and is expected to be especially attractive to industrial collaborators.

Infrared Microscopy and Spectroscopy. The ALS offers a unique capability in the areas of infrared microscopy and spectroscopy, in part because of its broad, continuous spectrum, which blankets the spectral region from the visible through the infrared to millimeter wavelengths, and in part because its brightness has been calculated to be between 10 and 1000 times greater than that of black-body sources. It also benefits from a pulsed time structure. Because infrared beams can be efficiently redirected with high-reflectivity mirrors, infrared beamlines could be constructed at the ALS bend-magnet ports that are otherwise blocked by insertion devices in the following sector, thereby enhancing the utilization of the facility. There are a number of such sites available. The research envisaged will center on adsorbates on metal and semiconductor surfaces, but other topics, such as high-temperature superconductors, "metallic" hydrogen and other materials in high-pressure cells, and time-resolved electronic responses of candidate materials for high-speed detectors, will also be given attention.

Infrared microscopy efforts will be directed towards the needs of industry, such as the examination of polymer laminates and contaminant particles on silicon wafers.

Full utilization of the ALS to address emerging needs of users from industry, academia, and government laboratories requires insertion devices (undulators and wigglers) and beamlines to carry the light from the insertion devices and bend magnets to the experimental end stations. It also requires completion of the 1277 gsm (13,750 gsf) of office, light laboratory, and support space for users in the unfinished second floor of the ALS building. Project costs include all safety systems necessary for full compliance with applicable regulations, orders, and ALS design specifications. In compliance with the National Environmental Policy Act (NEPA), an Environmental Assessment was prepared for the ALS and a finding of No Significant Impact was issued in 1988. In compliance with the California Environmental Quality Act (CEQA), an Initial Study Report was prepared and a Negative Declaration adopted in 1987.

Advanced Light Source Roadmap Initiative
Resource Requirements ($M)[a]

Category	Prior Years[b]	1996	1997	1998	1999	2000	2001	2002	Total
Operating	0.1	0.0	0.8	1.2	1.7	2.3	3.2	4.3	13.6
Construction: Beamline 10.0	0.0	0.0	0.0	1.5	2.0	0.7	0.0	0.0	4.2
Construction: Beamline 6.0	0.0	0.9	0.0	0.6	1.0	0.8	0.0	0.0	3.3
Construction: Beamline 4.0	0.0	2.3	3.7	0.0	0.0	0.0	0.0	0.0	6.0
Construction: Superbends (Phases 1 and 2)	0.0	0.0	0.0	0.1	1.0	3.7	8.6	0.0	13.4
Other Construction[c]	0.0	0.0	4.8	7.0	8.2	6.4	3.7	5.0	35.1

[a]Preliminary estimate of actual-year Berkeley Lab Budget Authority (B&R Code KC), per 1996 Conceptual Design Report.
[b]For production of conceptual design report and environmental assessment.
[c]Bend Magnet beamlines funding sources include GPE and ARIM, not included here.

Molecular Design Institute Initiative

The Molecular Design Institute, centered at Lawrence Berkeley National Laboratory, is dedicated to the development and application of novel approaches for designing materials and devices. The two existing paradigms for materials production—chemical synthesis and lithographic patterning of complex, interconnected structures—are converging towards similar nanometer length scales. The Molecular Design Institute integrates these two methodologies. The focus is on combining the ability of chemists and biochemists to build increasingly large and complex architectures at the molecular level with the ability of physicists to construct devices down to the 10-nm level. By integrating these sciences, new technologies would be developed that would have a critical impact in the defense area and on the nation as a whole, with applications in sensors, electronics, photonics, structural materials, and coatings.

Three major research areas are being addressed through this interdisciplinary effort:

- Combinatorial synthesis of materials.
- Development of nanometer-scale building blocks for constructing new materials.
- Connectivity and integration of these building blocks to form complex structures and devices.

The first area will extend the recently developed combinatorial methods of synthesis/analysis that are having a huge impact in biomedical research to the discovery of new solid-state materials. This requires applying the lithographic and analytical methods developed for physics to the synthetic methods of chemistry. This technology could lead to the discovery of a range of materials with greatly improved properties for use in devices and complex structures. The latter two areas will focus on developing tools that will allow the fabrication of structures and devices in a largely unexplored size realm, i.e., 2 to 100 nm. Manipulation of structures on the nanometer level by physicists and chemists has revealed a remarkable size dependence of their properties. Consequently, like the combinatorial project described above, the properties of these nanostructures, and devices incorporating them, open a new realm of materials research.

The foundation of Berkeley Lab's expertise in these areas has been built on earlier work supported by OER's Office of Basic Energy Sciences. Currently, support is through DOD's Office of Naval Research. The Institute brings together scientists from academia, government, and industrial laboratories. Initially, it includes participants from the Berkeley Lab, the University of California campuses at Berkeley and Los Angeles, Pennsylvania State and Rice Universities, and the California Institute of Technology, with industrial scientists from AT&T, IBM, Intel, Motorola, and Symyx.

Molecular Design Institute Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	3.0	3.0	8.0	8.0	8.0	8.0	38.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority from DOD and DOE.

New Chemistry for the Environment Initiative

New Chemistry for the Environment is to be a coordinated program focused on ways in which new "environmentally friendly" chemical and biochemical processes can be developed to replace existing polluting reactions and processes in the synthesis of bulk, fine, and specialty chemicals, including fuels, agro-chemicals, pharmaceuticals, etc. This program is based on UC Berkeley's strengths in chemistry, chemical engineering, and the various fields of biology. Emphasis would be on developing methods that make use of new sustainable feedstocks, produce "clean" products to replace the ones that pollute the environment, and avoid the production of pollutants as byproducts of chemical syntheses by designing highly selective processes that produce only the desired product.

The program would examine both new and existing products. Research into new products would include new-fuels studies (such as synthetic routes to new, cleaner fuels like hydrogen); new chemistry and biochemistry (such as synthetic routes to new pharmaceuticals, and specialty and commodity chemicals); and new materials research (such as synthetic routes to "cleaner," biodegradable materials and polymers). Areas of research into existing products would include new techniques of production by avoiding or limiting the use or generation of hazardous and polluting substances (e.g., reagents, solvents, and catalysts). Another important topic would be examination of new feedstocks targeted to replace nonrenewable (fossil) sources and hazardous feedstocks, and to increase energy efficiency over existing feedstocks. Finally, research into "reuse" of solvents and "byproducts use" would examine reactions designed to allow reuse of reagents, solvents, and catalysts, and/or allow use of unavoidable byproducts.

The program would involve multi-investigator, multidisciplinary teams from materials sciences, chemical sciences, and structural biology at Berkeley Lab. It would directly support the strategic directives of DOE in general, and the Offices of Energy Research, Fossil and Energy Efficiency in particular, in the mission areas of economic productivity and environmental quality. Several components of this initiative have been proposed as part of the Environmental Technology Partnerships program of OER and EM, while more general support from DOE would leverage investment still further.

New Chemistry for the Environment Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	1.0	2.0	2.0	2.0	2.0	2.0	11.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Estimate of actual-year Berkeley Lab Budget Authority from DOE.

Electron Beam Microcharacterization Facility Initiative

The Electron Beam Microcharacterization Facility (EBMF) will provide state-of-the-art instrumentation, laboratories and scientific support for electron-optical characterization of advanced materials at high-spatial resolution. The facility will be an essential and integral part of DOE's National Center for Electron Microscopy (NCEM) and as such will be operated as a national user facility. Research at the Facility will focus on establishing the link between microstructure and properties of solids in order to provide the scientific basis for understanding the behavior of a broad range of materials. The resulting progress is expected to lead to the discovery of novel phenomena and the development of new materials important for fundamental science and advanced technology.

Following the established mode of operation of the NCEM, access to the facility will be controlled by an external steering committee representing industry, universities, and government laboratories. Remote access via computer control, currently being developed at LBNL, will be an integral part of the facility's operation, making its capabilities readily available to a broad segment of the scientific community. As such, the facility will provide essential support to all of DOE's materials research programs in metals, alloys, and ceramics, as well as superconducting, semiconducting, and magnetic materials.

A new Dynamic Atomic Resolution Microscope (ARM) will provide unprecedented capabilities for imaging the internal structure of materials at atomic resolution under real-time dynamic conditions. This instrument will build on the established strength of the NCEM in atomic resolution imaging down to one Angstrom resolution. Whereas current instrumentation can reach this level of resolution only by time-consuming computer reconstruction from a series of images, the Dynamic ARM will be able to provide the same capability in real time by using high-energy electrons. This will permit observation of dynamic phenomena where until now only static images could be recorded. The development of new electron detectors will increase the temporal resolution to allow observation of reactions at time scales 100 to 1000 times faster than presently possible, while maintaining atomic resolution. LBNL capabilities for nanolithography can produce samples with specialized geometries tailored for "materials science in the microscope." A supporting instrument dedicated to dynamic *in situ* experiments at lower levels of resolution will complement these capabilities. Special stages will allow exploration of materials behavior under extreme conditions of temperature, stress, electrical fields, or environmental parameters. In addition to such stages as a high-temperature environmental cell with thin-film diamond windows, there will be provisions to develop highly specialized instrument configurations such as an *in situ* diamond anvil cell for high pressure studies, or an *in situ* nano-indenter for studies of friction, wear and fatigue. Other *in situ* efforts will focus on the mechanisms of electrochemical etching, electrochromic switching, interfacial segregation, wetting, corrosion, and other reactions of fundamental and technological importance. An advanced analytical microscope operating with a sub-nanometer probe size for energy-filtered high-resolution imaging and diffraction will complement the structural imaging capabilities of the NCEM's One-Ångstrom Microscope,

funded in FY 1994. Its capability to obtain spectrum images at nanometer resolution will fill a need critical to many materials programs to identify the structure and composition of nanometer volumes of materials.

The facility will further include instrumentation to characterize magnetic materials and their microstructures at the highest levels of spatial and temporal resolution. A Spin Polarized Low-Energy Electron Microscope (SPLEEM), to be installed in 1997, will be complemented with a Scanning Electron Microscope with Polarization Analysis (SEMPA). These instruments, both mainly for analysis of surface magnetism, will be supported by Lorentz imaging capabilities in the transmission mode, to be made available by modifying a field emission microscope acquired in 1996. Together, these instruments will provide unparalleled opportunities for the quantitative micro-characterization of magnetic structures and their relationship to physical and chemical microstructure in materials ranging from recording to electrical power generation.

Research at this facility will support a range of materials research efforts within DOE's Basic Energy Sciences Program. Sufficient laboratory space has been included to install supporting instrumentation, prepare samples, perform thermomechanical treatments, make measurements, and pre-characterize materials before examination by advanced electron optical techniques. Additional laboratory space will be important for industry, university, and government scientists who need to finalize experiments or perform sample preparation, as well as for resident scientists to perform materials research prior to electron beam microcharacterization. In addition to laboratory space and equipment, this initiative will provide facilities for workshops to educate industrial and university scientists and professionals in electron beam characterization, theory, computing, and sample preparation. The facility will also allow the NCEM to lead the materials characterization community in topical discussion meetings and workshops focused on forefront developments in the field. It is anticipated that an Environmental Assessment and Initial Study will be prepared for this facility in compliance with NEPA and CEQA.

Electron Beam Microcharacterization Facility Initiative Resource Requirements ($M)[a]

Category	1998	1999	2000	2001	2002	Total
Operating	2.0	2.0	2.0	2.0	2.0	10.0
Equipment	10.0	4.0	2.0	2.0	2.0	20.0
Construction	7.0	0.0	0.0	0.0	0.0	7.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Code KC).

Computational and Technology Research

High-Energy and Nuclear Physics Computing Initiative

To address forefront scientific issues, experimental high-energy and nuclear physics on the leading edge calls for complex experiments conducted by very large collaborations to detect and analyze increasingly large numbers of final-state particles and/or events. Experiments at colliders such as RHIC, LHC, the SLAC B-Factory, Fermilab, and at fixed-target accelerators produce huge amounts of data that must be cooperatively verified, analyzed, and interpreted by these collaborations. Massive computer simulations are necessary to understand these data and to compare measurements with models and theories. The challenge for the coming years is to provide cost-effective computing capabilities that will allow far-ranging collaborators to have seamless access to data and each other so that work can proceed in a "national collaboratory" mode.

The High-Energy and Nuclear Physics Computing Initiative will provide a National High Energy and Nuclear Physics (HENP) Collaboratory through the advanced computing, simulation, and remote-access capabilities at the National Energy Research Scientific Computing (NERSC) Center at Berkeley Lab. This Collaboratory will be dedicated to developing and applying forefront computing and networking to the kinds

of data analysis and simulation requirements that will spring from the next generation of large nuclear and high-energy physics experiments. The HENP Collaboratory will include teraflop-scale processor farms coupled to petabyte-scale robotic data storage with multiuser access to event databases. The Collaboratory environment will allow remote collaborators to participate in data analysis in a collegial fashion, rather than as isolated groups.

Berkeley Lab's institutional breadth makes it the right site for such an effort. Its resources include research groups in high-energy and nuclear physics that are major players in large collider experiments, an Information and Computing Sciences Division (ICSD) dedicated to advancing networking and national collaboratory capabilities, and the NERSC Center, which provides the computing infrastructure for this capability.

The Parallel Distributed Simulation Facility (PDSF) processor-array pilot project at Berkeley Lab will be the first step in demonstrating the collaboration of the NERSC Center, nuclear/high-energy physics researchers, and ICSD. Through the PDSF, we can verify the suitability of the "workstation farm" approach for the analysis and simulation of the next generation of large nuclear and high-energy physics experiments. Through this approach, large numbers of commercial processors (each of which analyze or simulate a single event at a time) are coupled with high-speed networks, robotic data storage/retrieval technologies are employed, and multiple remote users can access databases on a high-speed wide area network. Arrays of processors will be configured in architectures that are scalable to the size of the problem at hand. The virtue of the NERSC Center as a participant is that it can minimize the costs of such an approach by incrementally adding hardware and operating personnel to its existing infrastructure and have local scientists collaborate directly with NERSC personnel (to ensure that the Center's capabilities dynamically adapt to the changing needs of the science).

Berkeley Lab offers institutional support, scientific expertise, and state-of-the-art computing and networking development, making it the ideal site for its new mission as a major Energy Research Scientific Computing Center.

High-Energy and Nuclear Physics Computing Initiative
Resource Requirements ($M)[a,b]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	1.5	1.5	2.0	2.5	2.5	2.5	12.5
Construction	0.0	1.0	0.0	0.0	0.0	0.0	1.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority.

Advanced Computational Testing and Simulation (ACTS) Initiative

One of the advantages of computational science is that it enables the testing of theory in environments that are hostile to conventional experimentation. Experiments that are too dangerous, expensive, or politically undesirable, or infeasible because of time or spatial constraints, can be accomplished through computers with ever-increasing fidelity to physical reality. Examples of such scientific problems can be found in areas such as nuclear experiments, chemical weapon intercept, and environmental chemistry. Specific research areas of immediate applicability are in Partnership for a New Generation of Vehicles (PNGV), 3D boiler hydrodynamics, weapons simulation, and environmental remediation.

To address such large-scale computational problems, a user toolkit is needed to facilitate the application of scientific models to experimental, environmental, and simulation data. Under scientific direction, the toolkit would then package the information for processing on appropriate systems—parallel supercomputers, vector supercomputers, and/or workstations—which would then send the data to outputs or through further computational cycles. This initiative will begin the development of the ACTS Toolkit envisioned in DOE-2000. It will be pursued in conjunction with the Berkeley Lab National Collaboratory project, so that the

initial products will be oriented towards the problems of materials modeling, but will keep in mind reusability, which is a major goal of the ACTS Toolkit.

Advanced computational testing and simulation require a synergistic group of scientists, with expertise in both the scientific area of the problem being attacked and in the application of sophisticated computational and numerical techniques, plus convenient access to advanced computing facilities. The combination of a vigorous multiprogram Energy Research environment, the Center for Computational Science and Engineering, and the NERSC Center make Berkeley Lab an ideal site for this effort. In particular, Berkeley Lab has an active materials science program, centered upon the Advanced Light Source, experienced computational scientists in the Center for Computational Science and Engineering, and a state-of-the-art computational facility in the NERSC Center.

This initiative will pursue the development of ACTS tools in the areas of advanced numerical techniques; data assimilation, management, and understanding; and representation of complex geometries; as well as an advanced software framework for the integration of the other tools into a productive distributed environment.

Advanced Computational Testing and Simulation Initiative
Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	4.0	4.0	4.0	4.0	4.0	2.5	22.5
Construction	0	0	0	0	0	0	0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R code KC07).

National Collaboratory Initiative

The Department of Energy has a remarkable array of research facilities, many of which have no counterpart anywhere else in the world. These innovative, state-of-the-art facilities are important national resources that represent large federal investments in specialized energy, environmental, medical, physics, and industrial research. The facilities include high-energy and nuclear physics accelerators, neutron sources and synchrotron light sources, and smaller facilities such as electron microscopy centers. Each year, about 15,000 university, industry, and government-sponsored scientists conduct cutting-edge experiments at these facilities. As one example, Berkeley Lab's ALS can supply the world's brightest source of soft x-rays to dozens of experimental stations simultaneously for examination of semiconductors, magnetic materials, polymers and plastics, metals and ceramics, molecules undergoing rapid reactions, and structures within biological cells, as well as for many other applications.

The effective use of these facilities is largely constrained by the scientist's need to have physical proximity to the resources he or she requires, including research, computing, and data-handling facilities, as well as colleagues. This can be especially limiting when the scientist needs to use a unique facility such as the Advanced Light Source at Berkeley Lab or the Advanced Photon Source at Argonne. The return on investment of these very expensive experimental instruments could be increased severalfold if they were to be made conveniently available to qualified researchers throughout the DOE establishment, rather than only to those who are on site. That is the goal of the National Collaboratory effort.

This materials science National Collaboratory will be the prototype of a new way of doing large science. The scientists will remain in residence at their home institutions and have electronic access to experimental facilities, data-storage facilities, computational resources, and intellectual resources (other scientists) at other institutions as conveniently as if they were all located at the same institution. To realize this vision, a wide range of collaborative tools must be developed. To accomplish this, it will be necessary to solve existing problems in network performance and access controls, organization of massive scientific datasets, expanded

telepresence capabilities, remote instrumental control, and large-scale computational science. In addition, we must be able to apply this machinery to scientific problems worthy of this investment in infrastructure.

This initiative will use the Berkeley Lab's ALS as the initial experimental instrument, with a cadre of remote researchers at the University of Wisconsin. New technology will be employed and protocols developed to overcome the increasing "catatonia" (as it has recently been characterized) of the Internet to ensure that the ESnet links between Berkeley Lab and our collaborators are capable of both the response-time and carrying capacity necessary to conduct remote experiments successfully. Suitable authentication protocols will be designed and implemented. Internet-based data-management schemata will be developed that allow for multi-source storage, organization, and retrieval of data. A Visualization Laboratory will be enhanced by additional applications and tools of particular utility for investigations in materials science.

National Collaboratory Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	1.0	2.0	2.0	1.5	1.0	1.0	8.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R code KC07).

Molecular Theory Center Initiative (A Grand Challenge in Computational Chemistry)

Berkeley Lab's Molecular Theory Center, working closely with the NERSC Center, will seek to eliminate the computational bottlenecks that now limit the scale of molecular problems that can be solved by computers. This research—developing algorithms that scale well with problem size (and not simply numbers of processors)—is critical to leveraging the increased speed of the next generation of massively parallel supercomputing to allow the solution of problems of a scale now significantly beyond present capabilities.

Three examples of current, crucial bottlenecks that the Molecular Theory Center will address are:

Time-scale bottlenecks in condensed-phase molecular simulations. Straightforward molecular dynamics computer simulations provide chemically useful information on time scales that extend to the nanosecond region only, while many key reactive processes in solution occur on time scales that are slower by orders of magnitude. The development of nontraditional Monte-Carlo sampling techniques that focus on reaction pathways will permit the simulation of reactive processes in solution on long time scales.

Molecule-size dependence of electronic structure calculations. The computational complexity of standard *ab initio* electronic structure methods scales with system size in powers ranging from 3 to 7. Thus, to improve computational power by a factor of 10 would enable us to study only systems that are less than two times larger. The Center will pursue novel reformulations that reduce these scalings towards linearity in system size.

Dimensionality bottleneck in quantum dynamics. Current rigorous methods for first-principle determination of quantum dynamics and reactive scattering depend upon a power of the dimensionality of the system. This makes achieving even one additional degree of freedom a formidable undertaking. The Center will develop new methods—including semiclassical techniques—that address this problem.

Fundamental computational bottlenecks like the foregoing demonstrate how advances in computing power must be accompanied by advances in the scientific methods used by molecular chemistry and physics. The presence of the NERSC Center at Berkeley Lab should lead to advantageous synergistic interactions—not only with research groups in the chemical sciences, but also within other disciplines such as computational biology, materials science, and applied mathematics. Such alliances, coupled with the Center's

computational resources, promise to transform the scale of molecular problems that are amenable to computer simulation.

Molecular Theory Center Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.2	0.2	0.2	0.2	0.3	0.3	1.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual year Budget Authority (B&R code KC07).

High-Energy and Nuclear Physics

Large Hadron Collider Initiative

The primary goal of CERN's Large Hadron Collider (LHC) is the elucidation of "electroweak symmetry breaking," the phenomenon that gives rise to the masses of quarks and leptons. This is the physics for which the Superconducting Super Collider (SSC) was designed. Berkeley Lab is playing a leading role in the U.S. contributions to the ATLAS detector and the accelerator work. The ATLAS detector work is in collaboration with both UC Santa Cruz, UC Irvine, and the University of Wisconsin, and the accelerator work is being coordinated with efforts at Brookhaven National Laboratory (BNL) and Fermi National Accelerator Laboratory (Fermilab).

Since the LHC will have only one-third the energy specified for the SSC, it must compensate with a higher event rate. This will generate unprecedented problems for its detectors. Berkeley Lab is using its extensive experience with silicon detectors to respond to this challenge. Silicon detectors, with their high channel count, are the devices of choice in such high-rate environments. An enormous silicon strip tracker is being designed and Berkeley Lab is a leader in developing both the electronics and the detectors for this device. While our success with the silicon vertex (SVX) detector at CDF is a basis for this new effort, the very high particle fluxes at LHC introduce new requirements for radiation hardness in electronics and silicon detectors. We are attacking these problems using the resources of the Microsystems Laboratory and the 88-Inch Cyclotron.

Close to the collision point, the particle fluxes will be too intense even for silicon strip detectors. The the only known solution is pixel detectors. Under generic research sponsored by the SSC, Berkeley Lab pioneered work in this field. We are continuing this effort, which will produce an astonishing channel count, approximately 10^8. The small pixel size provides intrinsic radiation hardness, while the stupendous channel count keeps down occupancy. The development of the electronics for this device is a formidable challenge. The Detector Instrumentation Department of the Engineering Division is uniquely capable of meeting this challenge and works intimately with the Physics Division on this project.

The major Berkeley Lab accelerator contributions will be in three areas: interaction-region quadrupole magnets, accelerator physics, and beam-tube vacuum systems. The vacuum contributions include (1) design and fabrication of the warm (room temperature) vacuum system for the eight straight sections of the LHC, comprising altogether approximately 3.2 km of beam tube; (2) design and fabrication of the neutral beam dumps downstream of the interaction regions for the two large detectors—ATLAS and CMS ; and (3) fabrication of the beryllium beam tubes at the center of the interaction regions for ATLAS and CMS.

Development of interaction-region (IR) magnets is a joint task with Fermilab. Berkeley Lab will work with Fermilab on the development of a conventional IR quadrupole design, which Fermilab will scale up and fabricate as full-scale prototypes. Berkeley Lab will then develop an IR trim quadrupole design. One-and-a-half meter long prototypes of these magnets will then be fabricated at the Lab, and the 18 trim quadrupoles required for two IRs will be built. Berkeley Lab also will provide cabling and strand-coating technologies to the LHC project.

The primary Berkeley Lab accelerator physics efforts for LHC will be in tracking and beam-dynamic calculations and in calculation and measurement of the impedances of accelerator components seen by the proton beams. Depending on the timing of the U.S. agreement to participate in the LHC, the Laboratory may also contribute to beam instrumentation and to beam loading compensation of superconducting RF cavities.

Berkeley Lab will perform analysis, design, and fabrication work on the beam feedback system needed to stabilize the central beam motions in the LHC. The technologies needed are similar to those being developed at the Laboratory for the B Factory system, but are more challenging due to the need to preserve beam density in the absence of radiation damping.

Large Hadron Collider Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	2.0	6.3	9.0	7.0	6.0	4.5	34.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Code KA).

GRETA (Gamma-Ray Energy Tracking Array) Initiative

For many years Berkeley Lab has been one of the leaders in the development of gamma-ray detector arrays with high-energy resolution, high efficiency, and good peak-to-background ratio. This type of array is an important tool for the study of nuclear properties. Researchers at Berkeley Lab have conceived the idea and carried out the construction of Gammasphere, which is currently the most powerful array of its type in the world. Since April 1993, this national facility has been in use at the 88-Inch Cyclotron, and a total of 100 experiments have been carried out with about 200 participating users. It is expected that detector arrays will continue to improve, and many new areas of physics will become accessible with more powerful gamma-ray detector arrays. Both U.S. and European communities are working on the next generation of detector array.

A new concept for a gamma-ray array is being developed by a Berkeley Lab group. It is a shell consisting of closely packed, highly segmented Ge detectors, and it could reach a total efficiency of ~60%, which will give a resolving power 1000 times higher than that of current arrays. In such an array, each gamma ray interacts several times with the Ge detector. Therefore, with events of high gamma-ray multiplicity, it is important to identify the interactions belonging to a particular gamma ray. The high granularity of the segmented Ge detector enables us to resolve each of the scattering interactions and determine its position and energy. A tracking algorithm, using the position and energy information, will then identify the interactions belonging to a particular gamma ray, and the gamma-ray energy is obtained by summing only these interactions.

To realize such a detector array, R&D efforts are being pursued in three areas: (1) manufacture of segmented detectors that can give high-energy resolution and 3-D position information; (2) electronics based on pulse-shape digitization and digital processing of signals to give the energy and coordinates of the interaction points; and (3) an algorithm to identify interaction points belonging to a particular gamma ray. A prototype detector is designed and will be ordered soon. It will be tested together with the electronics, data processing method, and tracking algorithm. The immediate goal for the next year or so is to establish the feasibility of such a detector. The detailed design work could begin in 1997 and construction in 1998. A preliminary estimate of the schedule and budget is as follows.

GRETA Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.3	0.7	4.0	10.0	10.0	3.0	28.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (FY 1996 dollars), including equipment (B&R Code KB).

Km-Scale Neutrino Observatory Design Initiative

The detection of high-energy neutrinos offers unique opportunities for astrophysical investigations. Because neutrinos are not deflected by magnetic fields and interact only weakly with matter, they can be used to find and study objects for which other types of radiation would be absorbed by the intervening matter encountered over cosmic distances. The detectors currently being planned, built or deployed [AMANDA (Antarctic ice), BAIKAL (deep fresh water), and NESTOR (deep ocean water)] point the way toward a very large detector system — on the scale of a square or cubic kilometer — that is likely to be required to observe the low fluxes of high-energy neutrinos from very distant cosmic objects such as Active Galactic Nuclei. Other goals would be sensitive searches for WIMPS, understanding neutrino oscillations (observations of tau neutrinos), possible detection of supernovae (omnidirectional sensitivity), and currently unexplained phenomena such as gamma-ray bursters, which may be accompanied by a detectable neutrino signal. Design studies for such a detector can now usefully build on the expertise gained with current detectors. The main challenge for neutrino astronomy is to detect and reconstruct rare events while rejecting the relatively copious cosmic-ray muon background; this requires data of the highest quality and maximum information content. In addition, there are technical and logistical challenges connected with scaling up the number of elements in a cost-effective manner.

A powerful new technical concept developed at Berkeley Lab centers around a combination of analog and digital signal processing that begins in the optical modules located at depth (in either the ocean or polar ice). Digital data from each optical module will be transmitted through a single electrical cable to a local substring module, multiplexed with data from other modules, and thence over large distances to a base station. Berkeley Lab has been doing leading-edge development work on full-custom integrated circuits for recording the full waveform of signal pulse, and has developed the system concept applicable to the km scale. In collaboration with the Jet Propulsion Laboratory in Pasadena, Berkeley Lab has been doing studies on necessary simulation codes leading to understanding the detector system geometry, triggering modes, data acquisition, fault analysis, and physics performance. The next stage is for a broader approach to the development of the microcircuit technology and larger-scale simulations of the detector performance. At the end of the design phase, the new technology needed for a fully engineered design and scientifically optimized km-scale detector for high-energy neutrino astrophysics will be in hand. Deployment of full-function prototypes could begin in 2000.

Km-Scale Neutrino Observatory Design Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.5	0.8	0.8	0.7	0.2	0.0	3.0
Equipment	0.2	0.3	0.5	0.4	0.1	0.0	1.5

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Code KA, KB).

Health and Environmental Research

Genome Sequencing Initiative

A Genome Sequencing Initiative is intended to leverage the technology and expertise that thrive in the Berkeley Lab's Human Genome Center (HGC) towards large-scale DNA sequencing challenges. The HGC is oriented almost exclusively towards developing and implementing directed methodologies for cost-effective and accurate high-throughput human DNA sequencing. This work has five components. The first three components of the Center are all involved with new technology development for sequencing and are based on a collaboration between biologists, the automation group, and computer scientists. The fourth component is the sequencing production effort itself. The fifth component of the HGC is the biology effort that interfaces with and performs experiments derived from the completed sequence data.

The first component of the HGC, the biology component of the new technology group, has developed a directed strategy of DNA sequencing in which high-resolution physical maps are generated so that a small set of standard primer binding sites are positioned throughout the target sequences at every 300 base pairs. This mapped set of templates is then sequenced. Using this strategy, templates can be selected in a minimally redundant fashion, which means that template preparation requirements are reduced tenfold and sequencing reactions can be reduced fivefold. In addition, sequence assembly is straightforward because all the templates are mapped in relation to each other, with a resolution of about 30 base pairs, prior to sequencing. The biology group is continuing to optimize the biological procedures of the directed process.

The second component of the Center is the automation group, which is developing instrumentation to support the directed sequencing approach. Some of the modules have been completed and are currently in use: an image station that captures and analyzes the mapping information from agarose gels, a colony picker, an oligonucleotide synthesizer, and a robotic library replicator. Novel approaches to sizing DNA fragments using mass spectrometry, capillary electrophoresis, and high-density slab gel electrophoresis are all in the late development stages.

The third component of the HGC is the informatics group. The major goal of the group is to develop software that facilitates the sequencing effort. The developmental effort is aimed at all aspects of the process, beginning with the physical mapping efforts, continuing through the generation of the high-resolution map and template selection, followed by sequencing and assembly of templates, and concluding with the analysis and dissemination of the sequencing information. The programs that keep track of and display the physical mapping data are nearing completion. The emphasis of the work is shifting now to sequence assembly, editing, and analysis. Another aspect of the work is focused on developing mechanisms to make the data publicly accessible as it is being generated.

The fourth component of the Center is the production effort. More than 5 million base pairs of finished sequence have been completed. It is expected that the production group will almost double the current amount of finished sequence by completing about 5 million additional base pairs during the current calendar year.

The final component of the HGC is the biology program, which has been reconstituted to be closely integrated with the overall sequencing effort. The biology effort plays a role in selecting templates and then develops biological programs to interpret the large amounts of data in a biologically meaningful fashion. This program is addressed in the Environmental Assessment and Environmental Impact reports for the Human Genome Laboratory.

The collaborative efforts with the HGC are aiming towards the establishment of an automated venue for sequencing that will be ready in approximately 18 months. Current planning estimates suggest that this facility will have the capacity to sequence at least 100 megabases of genomic sequence per year.

Genome Sequencing Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating							
DOE	8.5	8.9	9.4	9.8	12.0	12.0	60.6
NIH	10.6	14.4	16.1	13.4	14.0	14.0	82.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority from DOE (B&R Code KP) and NIH.

Transgenic Research Initiative

A significant opportunity exists for Berkeley Lab to expand its transgenic capabilities and utilize the resources associated with the HGC. To fully realize the value of the mapping and sequencing information generated by the HGC, new genes must be identified and their biological function characterized. The genetically engineered mice will clearly play a fundamental role in the discovery of important human genes and the understanding of their function in biology and disease. The Transgenic Initiative is intended to advance Berkeley Lab's expertise in generating transgenic animals and enable Berkeley Lab's Transgenic Facility to better serve the greater scientific community.

The facility produces transgenic animals for Berkeley Lab investigators, enabling major studies of gene function in development and disease. The facility currently constructs animal models for such disease conditions as atherosclerosis, sickle cell disease, thalessemias, Down's syndrome (utilizing DNA provided by the HGC), and cancer. Other Berkeley Lab transgenic projects include the study of such basic biological questions as the control of steroid receptors, RNA editing, and novel interlukin sequences. In parallel with the generation of transgenics, the facility has developed the capability for inactivating genes in mice through targeted mutagenesis of embryonic stem cells. This system has proven effective for the production of germ line chimeras with high frequency.

To optimize the relationship between the facility and the HGC, new technologies need to be pursued. These include: (1) improved construction of *in vivo* libraries of regions of the human genome in transgenic mice; and (2) methods for creating large targeted deletions in mice of regions syntenic to areas of the human genome being deciphered by the Berkeley Lab HGC. The introduction of Human Yeast Artificial Chromosomes (YAC) into the mouse genome (YAC transgenics) has provided a technically feasible approach for creating *in vivo* libraries of large defined segments of the human genome in mice. *In vivo* libraries provide the ability to study novel phenotypes in the animal as well as enable the complementation of existing mouse mutations. The latter approach allows for the recovery of previously undetermined human homologues for existing mouse mutations.

This initiative will position the Berkeley Lab Transgenic Facility to serve as one of the premier transgenic facilities. The facility is ideally set up to provide cost-effective transgenics for investigators who do not possess the capabilities or resources to generate their own transgenic animal models. Berkeley Lab's transgenic expertise extends beyond mere production of transgenic animals. The facility possesses a strong instructional component. It provides inexperienced investigators with advice on construct design and preparation as well as instructions for screening and maintenance of the transgenic lines. The facility thereby provides a rational course for planning well-designed experiments, minimizing the number of DNA constructs and transgenic animals entailed, and ensuring successful results.

Transgenic Research Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.4	0.5	0.5	0.5	0.6	0.6	3.1
Construction	0.0	2.0	2.0	0.0	0.0	0.6	4.6

[a]Preliminary estimate of actual-year Budget Authority (B&R Code KP).

Environmental Biotechnology Initiative

The Center for Environmental Biotechnology (CEB) coordinates and implements all interdisciplinary, multidivisional research in environmental biotechnology at Berkeley Lab. CEB focuses on such environmental issues as: mixed contamination at DOE defense labs, defense base closures, petroleum refining and exploration, computer/metal electroplating industries, ore mining and processing, ground water/sewage, agriculture, aquaculture and forest-related wastes, as well as marine, wetland/marshland/ sediment pollution. Both basic and applied research programs are being established under six key focus areas:

Molecular Evolution of Microorganisms in Damaged Environments. Microbial community analysis is needed on how selective pressures have altered community function to not only tolerate, but to degrade or detoxify, hazardous or toxic material. Research is needed to characterize the genetic structure and code of microbial communities and the interaction with different or diverse members of the population. Comparisons to identified strains from clean sites or within existing culture collections will answer some basic questions and be useful in performing metabolic engineering that is stable and competitive within the ecosystem being examined.

Monitoring of *In Situ* and *Ex Situ* Bioremediation. Mass transfer in bioremediation is inadequately understood because of the limitations of technology to monitor microbial activity. Use of stable radioisotopes to monitor carbon metabolism and other gases present in soil as byproducts or end products of microbial metabolism is being investigated both at the bench and in the field. Applications of mono-layer polyacetylene films for use as environmental monitors of microbial activity also are being addressed.

Natural Augmentation of Bioremedial Activity. Indigenous microorganisms that have been exposed to contaminants can form robust populations through natural selection, enabling the microbial community to use the contaminant as a substrate for metabolism. Understanding how to consistently augment this robust population may have an advantage in optimizing bioremedial activity. Research is focusing on optimizing natural augmentation by incorporating ecophysiological parameters such as moisture, pH, salinity, redox potential, solubility, etc. This optimization would improve and stabilize microbial metabolic processes and allow evaluation of competition factors, such as waste products, soil binding properties, and gas–water interface effects on nutrient and microbial transport, that may affect establishment of an active community.

Structure–Function Relationships of *In Situ* and *Ex Situ* Bioremediation. Some of the barriers to employing microorganisms more effectively for remediation of contaminants in the field have been due to inadequate understanding of cell physiology in a natural environment. Research focus is on developing better kinetic models for bioremedial activity as it occurs *in situ and ex situ* in bioreactors. Physiological studies based on structure–function relationships, and examination of biofilm formation in different geological matrices, would improve our application of bioremediation in the field.

Health-Risk Assessment of Potential Hazardous Materials. The focus is on basic research and the development of assays using primary human cells and measurement of the levels of DNA damage and repair in order to better understand how pollutants are actively metabolized. We are assessing the health risk to humans by determining which pollutants, if ingested, inhaled, or absorbed, can be deleterious to human cells by causing abnormalities in cell structure and function after being metabolized by the cells.

Ecotoxicity Assessment of Bioavailability. This area concentrates on exposure to bioavailable genotoxic substances, on linkages between genotoxic responses, and on the resultant reproductive and developmental effects. By determining the effect of acute (high-dose, short-exposure) and chronic (low-dose, long-exposure) pollution exposures of small animals, and by assessing genotoxic damages *in situ*, realistic predictions can be made of the biological effects of genotoxic substances before they are discharged.

In addition to the main research thrust areas, this Berkeley Lab program administers and directs the Bioremediation, Education, Science and Technology (BEST) Program, which helps minority students to obtain hands-on experience in field operations and the laboratory. It is linked with CAL-EPA to validate and certify new environmental biotechnology for field applications. CEB focuses on integrating all of the existing capabilities within Berkeley Lab and establishing key synergistic links with outside laboratories. The use of this approach will save much time and money in the solving of several key environmental pollution problems within the DOE and DOD, as well as in the state of California.

Environmental Biotechnology Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	6.0	8.0	10.0	10.0	10.0	10.0	54.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP, EM, and Work for Others).

Boron-Neutron Capture Therapy Initiative

A brain cancer called *glioblastoma multiformae* (glioma) afflicts some 12,500 people a year in the U.S. alone and is almost impossible to treat by currently available means. One highly promising treatment approach is Boron-Neutron Capture Therapy (BNCT), in which the patient is given a medicine that contains boron. The boron-containing compound selectively accumulates in the malignant cells. The cancerous area is then exposed to a focused beam of neutrons. After capturing neutrons, the boron nuclei break apart, emitting very short-range radiation to destroy the cancer cells. Although glioma is the top-priority target, because its location and complicated geometry make it so resistant to complete removal through surgery, other cancers might prove treatable with BNCT if suitable boron compounds can be developed.

Now is the right time to re-examine BNCT in a tightly focused program of applied research and development that culminates in clinical trials. Two key advances have made it attractive: new, more-effective ^{10}B-enriched tumor-seeking compounds are available, and improved neutron sources can be made using accelerator technology rather than nuclear reactors. Berkeley Lab is in a unique position to host the development of this "next-generation" BNCT because of its accelerator expertise, surplus equipment from the decommissioned Bevalac accelerator, and long tradition of collaboration with medical centers that have world-class cancer research programs, such as UCSF.

To take advantage of these strengths, Berkeley Lab has formed a clinical working group, the West Coast Neutron Capture Therapy Association, that brings together personnel in all the relevant specialties from national laboratories and major university medical centers. We are seeking DOE support of a multifaceted BNCT program, encompassing technology development, basic science, clinical trials, and technology transfer. The goal is an aggressive, parallel-track R&D program that will build a Berkeley Lab treatment facility, develop ^{10}B-enriched compounds and supporting clinical techniques such as dosimetry and delivery verification, and conduct clinical trials on human patients by 1999.

Boron-Neutron Capture Therapy Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	1.0	2.0	3.3	3.3	3.3	3.3	16.2
Construction	1.7	1.5	0.0	0.8	0.0	0.0	4.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP).

Computational Biology Initiative

The Computational Biology Initiative seeks to link the revolutionary gains made in computer science and information management with the recent strides made in biology research for the understanding of complex data types and the inherent diversity of living things. At Berkeley Lab the primary focus will be to relate the information being generated from genome research to the next higher level, which is the folding, structure, and function of proteins. The ultimate goal is to increase our ability to use information about sequence in areas as diverse as: (1) factors related to individual susceptibility to exogenous chemical and physical influences; (2) signaling cascades; (3) subcellular structure and regulation; and, even, (4) re-engineering of protein sequence and function for improved performance in bioremediation. A second area of interest is computational modeling of nucleic acid structure, especially in chromatin, to account for observed data on effects of ionizing radiation and other environmental mutagens and carcinogens.

The Computational Biology program at Berkeley Lab would draw on several major areas of biology represented within the Laboratory, as well as on the expertise of the Information and Computing Sciences Division. In addition to the Structural Biology Division, the biology areas within the Life Sciences Division would be expected to play an active role. These areas include the Human Genome Center, the Department of Subcellular Structure, the Department of Radiation Biology, the Department of Cancer Biology, and the Department of Molecular and Nuclear Medicine. This effort represents an interdivisional activity at the Laboratory, as well as an interoffice partnership within DOE. Our long-term goal is the establishment of a Center for Computational Biology at Berkeley Lab.

As DNA sequences become available, the determination of the putative sequence of the protein gene product becomes a simple application of the translation of the genetic code from DNA to amino acid sequence. However, once given the amino sequence, neither the three-dimensional secondary structure nor the tertiary structure can readily be predicted. The flexibility of the units and the number of monomers mean that it is not feasible to search for all of the possible solutions. In reality, many of the techniques, such as energy minimization, give no assurance that the biologically interesting structures are observed.

The Computational Biology program at the Laboratory will develop theoretical tools to understand protein folding both by a top-down approach and by a bottom-up approach. The top-down approach will build on exciting expertise that currently exists at the Laboratory in neural network programming to extract rules and principles from the growing database of solved structures. The bottom-up approach will focus on molecular dynamics studies of hydration around hydrophobic and hydrophilic amino acid side chains, with the objective being to add realistic hydration effects in *ab initio* computation of the folding process.

Computational Biology Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.5	0.8	1.5	2.0	2.0	2.0	8.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP).

Fusion Energy

Heavy-Ion Fusion Science Facility Initiative

The U.S. Inertial Confinement Energy Program is applying and enhancing its research expertise and experience to assess and develop heavy-ion accelerators as drivers for an inertial fusion energy source for commercial power generation. The results of successful single-beam transport and multiple-beam experiments provide encouragement and justification to conduct larger, more complex experiments. The principal remaining accelerator issues that must be resolved to build a full-scale fusion driver are cost and the preservation of good beam quality under a variety of beam manipulations. These manipulations include acceleration, beam transport, beam bending, beam combining, longitudinal compression, and transverse focusing.

Berkeley Lab had proposed experiments to address nearly all remaining issues, but by late 1995 it became clear that funding was not forthcoming, so we restructured the program. It now has two principal thrusts: (1) accelerator and plasma science and (2) enabling technologies.

Accelerator science itself is largely the science of nonneutral plasmas. This research is synergistic with the new laboratory-wide effort in numerical science inspired by the transfer of NERSC. We plan end-to-end numerical simulations of existing and proposed accelerator systems. But it is still necessary to build a new accelerator for continued progress toward fusion energy.

Our work in accelerator and plasma science and our development of enabling technologies will lead to the construction of a multi-kilojoule accelerator that will not only address the remaining beam-manipulation issues like the experiments we proposed earlier, but also support a wide variety of experiments in beam-target interaction physics, the physics of high-energy density, and fusion target physics.

Together with results from the National Ignition Facility, this "final step" machine will, by 2005, provide *all* the data necessary to determine the feasibility of inertial fusion energy production. We plan to submit a Conceptual Design Report for the new machine in early FY 1998, leading to a four-year construction schedule beginning in FY2000. Research and Development Associated with Construction (RDAC) will begin in FY 1998. The expected total project cost of the new machine is $150 M.

Heavy-Ion Fusion Science Facility Initiative Resource Requirements ($M)[a]

Category	Prior Years	1997	1998	1999	2000	2001	2002	Total
Operating	5.0	7.0	5.0	5.0	5.0	5.0	5.0	37.0
RDACS	0.0	0.0	2.0	5.0	2.0	2.0	2.0	13.0
Construction	0.0	0.0	0.0	0.0	27.0	40.0	40.0	107.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (B&R Code AT) in FY 1995 dollars.

Energy Efficiency and Renewables

Building Performance Assurance Initiative

Berkeley Lab has launched the Building Performance Assurance Initiative to address the need to improve commercial building performance in the area of energy savings, comfort, and productivity. Over the last 15 years, Berkeley Lab researchers have played a critical role in developing the technology base for several new highly efficient, energy-saving building components (e.g., electronic ballasts, low-E windows) that have now achieved widespread use in buildings. Another big savings can occur, first through the integrated systems

analysis of an individual building's energy use, and then through implementing, commissioning, energy-use tracking, and diagnostic procedures that will assure proper performance of the building over its life cycle.

Commercial building performance in the U.S. consistently falls short of its potential, with costly results to people and institutions. Energy use in commercial buildings accounts for $85 billion per year, more than half of which could be saved if the experience in a small number of unique, carefully designed and operated buildings could be widely replicated. Such individual buildings have been designed, built, and operated to use less than half the energy of typical design practice today, and with levels of comfort, health, and productivity that exceed today's norms. The challenge is to develop and standardize a set of integrated building life-cycle computing tools and information systems that will incorporate all of these techniques so that they lead to significant cost savings in U.S. energy resource use.

The technical prescription to assure better building performance is conceptually simple: (1) using computer-based design tools, develop integrated building systems that meet occupant comfort and performance needs at less than half the energy intensity of today's new buildings; (2) construct the building as designed; (3) employ sophisticated but cost-effective commissioning procedures—a series of controlled subsystem functional tests during the startup of a newly constructed building—to verify that the building initially operates as designed; and (4) implement appropriate performance tracking and diagnostics procedures to ensure that ongoing operation continuously meets occupants' needs and building efficiency criteria.

The Building Performance Assurance's main project is composed of a number of related advanced development projects to create the following elements:

- The Building Life-Cycle Information Support System provides the information infrastructure for data exchange and archiving. A standard information infrastructure allows interoperable software tools to share information throughout the building life cycle.
- Design tools such as PowerDOE (formerly DOE-2) and the Building Design Advisor provide architects and engineers with the capability to predict the energy consequences of various design alternatives.
- Commissioning information tools verify that the major building heating, cooling, lighting, and control systems are capable of operating as designed.
- Performance evaluation and tracking tools continuously monitor and document building performance parameters and eventually link to diagnostic tools that provide automated assistance in improving ongoing building performance.

The project not only brings together the expertise of all parts of the Center for Building Science in the Energy and Environment Division, but also includes collaboration with the Information and Computing Sciences Division and the UC Berkeley campus. Several of these projects also have industrial partners and will produce useful near-term impact data as the research proceeds. This overall program is expected to change the total life cycle of buildings to make them ultimately more resource efficient and productive, thereby yielding major reductions in building operating costs and energy use impacts.

Building Performance Assurance Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	2.5	4.0	5.0	5.0	5.0	5.0	26.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab Budget Authority (B&R Code EC and Work for Others).

Energy Technologies for Developing Countries Initiative

The purpose of this initiative is to provide assistance to developing and transitional countries in their choice and application of energy technologies. The program supports technology choices that—when

compared with typical current technology—produce or use energy more efficiently, reduce emission levels of pollutants and greenhouse gases, and are economically competitive or superior on a life-cycle cost basis.

The new program consists of seven elements: (1) energy technology adaptation, (2) demonstrations, (3) key country programs (including China and India), (4) one-stop shopping network, (5) training, (6) applied R&D, and (7) institution building in developing countries and Eastern Europe. Initial work on the program began within the Office of Policy, Planning and Education during FY 1993. The program continued in the Policy Office in FY 1994, and was transferred to the Office of Energy Efficiency and Renewable Energy in FY 1995. During the transition, the specific program disappeared, but the activities contained within the initiative continue to receive financial support. A further development resulted in the creation of two new interagency activities, U.S. Country Studies and the U.S. Initiative on Joint Implementation (IJI). These two activities together accomplish many of the same objectives as the original initiative. The IJI activities also serve to promote partnerships on energy and environment projects between the United States and individual developing nations.

This program will be especially valuable in responding to needs of developing countries, the former Soviet Union, and Eastern Europe for technical assistance in limiting greenhouse gas emissions in a highly cost-effective manner. It will also provide important benefits in reducing future global oil demand and in helping to establish international markets for U.S. energy technology. This program is an important United States contribution to support recommendations made by the Intergovernmental Panel on Climate Change and the United Nations Conference on Environment and Development. The resources indicated below are for Berkeley Lab's activities for the national DOE program. Specific research proposals will be reviewed for NEPA and CEQA compliance requirements.

Energy Technologies for Developing Countries Initiative
Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	1.5	2.0	2.2	2.4	2.8	3.0	13.9
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Code PE).

Environmental Management

SELECT: A Science-Based Framework for Cost-Effective Environmental Cleanup Initiative

The SELECT framework directly addresses a national need to manage environmental cleanup systematically, and to make cost-effective decisions based on comparative risk analysis. The goal of the SELECT initiative is to design and develop a flexible, PC-based, object-oriented software system that will integrate, analyze, and present environmental information to all the different stakeholders who must confront waste cleanup problems—including site managers, engineers, scientists, regulators, and the public. It will assist these users in choosing cost-effective environmental remediation strategies based on scientifically sound risk analysis. SELECT primarily focuses on (1) cost-effective environmental remediation based on a comparative health-risk analysis of alternative remediation strategies, and (2) information visualization tools that enhance communication among stakeholders.

The initiative was spawned from the scientific advances that Berkeley Lab scientists made through DOE-supported research such as the OHER radon research program, the OBES geosciences program, and the radioactive waste program. This DOE-developed core competency at Berkeley Lab encompasses subsurface site characterization, contaminant transport, fate and exposure models, estimates of cancer risk from contaminant exposure, and the evaluation and improvement of remediation effectiveness, technologies, and

strategies. A number of features distinguish SELECT from similar activities elsewhere: its modeling of actual physical processes (as opposed to regulatory processes), its focus on human health risk reduction in a comparative context, and its ability to incorporate the most up-to-date scientific knowledge.

The SELECT methodology and the current prototype have been developed to demonstrate how we can model over time the current and future states of a contaminant plume for several remediation alternatives. The plume transport simulation is linked to a model that allows the user to assess multiple pathway exposures to households that have direct or indirect contact with the plume. Using rodent carcinogenic potency values and exposure estimates, including estimates of (often profound) uncertainty, potential cancer risk is estimated. Where possible, pharmacokinetic analyses of cancer risk are incorporated. Possible cancer hazards are compared to similarly estimated hazards from typical exposure to rodent carcinogens, e.g., to natural chemicals in the diet, which are common background exposures of the population. Costs associated with a specific remediation action are integrated with risk estimates to identify cost-effective strategies. Secondary risks produced by remediation are also evaluated. Information visualization tools are used to reduce the information to an understandable form that site managers can use to formulate strategic plans and that the public and other stakeholders can readily understand.

The SELECT initiative team is working to transform this prototype into an Internet-accessible computing tool that addresses the cleanup issues facing DOE, DOD, and the private sector. Major milestones for the five-year program include:

- Completion of a comprehensive uncertainty analysis
- Inclusion of all major VOCs
- Development of a robust economics model
- Inclusion of metals and radionuclides
- Expansion to include reproductive and ecological risks

At present, the SELECT methodology incorporates evaluation of uncertainties due to variability in population exposures. We are now extending the uncertainty analyses to additional components of SELECT (e.g., cancer potency, subsurface transport modeling), and are developing new methods for dealing with the overall uncertainties that arise from linking many different kinds of models—from transport to cancer potency—each of which is formulated differently. Currently, there is no consensus approach for comprehensive treatment of key sources of uncertainty in estimates of cancer potency for most rodent carcinogens, even though these may dominate all other uncertainties. We are working to develop flexible ways to represent, evaluate, and rank uncertainties and variability associated with exposure and potency data, utilizing reliable data evaluation methods and modeling techniques. Methods for estimating overall uncertainties for SELECT present a challenging scientific problem that will have applications to other integrated assessment models.

SELECT Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	2.0	2.5	3.0	3.0	3.0	3.0	16.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Codes EM, KP, and Work for Others).

Civilian Radioactive Waste Management

Yucca Mountain Percolation Flux Initiative

Percolation flux has been identified as one of the most important parameters to quantify for determining the suitability of Yucca Mountain, or any other possible site, for long-term storage of the nation's nuclear waste. In the case of Yucca Mountain, it is particularly important to test the key hypothesis of low seepage into the repository. Preliminary data showing the presence of young water at the repository level accentuate the need to understand the partitioning of flow between slow tuff matrix and fast paths, both in the vicinity of faults and away from mappable features in the potential repository area. Those in scientific programs need to know the variation in percolation flux in order to understand the unsaturated zone flow processes and to lend more realism to the calibrated site-scale and drift-scale models. Performance assessors need quantification of the percolation flux in order to determine the amount and distribution of water contact in drifts that will impact total system performance. Repository designers also need the information in order to plan the repository layout to avoid potential fast-flow paths and to assure stability of excavation near faults.

Berkeley Lab has prepared a detailed plan focusing on the site's Viability Assessment and Site Suitability determination. The purpose of this proposed testing and modeling program is determination of the percolation flux. The program will demonstrate the viability of the unsaturated zone as an effective barrier, provide understanding of fast paths in draining infiltration, and confirm unsaturated zone site-scale models and drift-scale submodels needed for Performance Assessment. An extensive set of data will be collected to generate spatial distributions (contour maps) of all relevant parameters that are important in determination of percolation flux. The main objectives of the test are to: quantify percolation flux, age of water, and parameter distribution; quantify seepage flux into drifts; determine the impacts of faults on percolation and age distribution; partition the percolation distribution between matrix flow and fast-path flow; calibrate models for site-scale representation of fluxes; and confirm conceptual models of the Yucca Mountain system. This information will be crucial to evaluation of waste isolation capability for the Viability Assessment in 1998, the Site Suitability Decision in 2000, and the License Application in 2002.

Yucca Mountain Percolation Flux Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.8	2.0	2.0	1.5	1.0	0.0	7.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority (B&R Code DB).

Other Sponsors

Advanced Lithography Initiative

A challenge to continued U.S. industrial competitiveness in microelectronics is developing techniques of lithography and pattern transfer at minimum feature sizes of less than 0.18 μm. This will lead to densities of over 10^9 transistors per chip. The advanced lithography program at LBNL's Center for X-Ray Optics (CXRO) focuses on the enabling technologies essential for soft x-ray (SXR) and extreme ultraviolet (EUV) optical imaging systems. These systems will be required for the creation of 0.1 μm features, implying the existence of 1-Gbit DRAMs. CXRO's lithography program will concentrate on the development of EUV/SXR interferometry for at-wavelength (130 Å) testing of optics, nanofabrication facilities for zone plates and reflective masks, high-precision metrology, and the necessary processing for pattern transfer.

LBNL's initiative responds to programmatic needs established by both the Department of Defense, the Department of Energy, and the U.S. Semiconductor Industry. A successful program requires an integrated consortium of industrial, university, and national laboratory scientists to break new scientific and technical ground well in advance of the competition and to train a new generation of scientists to carry the project to fruition in the 21st century. The consortium will need dedicated laboratory research facilities with modern high-brightness, partially coherent x-ray and EUV sources; expertise in short wavelength nanometer-scale structures; and the synthesis of new materials whose structures are controlled at the atomic level. ARPA, the DOE, and a local semiconductor company have already invested in the ALS facilities and are seeking a broader collaboration. These facilities will include insertion devices, bend magnets, and beamline components; metrology stations to test all optical surfaces and coatings; and advanced EUV interferometers for testing optical surfaces and integrated optical systems; as well as equipment that will support the fabrication of nanostructures and the synthesis of artificially structured materials. Specific initial elements are to include:

- A high-brightness coherent undulator beamline for at-wavelength EUV interferometry
- A direct-write electron beam "nanowriter" for diffractive optics and mask patterning
- Component and system EUV interferometry
- An EUV metrology bending magnet beamline for absolute radiometry and calibrations

A continued investment would further the consortium efforts and lead to improved American competitiveness in this critical technological area. Costs include operational procedures and equipment design in compliance with DOE ES&H orders and regulations. As proposals under this program are developed, they will be reviewed for NEPA and CEQA documentation requirements.

Advanced Lithography Initiative Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating[b]	3.0	3.0	3.0	2.5	2.5	2.5	16.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate of Berkeley Lab actual-year Budget Authority from DOD.
[b]Costs are primarily for equipment through FY 1999.

X-ray Etching of Microelectromechanical Systems Initiative

Microelectromechanical systems (MEMS) systems are made by applying processing techniques developed for the semiconductor industry to the design of microscopic sensors, actuators, motors, and passive devices. This technology provides a powerful tool for mass production and miniaturization of mechanical systems to a dimensional regime not available to traditional machining operations. The synergy with integrated circuit manufacturing provides the potential for integration of mechanical systems with associated electronics.

One technique specifically developed for the creation of high-aspect-ratio devices is called LIGA (a German acronym for Lithographie Galvanoformung, Abformung). LIGA is a combination of deep x-ray lithography, electroplating, and injection-molding processes that allows the fabrication of microstructures with lateral dimensions as small as a micrometer, vertical dimensions of several hundred micrometers, and 0.1-micron tolerances. This type of x-ray lithography depends on the existence of synchrotron radiation sources that can provide a sufficient flux of highly parallel x-rays in the 3–10 keV range. The ALS is an excellent source of radiation for this application. The techniques of deep x-ray lithography are used in the construction of passive structures, micromotors, acceleration sensors, microgears, and linear comb drives. We have demonstrated the basic processes in collaboration with JPL, SNL-CA, and SSRL and are now actively designing and fabricating novel micromechanical devices that exploit the properties of deep x-ray lithography for academic and industrial clients.

This technology can revolutionize the energy, automobile, aerospace, and medical fields in the same manner that integrated-circuit process technology revolutionized the electronics industry. Berkeley Lab seeks solutions to the basic problems that currently slow the acceptance of this technology.

X-ray Etching of Microelectromechanical Systems Initiative
Resource Requirements ($M)[a]

Category	1997	1998	1999	2000	2001	2002	Total
Operating	0.3	1.5	1.5	0.6	0.6	0.6	5.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Preliminary estimate at Berkeley Lab actual-year Budget Authority from DOE (ER-LTA) and Work for Others, including DOD and NASA.

PROGRAM DIRECTIONS

Berkeley lab has a broad range of sponsors for its multidisciplinary scientific and technical research. A resource summary of major programs is included as Secretarial Office Funding (p. 6-3) of the Resource Tables.

Office of Energy Research

Basic Energy Sciences

Materials Sciences

Berkeley Lab is one of the world's leading centers of research in materials sciences and the chemistry and physics of materials that are important to both the production and efficient use of energy. In addition, outstanding programs exist in advanced energy projects, in engineering and geosciences, in biological energy research, and in applied mathematics. Several of these programs are expected to expand, as indicated below.

Basic Energy Sciences (BES) programs in materials sciences will continue to emphasize new and forefront research projects for the synthesis, processing, and characterization of advanced materials. Expanded areas include the design and construction of synchrotron-radiation instrumentation and its application to important programs in materials sciences and advanced materials synthesis and fabrication technologies, especially at the atomic scale. Leading programs continue in x-ray optics, electron microscopy, solid-state physics, surface sciences, catalysis, polymers, biomolecular materials, metallurgy, electrochemical materials, electronic materials (including super- and semiconductors), ceramics, and materials chemistry. The ALS, a third-generation synchrotron-radiation facility, produces the world's brightest beams of ultraviolet and soft-x-ray radiation. The commissioning of the injection system and storage ring has been completed. The ALS, Center for Advanced Materials (CAM), Center for X-Ray Optics (CXRO), and National Center for Electron Microscopy (NCEM) are organized interdisciplinary research centers that bring DOE resources to bear on scientific challenges of national importance.

In support of the ALS, the Laboratory is conducting research on storage-ring physics and engineering, ultrahigh-vacuum technology, instrumentation and feedback systems, insertion devices, beamline optical systems, and magnet systems. At CXRO, research is conducted on advanced optical-system components for the utilization of high-brightness photon beams.

CAM will continue major research efforts selected because of their potential impact on U.S. industrial strength. The research focus evolves with new discoveries and with the changing needs of U.S. industry and

the programs of the DOE technology offices for fundamental research to underlie its technology base and developmental activities. The following programs presently constitute the major emphasis of CAM.

- The Surface Science and Catalysis Program focuses on studies of advanced catalysts for clean fuels, pollutant reduction and methanol synthesis, and the atomic-scale surface structure and chemical and mechanical properties of solids and adsorbed monolayers. Advanced surface instrumentation includes nonlinear optical techniques, scanning tunneling and atomic-force microscopies, and advanced Raman spectroscopy.
- The Electronic Materials Program focuses on theoretical and experimental studies of basic materials problems pertinent to the development of advanced electronic and optical materials. Semiconductor thin-film crystal growth and characterization, and comprehensive investigations of structural properties of heterointerfaces are pursued.
- The Polymers and Composites Program pursues polymer synthesis and studies of the relationships between polymer processing and microstructure, focusing on anisotropic materials and surface interactions between polymer liquids and metals.
- The High-Performance Metals Program addresses the mechanisms of structural failure, including fatigue and fracture in metals and intermetallics, and is concerned with the theoretical and experimental studies of the properties and development of metal alloys, formable steels, advanced intermetallics, and materials for high-field superconducting magnets.
- The Ceramics Science Program supports research on the development of predictive, quantitative theories of densification and microstructure development, the application of these theories to produce and evaluate advanced structural ceramics with improved high-temperature performance, and a new understanding of fatigue and other failure mechanisms in ceramics.
- The Biomolecular Materials Program explores the application of recent advances in biochemistry, molecular biology, and bioorganic chemistry to the synthesis of novel materials. Emphasis is on the use of natural, genetically engineered, and "created" enzymes; novel (bio)polymers; and self-assembling thin films to control surface properties and form the basis of sensors.
- The High-T_c Superconductivity Program focuses on basic science, including theory, synthesis, and characterization of new materials, and on thin films and their applications, including devices such as SQUIDs and bolometers.

NCEM, a national user facility, is supported by the DOE Metallurgy and Ceramics Program but contributes substantially to research in other fields, such as biology and geology. The heart of NCEM consists of two microscopes: the High-Voltage Electron Microscope, the most powerful microscope of its kind in the U.S.; and the Atomic-Resolution Microscope, with a resolution of 1.5 Å, currently the highest in the U.S. To maintain U.S. leadership in electron microscopy, we are proposing to enhance the Center through the design and acquisition of new state-of-the-art microscopes.

Research at NCEM is carried out on a wide range of materials, including studies of high-temperature superconducting materials, structural materials, magnetic materials, ceramics, and amorphous silicon semiconductor materials. Research on the structure and properties of transformation interfaces has the goal of determining the atomic configuration at structural boundaries and the relationship between structure and properties at the interface.

Berkeley Lab participates in the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials. Materials Sciences Division investigators lead projects in the seven focus areas: Metal Forming, Materials Joining, Hard Magnets, Surface Hardness, Corrosion Coatings, Photovoltaics, and Polymers.

Chemical Sciences

DOE's Chemical Sciences Program supports focused research in several Berkeley Lab divisions. Efforts in the Chemical Sciences Division emphasize chemical physics, dynamics and mechanisms of chemical reactions and combustion processes, catalysis, electron spectroscopy, atomic physics, photochemistry, theoretical chemistry, and chemistry of the actinide elements and their relationship to environmental issues.

Programs in the Energy and Environment Division focus on advanced combustion and the mechanisms for minimizing emissions and improving fuel efficiency. In the Structural Biology Division, programs in photochemistry and the chemistry of electronically excited molecules are being conducted. In the Nuclear Science Division, a study of the chemical properties of the heaviest elements is being conducted. In the Physics Division's mathematical department, a study of hydrodynamical computational models for combustion processes is being carried out. This research is directed toward developing high-accuracy techniques that take into account both the turbulent flow and chemical interactions of these combustion processes.

The Laboratory's extensive chemical physics research includes several major programs. One program focuses on spectroscopic studies of the structures of reactive intermediates. Laser-induced fluorescence, multiphoton ionization, and negative-ion photodetachment are used to study reactive species such as free radicals and cluster ions that may be important in combustion processes, reactive plasmas, and high-technology manufacturing processes. Techniques such as crossed molecular beams are used for advanced and novel studies of the dynamics of important reactions with the goal of understanding elementary chemical reactions under single-collision conditions or through laser excitation. Berkeley Lab has been at the forefront in the development of crossed-molecular-beam techniques, and this research on reaction dynamics and combustion is expected to grow during the next several years with the chemical dynamics beamline (9.0) at the Advanced Light Source.

The program in reactivity at surfaces and interfaces will involve molecular studies of interfacial phenomena using new techniques in laser spectroscopy and x-ray scattering. The program is designed to gain an understanding of chemical reactivity in key areas of energy science, including nearly all catalytic reaction systems, solar-energy conversion technologies, light-assisted chemical syntheses, electrochemical energy-conversion technologies, and corrosion phenomena. Another effort includes research into the photochemistry of materials in the stratosphere (with applications to the role of trace gases in the "greenhouse effect").

Chemical energy research at Berkeley Lab has revealed new reactions between transition metals, such as rhenium, and organic molecules that are important to the improvement of catalysis involved in coal-conversion processes. Continuing program areas focus on the fundamental chemistry of important environmental and fuel species, including aqueous and gaseous species of carbon and sulfur. Catalytic conversion of carbon monoxide and hydrogen to gaseous and liquid fuels is studied to develop more efficient catalysts for hydrocarbon production.

The goal of research programs in theoretical chemistry is to accurately predict chemical reaction dynamics, especially those that are too complicated to be solved experimentally.

Research in the actinide chemistry program in the Chemical Sciences Division has two thrusts: (1) the design and synthesis of sequestering agents for treatment of actinide poisoning and for possible application to spent reactor fuels, and (2) the preparation and study of new compounds incorporating actinides. A program to investigate the chemical properties of the heaviest elements (Z of 102 to 106) at the furthest reaches of the periodic table is being undertaken in the Nuclear Science Division.

Research in the energy and environment area includes theoretical and experimental programs on ignition, reactivity, turbulence, and energy transfer in combustion systems. Advanced approaches include studies of photodissociation, laser spectroscopy methods, molecular-beam mass spectroscopy, and the use of unimolecular kinetics for the theoretical study of high-temperature reactions important to combustion. Another area of research is laser-material interactions for chemical analysis.

Research in structural biology is directed at a fundamental understanding of the chemistry of electronically excited molecules, with attention on features that relate to the conversion of photon energy and the photo-assisted synthesis of high-value compounds. Projects focus on the manganese catalytic function in artificial photosynthesis, the photoinduced reduction of CO_2 into organic products, and polyelectrolyte interfaces for increasing quantum efficiency in photosynthetic processes. Other work explores chemistry induced by red and near-infrared light, the most abundant form of energy available from the sun. The focus is on redox reactions in solution that may lead to new concepts for chemical storage and conversion of these long-wavelength quanta into electricity and on their use for controlled photochemical

synthesis in a solid matrix. A major new effort is directed at monitoring elementary reaction steps in these environments by time-resolved Fourier-transform infrared spectroscopy.

Engineering and Geosciences

The Geosciences Program at Berkeley Lab is strengthening its multidisciplinary effort to support the scientific basis of many energy- and environmental-related technologies, including development of hydrocarbon and strategic-mineral resources, remediation of toxic waste sites, safe disposal of radioactive and toxic chemical wastes, and exploitation of geothermal energy. Earth sciences researchers at Berkeley Lab are among the leading experts in the areas of subsurface imaging of the structure and dynamics of the earth's crust, experimental investigation of the mechanisms by which lithospheric processes influence energy resources, and numerical modeling of geochemical and hydromechanical processes occurring in heterogeneous fractured rock formations.

Geohydrology research at Berkeley Lab includes experimental studies of the physical behavior of fluid-saturated rock, numerical modeling of coupled processes in subsurface reservoirs, and investigation of the mechanisms associated with chemical transport and multiphase fracture-flow phenomena. New algorithms are being developed to greatly increase the efficiency of the numerical solution of flow and transport equations.

Geophysicists, supported by Berkeley Lab's Geophysical Measurements Facility and the Center for Computational Seismology, are developing methodologies and instruments to define crustal structure over a range of scales, to monitor processes in subsurface reservoirs, and to track the movement of contaminated plumes in underground aquifers. Borehole seismic and electromagnetic source development, coupled with real-time signal processing, are keys to improved high-resolution imaging capabilities. On a laboratory scale, new approaches are being employed to understand fracture processes and wave propagation in fractured media. Other geophysical research uses new computational codes to measure fracture properties in subsurface reservoirs and to map hydrofractures at well sites.

Geochemical studies focus on the thermodynamic properties of electrolytes, the generation and migration of petroleum compounds, and the interactions between minerals and groundwaters. Analytical capabilities of the Center for Isotope Geochemistry provide a powerful means of characterizing natural systems. This center is an important element in many of the multidisciplinary geological and environmental investigations at Berkeley Lab. It provides a focus, in collaboration with geophysicists and geologists, for continued study of crustal processes as part of the multiagency Continental Scientific Drilling Program.

Energy Biosciences

Berkeley Lab's program continues to improve understanding of the unique features of photosynthetic organisms for collecting light energy and storing it as chemical energy. One project uses spectroscopic techniques to map the components and kinetics of light reactions. The genetics of the photosynthetic apparatus of single-celled organisms are studied to allow application of DNA-cloning techniques to elucidate photosynthetic mechanisms. The light regulation of gene-encoding components of the photosynthetic apparatus in plant protoplasts is also being investigated. The DOE Division of Energy Biosciences is also supporting research at Berkeley Lab's Center for Advanced Materials on the enzymatic synthesis of materials.

Computational and Technology Research

Computing Sciences

The Computing Sciences Directorate at Berkeley Lab was formed to pioneer a holistic approach to computational science by bringing together in a single organization:

- The National Energy Research Scientific Computing (NERSC) Center: an extremely powerful computing environment incorporating very great computing capability, capacity, and associated storage;
- The Center for Computational Science and Engineering (CCSE) and the Berkeley Lab Mathematics Department: research groups composed of mathematicians and computational scientists, who are developing the advanced methods, algorithms, and procedures for the solution of very intractable problems in basic science that will make effective use of the NERSC environment;
- The Energy Sciences Network (ESnet): the backbone of DOE's network facilities; ESnet provides access to the NERSC computing environment—and to other research, experimental, and computational facilities—by any scientist in the nation and by international collaborators;
- The Computer Science Research Department: a computer science research program that concentrates on increasing the effectiveness of the NERSC environment (for example, by resolving network congestion problems, developing protocols that facilitate the remote control of experiments, devising methods to support networked multimedia, and devising new data storage and retrieval strategies to facilitate the use of extremely large datasets); and
- A vision of a new, location-independent, way to do collaborative science.

In addition, Computing Sciences is committed to working closely with both industry and the local academic and research communities to ensure the continuing synergy of these disciplines in the creation of new hardware and software architectures to advance the art of computer-assisted science, and to providing for the staff of Berkeley Lab a computing and communications infrastructure that is second to none.

It is perhaps worth saying a few additional words about the vision that is driving Computing Sciences. Although great strides have been made in communications and remote computing, science today is still largely constrained by the scientist's need to have physical proximity to the resources he or she requires, including research, computing, and data-handling facilities, as well as colleagues. Our goal is to remove all location-dependent constraints so that a scientist can control experimental facilities in one place and store the results somewhere else, collect software and additional data from other places and invoke the necessary computational processes at still other sites, all the while conferring in real time with colleagues around the world, just as if they were all at the same location. This exciting prospect for the accelerated development of science has been institutionalized within the Department of Energy as DOE-2000.

The NERSC Center provides high-performance computing, information, and communications services for researchers whose work is supported by the Office of Energy Research (OER). Currently, there are about 4,000 NERSC customer accounts. These researchers work within nearly 200 different institutions across the United States, including national laboratories, universities, private laboratories, and industrial organizations. The OER programs served by NERSC include Fusion Energy, High Energy and Nuclear Physics, Basic Energy Sciences, Health and Environmental Research, and Scientific Computing. NERSC is in the process of installing several new computers at the Berkeley Lab, and by the end of FY 1996 will have several Cray J90s and a T3E, as well as the C90 from Livermore. At the same time, the storage system is being significantly upgraded.

Scientists associated with the NERSC Center are working closely with other scientists supported by OER, at Berkeley and at other laboratories, to develop a number of multidisciplinary initiatives that will exploit the powerful facilities being installed. (Several of these are described in earlier sections of this Plan.) In addition, NERSC staff are continuing the parallelization and optimization of user codes for supercomputers and expanding the Center's use of the World Wide Web for information presentation and retrieval.

For the NERSC Center to fulfill its programmatic mission, it is expected that fairly regular upgrades in both the computational and networking capabilities of NERSC and ESnet will be necessary. In addition, NERSC and Berkeley Lab will pursue a number of vigorous programs in both areas of the DOE-2000 effort: the National Collaboratories and the Advanced Computational Testing and Simulation (ACTS) program.

ESnet supports national and international access to the NERSC Center and, more generally, the needs of DOE scientists and collaborators throughout the world, whether or not they compute at NERSC. ESnet was

created to facilitate access to ER scientific facilities, to provide needed information dissemination among scientific collaborators throughout all ER programs, and to provide widespread access to existing supercomputer facilities. Agreements are in place or being developed to extend availability of ESnet to other program areas of DOE. Specific goals for ESnet development include the avoidance of redundant computer network costs; support for multivendor operations; the introduction and rapid assimilation of appropriate new technologies; support for the distributed computing functions of the National Collaboratories; interfacing with other regional, federal, commercial, and international networks; and providing significant contributions toward national and international efforts to define and establish a global information infrastructure.

Another major component of Computing Sciences at Berkeley Lab is Large Scale Scientific Computation. This program conducts in-depth studies into discretization techniques and adaptive numerical methods, with particular emphasis on studies in fluid mechanics. These studies are especially important, as fluid dynamics plays a key role in a multitude of scientific and technological areas. For example, the performance of combustion systems depends critically on the fluid-dynamic mixing of fuel and oxidants. The design of energy-efficient transportation systems and turbomachinery requires reliable treatment of turbulent-flow phenomena. Environmental examination of the long-term climatological effects of greenhouse gases requires a combination of models for both geophysical fluid dynamics and complex chemical interactions. Advances in computer hardware and numerical methods have brought us to the point where it is possible to study complex physical phenomena by using carefully designed numerical experiments. The goal of this research is to develop the techniques required to model complex fluid flows and to apply these methods to the discovery and analysis of fundamental physical phenomena.

A major focus of the Large Scale Scientific Computational program is computational fluid and combustion dynamics. These efforts support the HPCC Grand Challenge Project on Computational Fluid Dynamics and Combustion Dynamics. The program combines high-resolution finite difference methods with adaptive techniques to focus computational effort where it is required. The algorithms are designed to effectively exploit modern multiprocessor architectures and are being implemented within a software framework that will make the techniques readily accessible to other scientists and engineers in the fluids community. To achieve this end, effort is focused on three objectives. The first is to broaden the range of regimes in which these algorithms can be applied. This goal would be achieved by focusing the research on "Grand Challenge" problems in combustion dynamics and other areas of fluid dynamics that are of considerable scientific and programmatic interest to DOE. The second objective is to develop the programming methodologies necessary to implement these methods on the massively parallel architectures that will provide the computing power required to solve these problems. The third objective is to develop the software tools needed to support the core computational methodology. These tools would include graphical analysis tools to interpret the highly complex, time-dependent, three-dimensional data that are the output from these calculations, user input tools to aid the preparation of models, and software interfaces to make the methodology accessible to a broad range of scientists and engineers. This effort is an integrated research effort between LLNL, LANL, and two university participants—the Courant Institute for the Mathematical Sciences and the University of California at Berkeley.

Ongoing Programs

The program in mathematics at Berkeley Lab centers on the development of numerical and analytical methods and their application to the most challenging problems in physics and engineering. Investigations that were started within the Berkeley Lab Mathematics Department have been at the frontiers of such topics as vortex methods, random-choice techniques, high-resolution methods in gas dynamics, front-propagation techniques, and lattice and polymeric models in turbulence.

The five most active areas are: vortex and particle methods, interface techniques, the statistical mechanics of vortex systems, the parallel implementation of codes for large-scale scientific computing, and fast algorithms. In the first area, recent successes include the design and experimental validation of vortex codes for three-dimensional turbulent flow around complex bodies, rapid implementation of particle methods, and numerical studies of engineering flows and of suspensions. In the second area, we are

developing and applying state-of-the-art algorithms, such as the level-set methodology and new surface integral techniques for following free surfaces. These techniques allow models of complex problems in crystal growth and dendrite solidification, minimal-surface and capillarity theory, two-phase flow, and flame propagation. In the third area, we are implementing renormalization schemes for vortex interactions, have undertaken a systematic analysis of vortex motion in constant temperature systems, and are applying it to problems in superfluidity. In the fourth area, we are one of the leaders in the practical implementation of highly sophisticated codes for realistic problems on massively parallel processors. In the fifth area, we are developing and implementing new fast algorithms for elliptic and parabolic, linear and nonlinear problems.

One recent accomplishment, important for understanding the affects of turbulence on solid objects, was studies on the "Law of the Wall" used for design of aircraft engines, wind tunnels, compressors, and the space shuttle. Based on theoretical studies at Berkeley Lab and UC, experimental results have supported the need to replace the 60-year-old single equation with a family of scaling laws.

The High-Speed Network Research Program will continue to probe the dynamics of congestion on high-speed networks, with the immediate goal of implementing practical multimedia conferencing over ESnet. (Note: Some of the early results of this work received an IR-100 Award in 1995.) This will include extensive network and gateway performance modeling, investigation of the scaling of congestion effects with increasing traffic, and improving the usability and robustness of the conferencing tools that have already been developed.

The Scientific Database Management Research Program will continue to investigate the latest data-management techniques suited to scientific and statistical applications. New requirements arise from the structure of some scientific data (e.g., sparse multidimensional tables, temporal data) and operation needs (e.g., transposition, aggregation, random sampling, proximity searches). Thus, new and efficient techniques for data-storage organization, new algorithms for data manipulation, and new data-modeling methods to improve the semantics of scientific data are being developed.

The Berkeley Lab is the site of a proof-of-principle of the National Collaboratory. A joint effort with the University of Wisconsin demonstrated that we can monitor a complex experimental device (the ALS) by electronic means over a great distance. This work will continue with the development of a collaboratory testbed for the development of safe and effective protocols for direct control of experiments.

A recent area of research, in collaboration with the Xerox Palo Alto Research Center, has been multimedia conferencing. New protocols have been developed to support high-quality audio and video conferencing. New protocols also have been developed to support high-quality audio and video transmission on ESnet and other parts of the Internet. In addition, work is being done to incorporate an interactive "whiteboard," or graphic display window, in which network users can make real-time modifications.

Another expanding area of research and development is the Visualization Laboratory, a facility that will combine state-of-the-art computer equipment and scientific visualization software to provide research scientists with new tools for exploring their data in innovative ways. Construction of the Visualization Laboratory is now nearing completion. Initial users will be the ongoing Berkeley collaborations in such diverse areas as virtual reality interfaces to nuclear medicine treatment of eye tumors and petroleum reservoir simulators. The Visualization Laboratory has been designed to integrate into the NERSC environment, and collaborations between NERSC users and the Berkeley Lab Visualization Group are forming. It is expected that the first NERSC collaborations will be operational before the end of calendar year 1996.

Technology Research

The Laboratory Technology Research Program supports DOE's basic science mission with focused research projects between industry and the national laboratories. The partnership program couples the goals of the laboratories with the needs of industry under a highly selective, cost-effective, merit-reviewed program that optimizes returns to the labs and to industry. Many high-risk, medium-term projects bridge the gap between basic and applied science. The Laboratory Technology Research Program is Berkeley Lab's core

program to further research for technology transfer objectives—from Laboratory-developed science to useful applications for the American public.

Different collaborative funding mechanisms are used to support this program. These include CRADAs (Cooperative Research and Development Agreements), Personnel Exchanges, Memorandum of Understanding, and Technical Assistance Agreements. In all cases, DOE funds support Laboratory researchers only; no dollars pass to industry. At Berkeley Lab, industry has contributed 62% of program funding, which includes a "funds in" component (direct-cash funding to the Lab research project). Funding commitments through FY 96 are shown in the Laboratory Technology Research Funding table, below.

Research projects in the ER-LTR Program focus on intelligent manufacturing, tailored materials, energy and environment, and biotechnology and health. Currently, 106 research projects are funded through the ERLTR Program. Sixty-five projects are collaborations with small businesses; forty-one are with medium-sized and larger companies. Some of our industry partners are: Advanced Lithography Group, Amgen, Applied Materials, Bay Technical Products, Cerametec, Colog, Dupont, General Atomics, General Nanotechnology, Hewlett-Packard, IBM, Intel, Ion Diagnostics, ISIS Pharmaceuticals, Kaiser Foundation Hospital, Motorola, Octree, Optical Coating Laboratory, Quantum Group, Rhone Poulenc, Rouge Steel, SI Diamond Technology, Somatix Therapy, Spectrum Sciences, Sunsoft, Teledyne Lars, and Western Atlas. Projects typically range in size from less than $100,000 to about $2 million.

Laboratory Technology Research Funding[a]

	$ Millions	% of Total
DOE Contributions	25	38
Industry Partner (In Kind)	35	54
Industry Partner (Funds In)	5	8
Total	65	100

[a]Funding commitments through FY 1996.

Core Technology Transfer Program for Laboratory Technology Research ($M)[a]

	FY 95	FY 96	FY 97[b]
Partnership Projects (ea.)	88	76	50
DOE Funding	7.8	7.8	6.1
Industry Partner Funding			
– In Kind	14.5	8.0	6.3
– Funds In	1.7	1.3	0.8
Total Industry Partner Funding	16.2	9.3	7.1
Industry Partner Funding – % of Total	67%	54%	54%

[a]Includes program commitments through FY 1996 and estimated FY 1997 allocations.
[b]Estimated FY 1997 allocations assume QRP Program of $2 million.

Nuclear Physics

Nuclear physics research at Berkeley Lab will continue to focus on the experimental and theoretical investigation of the structure and properties of nuclei, emphasizing studies of nuclei under extreme conditions (temperature, isospin, angular momentum, and energy density). Berkeley Lab research programs are closely coupled with national priorities in nuclear science, as defined in the Nuclear Science Advisory Committee 1996 Long Range Plan for Nuclear Science. The Laboratory research programs also play an

important role in the education and training of young scientists. In addition, ongoing technology development efforts contribute to significant advances in nuclear instrumentation.

Berkeley Lab has played a seminal role in defining the forefront of relativistic heavy-ion physics since the field's inception and continues to maintain its leadership role. Experiments are presently being carried out at the AGS at Brookhaven National Laboratory (BNL) and the SPS at CERN. Analysis of data from Bevalac experiments continues to yield new physics results. The EOS Time Projection Chamber (TPC) has been moved to the AGS (from the Bevalac) to continue its forefront studies at higher energies. At CERN the construction phase of NA49 has been completed and a first successful run with lead beams carried out.

The main focus of the future high-energy heavy-ion research program at Berkeley Lab is the Relativistic Heavy Ion Collider (RHIC), which is currently scheduled to be completed at BNL in 1999. Berkeley Lab is the lead laboratory for the first approved RHIC experiment, the Solenoidal Tracker at RHIC (STAR) detector. With 47 physicists, engineers, and technicians (including the project director) from Berkeley Lab working on this experiment, the STAR collaboration now consists of over 350 physicists and engineers from 34 institutions internationally. Much of the detector construction, now nearing completion, has been carried out at Berkeley Lab; installation at RHIC is expected to begin next year. The goal of the STAR experiment is to study particle production on an event-by-event basis to identify the phase transition between normal nuclear matter and quark matter (a plasma of free quarks and gluons). It is believed that the quark–gluon plasma existed soon after the Big Bang at the creation of the Universe and may exist now in the cores of neutron stars.

As the preparations for ultrarelativistic heavy-ion collision experiments at RHIC (BNL) and LHC (CERN) proceed, one of the most pressing theoretical questions concerns the initial conditions of the matter created early in the reactions. In the past few years there have been significant advances in perturbative QCD-based descriptions of high-energy collisions, and the Nuclear Science Division Theory Program is continuing its vigorous efforts in this area of research. The already substantial visitor program will be further expanded as it has been shown to be an economical way to add both breadth and depth to the local theory effort.

In collaboration with the Physics Division, the Information and Computing Sciences Division, and the National Energy Research Scientific Computing Division, the Nuclear Science Division has proposed an initiative to provide a large-scale computing capability for high-energy and nuclear physics experiments at Berkeley Lab. This initiative will provide for the development of new concepts for data analysis and event simulation and distribution over networks.

A broad and versatile nuclear structure and reactions research program is centered at the Laboratory's 88-Inch Cyclotron. The Cyclotron is operated as a National Facility and is equipped with two state-of-the-art ECR ion sources capable of producing high-charge-state ions of most elements.

The Cyclotron is the site of Gammasphere, a national gamma-ray facility that consists of a 4π array of 110 Compton-suppressed high-purity germanium detectors. It was recognized several years ago that even a modest fraction of the full system would be very powerful; thus, an Early Implementation phase of operation began in April 1993 and ended in January 1995. Phase 1 operation began in March 1995, with about 50 detectors, and is currently operating with over 90 detectors. Full operation with 110 detectors is planned for summer 1996. At this stage, Gammasphere is clearly the outstanding detector array of its type in the world. Approximately 100 experiments have been completed thus far by about 200 nuclear scientists coming from U.S. universities (~50%), national laboratories (~25%), and foreign institutions (~25%). In addition to the discovery of new superdeformed bands, these users also have observed many other new phenomena, including possible new nuclear symmetries, identical bands in different nuclei and pairing correlations in superdeformed nuclei. Recently, the first transitions linking the superdeformed bands with known states near the ground state of the nucleus have been seen, providing a large step forward in understanding the physics of these elongated nuclei.

Future experiments will seek to understand these new phenomena and will also focus on a search for hyperdeformed nuclei and the study of neutron-rich nuclei. Auxiliary detectors are extending the power of Gammasphere very significantly, and several of these have been, or are being, developed by Gammasphere users. For example, an inner 4π charged particle detector system, MicroBall, extends the capabilities of Gammasphere and enables studies of angular momentum transfer and alignment in deep-inelastic reactions

with discrete gamma rays. Plans are being developed for Gammasphere to spend approximately one year at Argonne National Laboratory in FY 1998 to operate in conjunction with the Fragment Mass Analyzer for studies of nuclei far from stability.

In order to pursue the physics of nuclei at high spin and angular momentum in even more detail, the nuclear structure group is also developing the next generation gamma-ray array, the Gamma-Ray Energy Tracking Array (GRETA), which would have a resolving power a thousand times that of Gammasphere. This array would consist of a shell of highly segmented germanium detectors. The R&D required to establish feasibility is presently under way.

The nuclear structure of nuclei far from stability is also being investigated at the 88-Inch Cyclotron. This includes, for example, light proton-rich nuclei and heavy nuclei. Several factors, including the availability of intense (microampere) beams and the technology for handling radioactive beams, have combined to make the 88-Inch Cyclotron facility one of the leading laboratories in the world for the production and study of transuranic nuclei. A few years ago, the discovery of element 106 was confirmed at the 88-Inch Cyclotron and the name seaborgium suggested. Now, the chemistry of this element is under study. The first results indicate that it behaves like its homologs, tungsten, and molybdenum. This research program will continue to use the Cyclotron to produce and characterize new elements and isotopes, and to train students in modern nuclear and radiochemical techniques. A new high-efficiency mass separator, the Berkeley Gas-Filled Separator (BGS), is under design and is expected to be ready for use in late 1997. It will be used for studying many types of exotic nuclei with very small cross sections —including heavy and super-heavy elements, proton dripline nuclei, and neutron-rich nuclides.

Experience gained with the BGS will aid in the design of two other planned separators. A superconducting gas-filled separator, GFS, is being designed as a powerful selection device for general use with Gammasphere. GFS will be completed by the time Gammasphere returns in FY 1999. Another (large) superconducting gas-filled separator is being considered as a successor to BGS to provide additional research opportunities over the longer term.

A different source of information about nuclei comes from studying the behavior of hot systems formed after a nuclear reaction. The Nuclear Reactions group will continue its program to characterize the physics of the emission process of these hot nuclei, from its onset as binary compound nucleus decay to its full development as multifragmentation.

The Weak Interactions Group conducts a variety of experiments that address fundamental questions in the standard model of electro-weak interactions: laser trapping of radioactive ^{21}Na will be used to search for a right-handed component of the weak interaction; measurements on ^{10}C decay will provide the most precise value to date of the Cabibbo angle; tests of time reversal invariance in the isospin-hindered decays of ^{56}Co and ^{134}Cs are under way; and a search for parity mixing in atomic transitions is planned, as are tests of the validity of the conserved vector current hypothesis and of charge conjugation symmetry. These experiments complement the high-energy physics approach and are of very high precision. A new facility for exotic atom trapping, FEAT, is now in operation at the 88-Inch Cyclotron, to further this forefront research program.

Berkeley Lab's Institute for Nuclear and Particle Astrophysics (INPA) was founded in late 1993 to bring together Berkeley Lab research in astrophysics, including topics such as solar neutrinos, cosmic rays, dark matter, supernovae, cosmic background radiation, fundamental interactions (described above), and theoretical astrophysics. In collaboration with eleven other institutions from Canada, the United States, and the United Kingdom, Berkeley Lab is participating in the Sudbury Neutrino Observatory (SNO), an experiment to detect neutrinos from the sun and supernovae. Installation of the detector components is nearly completed in the SNO laboratory, 6800 feet underground in the INCO mine near Sudbury, Ontario. Berkeley Lab scientists have played a major role in the installation and are now turning their efforts toward data acquisition and analysis software, and detector calibration in anticipation of the first physics results next year. Members of INPA are involved in two initiatives that cut across group and division boundaries. One is a high-energy physics initiative—the development of the next generation of high-energy neutrino detector, which may have an effective sensitive volume of one cubic kilometer. Another initiative is a proposal (in

collaboration with the Isotopes Project and UC Santa Cruz) to establish a nuclear astrophysics data center at Berkeley Lab.

The Isotopes Project of the Nuclear Science Division provides evaluated nuclear structure and decay data for the world nuclear physics community. The group has an expanding leadership role within the U.S. Nuclear Data Network. This includes responsibility for the compilation and evaluation of data from the new gamma-ray detector arrays, and the development of electronic access to all the network's extensive data files. The eighth edition of the *Table of Isotopes* was published this year, both in hard copy and (for the first time) on CD-ROM.

Another vital area of the nuclear science program is continued development of the 88-Inch Cyclotron's capability to deliver nuclear beams for world-class research. Improvements in progress include an upgrade of the Advanced Electron Cyclotron Resonance (AECR) ion source so that it can operate at higher magnetic fields and frequency, further increasing the Cyclotron's performance for heavy-ion beams (A>100), and a project to improve the flexibility and precision of the beam timing characteristics of the 88-Inch Cyclotron. The goal of this latter project is to develop a fast beam-chopping system that could chop out individual beam pulses and enable the study with the Gammasphere detector of short half-life nuclear states with lifetimes greater than 100 ns. A project to modernize the radiation safety interlock system is nearing completion. In the longer term, construction of a new, third-generation superconducting ECR source to provide higher energy and higher intensity heavy-ion beams will open up additional new research opportunities and advance ECR technology.

High-Energy Physics

In high-energy physics, the Laboratory continues its strong and diverse program of experimental and theoretical research, including the development and operation of innovative detectors and research on advanced accelerator components and concepts. Berkeley Lab is actively participating in the national effort to design future facilities, including an asymmetric B Factory at PEP.

The Laboratory's experimental programs in high-energy physics focus on the properties of quarks and leptons, the basic constituents of matter. Their interactions are mediated through the gauge bosons, namely, massless photons and gluons and massive W and Z particles. Efforts to study these particles emphasize the development of sophisticated detectors and their operation at colliding-beam facilities. Major experiments are in progress or in active preparation at SLAC and Fermilab.

Berkeley Lab has a major role in both of the two large detectors at the Fermilab Tevatron Collider—the Collider Detector Facility and the D-Zero. In 1995, the two collaborations made simultaneous announcements of the discovery of the top quark. The effectiveness of the Collider Detector Facility has been enormously enhanced by the Silicon Vertex Detector, for which Berkeley Lab was the lead institution. This work involved close collaboration among the Physics Division, the Engineering Division, and industrial suppliers. The Silicon Vertex Detector has achieved approximately 10-μm resolution in the transverse plane. The result is that B physics has been opened up to an unprecedented and unexpected extent. This detector has played a crucial role in the CDF discovery of the top quark. Berkeley Lab groups working on this experiment are involved in analysis of B decays, and the measurement of the W mass and top quark masses. Meanwhile, the D-Zero detector has made important measurements of tri-gauge couplings, with Berkeley Lab playing a key role. Berkeley Lab groups are involved in analysis of W and Z events. Berkeley Lab is heavily committed to the design and fabrication of the SVX-2 chip for D-Zero and the SVX-3 for CDF. These chips are being developed jointly with Fermilab.

Berkeley Lab is also a major participant in the B Factory at Stanford Linear Accelerator (SLAC). This project will examine B-meson decays. The studies of B-meson decays are limited today by the relatively low rate of events produced at e^+e^- storage rings. To study the most interesting processes within the Standard Model, e.g., rate decays and, even more important, the phenomenon of charge conjugation-parity (CP) violation, an effective increase in the event rate by at least a factor of 100 is required. In the B Factory, this will be accomplished by increasing the luminosity by a factor of 10 and by simultaneously increasing the event sensitivity through the use of asymmetric collisions (equivalent to another factor of 10 in luminosity).

Construction of the $177 million PEP-II accelerator began in January 1994 and will extend through the end of FY 1998. The project is being carried out as a collaboration of SLAC, Berkeley Lab, and LLNL. Berkeley Lab construction activities focus mainly on the Low-Energy Ring. In particular, Berkeley Lab is responsible for fabrication of the Low-Energy-Ring arc magnets (roughly 200 dipoles, 300 quadrupoles, 150 sextupoles, and 200 corrector dipoles) and some of the key "special" magnets in the interaction region. We are also responsible for fabrication of the arc vacuum system (about 1500 m of vacuum chambers) and for a portion of the PEP-II power supplies (corrector supplies and high-power, nonchopper power supplies). Staging and fabrication space sufficient to serve the PEP-II project has been identified on site. Berkeley Lab has played a key role in the development and testing of the innovative multibunch feedback systems and will be responsible for providing the transverse feedback systems for both PEP-II rings. Berkeley Lab accelerator physicists and engineers continue to play key roles in the B Factory project, including serving as Deputy Project Director, and as System Manager and System Engineers for the entire Low-Energy Ring. In FY 1998, Berkeley Lab personnel will play a leading role in the commissioning of the Low-Energy Ring.

Berkeley Lab will have a major part in the design and construction of the silicon vertex tracker for the B Factory. This is an especially critical component of the detector because it is essential to determining the location of the B decay vertices. The Laboratory's effort builds on its extensive experience with the SVX in the Collider Detector at Fermilab (CDF), with its major accomplishment being for the Solenoidal Detector Collaboration (SDC), and on the design of the D-Zero upgrade planned at Fermilab. The silicon vertex tracker will require substantial contributions from the Engineering Division, as well as from the Physics Division itself.

In addition, Berkeley Lab will assume responsibility for other components of the B Factory detector. Particle identification is a particularly important challenge since it is essential to determining the particular decay modes being observed. Berkeley Lab will continue its work on the DIRC (Detection of Internally Reflected Cerenkov Light), which led to its selection as a particle I.D. device. The Laboratory will also undertake a substantial role in electronics and computing for the B Factory detector. This detector will have enormous computing needs, and Berkeley Lab will be a leader in designing the overall architecture for this work, with leadership coming from the Information and Computing Sciences Division.

The Astrophysics Program of the Physics Division has three components: cosmic microwave background measurements, a search for dark matter, and a search for distant supernovas. The cosmic microwave background program may be extended with new satellite-borne detectors. The dark matter search component has embarked on a several-year program of experimentation. The distant supernova search program has already discovered several very distant supernovas, including the most distant one ever observed. An expanded program should find a few dozen distant supernovas, enough to determine the mass density of the universe.

Berkeley Lab, through its Institute for Nuclear and Particle Astrophysics, is playing a leading role in the development of techniques that will be required to construct and operate a very large-scale neutrino detector using either water or ice as the basic medium. Muons created in neutrino interactions generate Cerenkov radiation in the ice or water, and this light can be detected with photomultiplier tubes. Relatively modest scale efforts of this sort are currently under way, notably AMANDA in Antarctica and DUMAND, near Hawaii. It is clear from projected event rates that a truly large-scale detector, with a volume of roughly a cubic kilometer, will be required ultimately. LBNL efforts are focused on the development of an optical module, which uses blue LEDs, and on an innovative integrated circuit, the Analog Transient Waveform Recorder. The latter provides extremely high-speed recording of the signal on the phototube with very low power consumption. These twin developments are major advances for large-scale neutrino detectors.

The Laboratory also has a strong theoretical particle physics group, whose work ranges from highly theoretical topics to others closely related to current experiments. A substantial effort is being devoted to theoretical studies in support of physics in the multi-TeV energy range.

The Particle Data Group performs a service for the world's high-energy physics community through its compilations of particle properties. This includes the recent enhancing of database accessibility through computer links.

Advanced detector development is aimed at long-range research in detector problems relevant to proposed hadron colliders. The program emphasizes the development of radiation-hardened devices, pixel devices, monolithic amplifier arrays, and data-acquisition electronics.

Accelerator physics and engineering for the design and application of particle beams is a Berkeley Lab core competency that has long played a leading role in research and development for high-energy physics facilities. In the recent past, for example, Berkeley Lab experience with beam cooling resulted in successful systems at the Tevatron I. Most recently, Berkeley Lab has turned its attention to high-luminosity lepton colliders such as B-meson factories and has been using its combination of analytical and practical expertise to solve a variety of problems such as beam–beam instabilities and damping of higher-order modes.

A comprehensive, integrated approach to superconducting magnet R&D is a part of the competency that Berkeley Lab applies to high-energy physics. The program emphasizes two major aspects of building higher-field and higher-quality magnets. An ongoing effort to make wire for greater current density explores small filament diameters (2–3 μm) and brittle superconductors such as niobium–tin. Improved cable designs are also a major focus of activity. These achievements come together in the development of stronger and more efficient accelerator-type magnets, one of which set a field-strength record of slightly more than 10 tesla in 1992 testing. Other highlights include efforts to make better magnets and to find better ways of designing magnets.

In a futuristic program aimed at a next-generation, high-energy electron collider, Berkeley Lab scientists, collaborating with LLNL and SLAC colleagues, are working on the Two-Beam Accelerator. This concept, pioneered at Berkeley Lab, uses either a free-electron laser or a relativistic klystron to generate extreme levels of microwave power, which is then applied to a high-gradient linac structure.

Health and Environmental Research

Life-sciences-related research activities include six research program areas: gene expression and genome mapping; structural biology; nuclear medicine and functional imaging; carcinogenesis, mutagenesis, and radiation biology; environmental and health-effects research; and measurement technology. These programs form a core of research conducted for DOE's national programs supported by the Office of Health and Environmental Research (OHER). Program expansions are anticipated in human genome research, structural biology, gene expression, growth regulation, molecular medicine, and environmental science.

Gene Expression and Genome Mapping

Important research growth areas for Berkeley Lab are studies on human genome structure and regulation of gene expression. Research at the Human Genome Center includes generation of physical and genetic maps, identification and localization of expressed genes on human chromosome 21, and development of techniques for efficient sequencing of human DNA and automation of these techniques. Analysis of the biologically relevant signals culled from sequence information is under way. A physical map of the *drosophila* genome, along with the identification of expressed genes, is being developed in collaboration with UC Berkeley and Harvard University. The biological function of the human DNA sequences identified by the Human Genome Center will be determined using genetically engineered mice developed by researchers at Berkeley Lab.

Berkeley Lab's Life Sciences Division conducts several related research programs on gene expression within mammary-gland and blood-forming systems. The highly secretory mammary epithelial cells provide excellent models for gene expression and chemical- and radiation-induced carcinogenesis and are now also providing vehicles for production of genetically engineered foreign genes. Berkeley Lab has identified hematopoietic research for expansion. Blood-forming cells are important targets of radiation-induced damage and are versatile models of stem-cell differentiation and regulation of gene expression.

Molecular cytogenetics describes a set of pioneering diagnostic methodologies for biomedical applications—many of which have already made a significant contribution to the megabase sequencing effort in the Human Genome Project. The research program centers in particular on refinements in

hybridization technology to increase the speed, sensitivity, and specificity of hybridization to allow rapid identification and mapping of genetic aberrations.

Structural Biology

One thrust of Berkeley Lab's structural biology program is to determine the structure of biologically important molecules and complexes to gain insight into their function. An important new direction is toward x-ray-based research at the ALS, although the program has other facets as well. X-ray crystallography, electron crystallography, and NMR spectroscopy focus on protein and nucleic acid structures.

Activities at the ALS are an essential part of the future of structural biology research, and have been strongly supported by the Office of Health and Environmental Research. New applications of advanced imaging, diffraction, and spectroscopy techniques will greatly strengthen both our local efforts and DOE's national program in structural biology. The ALS will offer major new resource opportunities for life sciences research in several emerging areas of scientific emphasis, especially in x-ray crystallography, x-ray spectroscopy, and x-ray microscopy.

In support of x-ray crystallography, a Multiuser Crystallography Center has been established to conduct static and dynamic analyses of macromolecular architecture and other structures, such as microcrystals with precise wavelength tuning. The facility addresses the high demand for beam time with a multiuser configuration and user-friendly design and operation.

A beamline for x-ray spectroscopy has been funded to determine biochemical properties at high spatial and temporal resolution within cells and organelles. Many experiments will exploit the capacity to control the polarization of synchrotron radiation.

An x-ray microscopy instrument has been installed on a beamline to investigate tissues, cells, and organelles in specimens that are too thick for electron microscopy, but at a resolution greatly exceeding the limits of light microscopy. Among the benefits of x-ray microscopy at the ALS will be the ultimate possibility of three-dimensional imaging.

Studies based on high-resolution electron crystallographic structure analysis and x-ray diffraction are also elucidating the structure of specific membrane proteins involved in transmembrane signaling and ion channels. Using unique techniques for electron diffraction and imaging of crystalline sheets of membrane proteins, structural studies will focus on such membrane-bound proteins and integral membrane proteins as channels and pumps, chemotaxis receptors, and receptors for extracellular matrices.

Hard-x-ray radiation from a wiggler will make it possible to develop technical capabilities in synchrotron-based protein crystallography that have never been attempted before. One such advance is specialized x-ray optical devices that will provide multiplexing and time-sharing capabilities leading to more efficient use of the available beams. Another will use x-ray microfocus technology to extend data-collection capabilities to protein microcrystals as small as 20 μm or less.

Current research is exploring new concepts in the realm of soft-x-ray microscopy of biological specimens. The goal is to test ideas such as high-resolution fluorescence microscopy using lanthanide chelate labels. A scanning x-ray microscope designed to exploit these techniques would use a specially designed undulator, optimized for light output in the "water window" range of x-ray wavelengths.

Berkeley Lab has also established a unique center of excellence, the Program for Biomolecular Design, that will bridge the chemical, biological, and computer sciences by combining the expertise at Berkeley Lab and UC Berkeley. The program will catalyze an understanding of biological systems with the ability to analyze and manipulate chemical structure. The aim is to redesign natural biological molecules to create new classes of novel biomolecular structures with applications to major problems in the medical, biological, and environmental sciences relevant to DOE missions.

Nuclear Medicine and Functional Imaging

Research in nuclear medicine includes new studies in molecular biology and continuing studies of improved radiopharmaceuticals and advanced instrumentation for applications to medical science. A systematic search for new, ultrafast, heavy-atom scintillators and the development of solid-state photodetectors for high-resolution, positron-emission tomography have led to new concepts in detection. A new multilayer, high-resolution tomograph is planned for use in medical studies of the human and animal brain and heart. Imaging instrumentation initiatives include plans to establish a 10T whole-body NMR national resource.

Methods for the production of radioisotopes and for the labeling of biochemical substrates to be used in noninvasive imaging have contributed to the effective use of these diagnostic imaging tools. Newly developed radioisotope generators give greater flexibility to the application of short-lived, positron-emitting isotopes by using long-lived parent radioisotopes, and automated elution techniques for the delivery of short-lived radionuclides.

Following Berkeley Lab's tradition of radiobiology and isotope chemistry, the Laboratory is supporting DOE's Health and Environmental Research program to conduct isotope-based research and to provide tracer isotope resources for the nation's biomedical research community.

In parallel with an emerging national trend in molecular nuclear medicine, Berkeley Lab has initiated studies in four new areas: (1) use of modern instrumentation with transgenic animal models to pursue the relationship between genomic variations and the occurrence of atherosclerosis, with particular emphasis on oxidative disease mechanisms; (2) use of advanced noninvasive methods of nuclear medicine and NMR to study the relationships among neuroreceptor concentrations, brain metabolism, mental disorders, and the genome; (3) development of labeled DNA probes (aptamers) for specific proteins associated with inflammatory diseases, autoimmune conditions, atherosclerosis, and cancer; and (4) use of nuclear medicine methods to monitor gene therapy.

Carcinogenesis, Mutagenesis, and Radiation Biology

Berkeley Lab has a number of strong research programs in cell, molecular, and radiation biology related to cancer etiology:

Control of Growth, Differentiation, and Genomic Stability. Berkeley Lab has strong programs in the elucidation of mechanisms that control cell proliferation, differentiation, and genomic stability, and the abnormalities that occur in each of these processes during and prior to tumorigenesis.

Hormones and Extracellular Matrix. Research is directed toward identifying the intracellular molecules that mediate cells' responses to hormones, particularly the sex steroids, and the extracellular matrix (ECM). Investigators have demonstrated the importance of hormones and ECM in maintaining the balance between growth, differentiation, and death in normal tissue; mediating the tissue response to radiation; and initiating neoplasia. Researchers are now working towards understanding the molecular bases for the actions of hormones and ECM and developing methods to modulate their activities.

Hematopoiesis. Using rodent and human cells in culture and *in vivo,* investigators are examining how differentiation and malignant transformation are controlled in blood-forming cells. In particular, there is a substantial research on how tissue-specific gene expression is regulated, to identify chromosomal changes that occur in these cells after exposure to carcinogenic stimuli, and to characterize and isolate hematopoietic stem cells.

Mammary Biology. A large, multi-investigator program in mammary gland biology aims to understand the extracellular signals and intracellular mediators that control mammary epithelial cell growth, development, functional differentiation, and death, particularly as it relates to various stages of tumorigenesis. Investigators are studying epithelial-stromal interactions, ECM–cell and cell–cell interactions, growth factor and ECM receptors and the intracellular signaling pathways, and transcription factors that are key regulators of growth and differentiation.

Oncogenes and Tumor Suppressor Genes. In another area of research, investigators are learning how protooncogenes (which, through mutation, become oncogenes) and tumor suppressor genes function in normal and neoplastic cells. Using both viral and cellular genes, investigators are determining the roles protooncogenes and tumor suppressor genes play in determining the cell phenotype resulting from environmental signals, such as growth factors and ECM- and DNA-damaging agents, as well as genetic programs, such as replicative senescence and terminal differentiation.

Radiation and Chemical Carcinogenesis. Berkeley Lab researchers are studying the biological responses of cells and organisms to environmental hazards such as ionizing radiation, including radon. These studies will shed light on the consequences of low-dose exposure, which is important in assessing the risk associated with space exploration, certain occupational hazards, and medical diagnostic techniques. These studies also are providing a molecular understanding of how DNA lesions are acquired and repaired. The effects of ionizing radiation on microenvironments in terms of rapid and global tissue remodeling are also being assessed with respect to carcinogenesis.

DNA Repair. Activities in the area of DNA repair include cloning human genes by complementation of repair defects in lower organisms, studies on how the structural constraints and genomic organization affect damage and repair, and the inducible responses to DNA damage.

Subsurface Science

In OHER's Subsurface Science Program, Berkeley Lab research in environmental characterization focuses on the effect of natural subsurface heterogeneity on microbial behavior. The goal of this research is to relate the effect of physical heterogeneity in the subsurface to microbial behavior.

The heterogeneity research is part of the Subsurface Science Program's Heterogeneity and Bacterial Transport Subprogram. This highly interdisciplinary work is closely coordinated with efforts at Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL), Notre Dame, and Purdue. It contributes to meeting the goals of the subprogram by improving the means of relating subsurface physical properties to the microbial heterogeneity of natural systems. A large number of field scales of heterogeneity range from the pore scale to the bed scale and beyond. To relate the significant scales of variation of microbial and chemical behavior to the variation of physical properties, it is critical to know the scales at which various processes dominate. Without this knowledge, it would be impractical to attempt to relate a small-scale process (i.e., microbial behavior) to field-scale measurements.

The goal of the work is to use subsurface imaging to identify the fundamental scales of variation of physical parameters that control transport behavior relative to predicting subsurface microbial behavior. With this information, it may be possible to relate physical and chemical heterogeneity (i.e., those parameters that geoscientists have experience measuring *in situ*) to significant microbial heterogeneity and thus explain and predict their behavior in the subsurface. This approach uses controlled meter-scale field sites and supplementary laboratory and intermediate-scale information to characterize those physical properties that affect fluid flow and chemical transport and can be imaged with *in situ* methods. The work must be tightly integrated with chemical and microbial characterization and process definition efforts that will be undertaken in the subprogram. At DOE sites where information has been gathered on the microbial and chemical properties, field work will be carried out to define and characterize the natural subsurface physical heterogeneity. This work is being done in close collaboration with PNNL, ORNL, and the University of Virginia as part of DOE's Subsurface Science Program for studying subsurface heterogeneity and bacterial transport.

Environmental Sciences

Environmental research at Berkeley Lab is composed of multidisciplinary efforts to solve global, regional, and local environmental problems. In particular, the research is focused on epidemiological factors, the mutagenic potential of contaminants, subsurface contamination, and indoor air quality, all conducted for OHER.

The Laboratory is advancing programs in support of DOE's research initiatives on the subsurface environment. The Laboratory's proposed programs encompass the biological and hydrogeochemical control and remediation of toxic waste. Specific projects include characterization of contaminants, subsurface heterogeneity, transport processes, and enhancement of restoration methods. Improved risk-estimation methods will enable the deployment of cost-effective remediation technologies.

Berkeley Lab is developing an interdisciplinary program to investigate the processes that lead to changes in the physical and chemical characteristics of the atmosphere and other potential changes in the ecosystem. Initial research subjects include atmospheric processes that are involved in the generation of nucleating particles from artificial and natural sources; heterogeneous chemical processes; the role of particulates in the formation of clouds, and the resulting chemical and physical changes in the atmosphere; and atmosphere–ecosystem interactions.

The Berkeley Lab program on radon migration includes unique experimental facilities for studying radon movement in soil and into buildings under controlled conditions. These studies will allow comparisons with detailed numerical simulation models. In addition, the radon research program examines the effects of other parameters, including other indoor air pollutants, building construction and operation, and climate conditions, on the resulting indoor radon concentrations and, ultimately, on the radiation doses to the building occupants from these indoor exposures.

The mission of OHER's Natural and Accelerated Bioremediation Research (NABIR) program is to provide the scientific understanding needed to harness natural processes and develop methods to accelerate these processes for the bioremediation of contaminated soils, sediments, and groundwater at DOE facilities. With Berkeley Lab's Center for Environmental Biotechnology playing a facilitating role, the NABIR program is in the process of identifying the scientific leadership and encouraging the development of interdisciplinary teams for addressing these problems in a creative and effective way. The program will focus on basic research needed for *in situ* and *ex situ* bioremediation of complex mixtures of contaminants present at DOE facilities. Primary contaminants of concern include mixtures of halogenated compounds, organic acids, chelating agents, heavy metals, and radionuclides. Scientific understanding will be gained by performing fundamental laboratory and field research on biotransformation and biodegradation processes, community dynamics and microbial ecology, biomolecular science and engineering, biogeochemical dynamics, and innovative methods for accelerating and assessing *in situ* biogeochemical processes. Computational models also will be developed as integrating tools, as well as to provide methods for predicting and optimizing the effectiveness of bioremediation.

Analytical Technology

Excellence in measurement technology is key to the success of OHER programs. Refinements in sensors and analytical techniques have been developed at Berkeley Lab for a number of years. New detector configuration and the discovery of new scintillation will significantly benefit the positron-emission tomography program of OHER. Research and development of the associated electronic signal-processing techniques complement this work. OHER support for x-ray detectors at the ALS and other synchrotron sources will utilize Berkeley Lab expertise and provide significant advances in image resolution and chemical characterization of biological materials.

Fusion Energy

Fusion energy research at Berkeley Lab focuses on accelerator systems supporting the nation's inertial-confinement and magnetic-fusion energy programs. The Laboratory's expertise in materials, superconductivity, and computational science are important assets that augment the Laboratory's accelerator research. The Laboratory's heavy-ion fusion accelerator research has focused on the physics and technology of induction acceleration as the means for producing high-current, heavy-ion beams as drivers for inertial-confinement fusion systems. In comparison with other possible inertial-fusion drivers (e.g., lasers), beams of heavy ions offer important advantages for practical applications, including high efficiency from the "wall plug" to the beam, good potential for beam-to-pellet energy focusing and coupling, and high pulse-repetition rates. Berkeley Lab's current efforts have resulted in successful completion of the

multiple-beam experiment to examine the initial accelerator components for space-charge-dominated beams undergoing current amplification.

Beam quality (focusability) and cost are the two primary accelerator issues remaining that still must be resolved to generate economical fusion power. The Laboratory has a two-pronged effort in beam science and advanced technology to address these issues. This research will enable the design and construction of a multi-kilojoule accelerator that will provide the scientific and technical database for building a full-scale fusion driver. The multi-kilojoule accelerator will also provide the capability needed for a wide range of experiments in beam physics, beam-target interaction physics, and fusion target physics.

The induction acclerator technology that will be developed for fusion applications also has a variety of other uses. For example, an induction accelerator that uses 5-MW beams of protons at 1 GeV to generate spallation neutrons in 100-ns bursts at a repetition-rate of 10 Hz would be quite similar to, but one-tenth the size and cost of, an inertial fusion driver. At higher average power levels (i.e., high repetition rates), induction accelerators are candidates for accelerator-based pulsed reactors for waste transmutation, for tritium production, and for a fusion material test facility.

In magnetic fusion energy, Berkeley Lab has traditionally been a leader in the design and development of neutral-beam systems, its most notable achievement being the standardized Common Long-Pulse Source (the effort continues to have numerous technology-transfer spinoffs). Many proposals for future magnetic-fusion projects involve injection of dc neutral beams at high currents and at high kinetic energy. The beams play a significant role in heating the plasma and in driving the toroidal current noninductively in the steady state. Future Berkeley Lab work is likely to be carried out under the aegis of the Japan Atomic Energy Research Institute (JAERI).

An additional contribution to the magnetic fusion program in the Berkeley Lab's Materials Sciences Division is the research on alloys and weldments for low-temperature superconducting magnets for magnetic-confinement fusion systems. The alloys must withstand extremely high magnetic fields at the cryogenic temperatures needed for superconductivity.

Energy Efficiency and Renewables

The Berkeley Lab program in Energy Efficiency and Renewable Energy comprises a broad set of related activities that provide research support and technology development in the furtherance of national goals to reduce energy demand and cost to consumers, balance environmental concerns with economic development, and enhance energy security. Berkeley Lab's programs are principally in electrical-energy storage and distribution, buildings, industry, transportation, utility systems, and geothermal systems.

Utility Technologies

The work on electrochemical energy storage, described below under Transportation Technologies, will provide stationary energy-storage options for load-leveling applications. In another effort, work is ongoing to understand the effects of electromagnetic fields on biological systems.

A multidisciplinary program addresses the characterization and development of geothermal energy resources. The current program consists of field, laboratory, and theoretical studies covering four principal technical areas: delineation and evaluation of geothermal systems, definition of reservoir processes, modeling of reservoir dynamics and exploitation effects, and optimization of field-management practices.

Reservoir technology work will lead to more accurate predictions of the responses of a geothermal reservoir to exploitation for optimum management through carefully designed fluid-production and injection operations. Joint field projects with U.S. geothermal developers and utilities continue to be highly productive, as do collaborations with organizations in Mexico, Iceland, and Italy.

Currently, Berkeley Lab is investigating The Geysers, the largest geothermal field in the world, as well as several other systems in California and Nevada. This investigation is part of a DOE–industry, multi-institutional collaboration. More generally, the U.S. geothermal industry, including utilities, continues to be

assisted by Berkeley Lab's geothermal program in its effort to develop hydrothermal (hot water and steam) resources in the U.S. and abroad. Instrumentation, field techniques, data interpretation methods, and computer codes developed at Berkeley Lab, which are used in locating, evaluating, and optimizing the exploitation of geothermal systems, are being transferred to the private sector. The assistance to industry also includes the collection and release of information on geothermal prospects throughout the world.

Berkeley Lab is performing extensive analysis of the energy demand in China: historical studies of determinants of energy intensity, case studies of energy-efficiency decision making in industrial facilities, analysis of possible energy-efficiency investments, and assessments of energy-efficiency business opportunities.

Magnetic-field interactions are being evaluated in experimental animal systems and in tissue and cellular systems potentially sensitive to this nonionizing radiation. This program will develop theoretical models of magnetic-field interactions with biological systems and provide essential data for assessing the potential effects of magnetic fields.

Industry Technologies

This effort focuses on advanced industrial concepts, including energy-efficient chemical separations, the opacification of aerogels for high-performance insulation in nonview applications (e.g., refrigeration), and other industrial applications. Work is under way on two projects on catalysts for industry: theory-assisted design of metal and zeolite catalysts; and chemistry, immunology, and modeling as tools for the rational design of stable, active enzymes.

Transportation Technologies

Berkeley Lab manages the Exploratory Technology Research Program, which is the electrochemical research arm of DOE's Office of Propulsion Systems. The primary goal of this program is to advance the development of high-performance rechargeable batteries and fuel cells for use in electric vehicles. The battery performance goals for this program have been established by the U.S. Advanced Battery Consortium. Berkeley Lab research areas include exploratory R&D on new electrochemical systems, supporting research for advanced rechargeable batteries presently under development, materials science research for improved battery components, fundamental electrochemical research to improve electrochemical energy-conversion efficiency, and characterization of advanced electrodes and electrolytes for use in fuel cells.

Berkeley Lab is working in conjunction with the other DOE multiprogram laboratories to assist DOE in its role in the federal–industry Partnership for a New Generation of Vehicles (PNGV). Berkeley Lab expertise available to PNGV includes the above areas, as well as combustion and emissions, lightweight materials, and improved manufacturing techniques.

Building Technologies

Berkeley Lab will continue activities related to residential and commercial buildings in a program of laboratory and field research, modeling, data analysis, and partnerships with industry to accelerate market impact of our research. This work is a coordinated systems approach to designing building components as well as entire buildings with improved energy efficiency and better conditions for human health, comfort, and productivity. Modeling and field measurements verify results on the economic costs and benefits of using energy efficiently. Important aspects of the work include measurements of indoor air quality and possible health effects of proposed efficiency measures.

The Laboratory has a leading role in applied research in four areas related to energy efficiency in buildings: windows and daylighting, artificial lighting, computer modeling of building energy use, and infiltration/ventilation and indoor air quality. The general objective of these programs is to develop advanced energy-efficient technologies, computational tools, and experimental facilities. This will allow evaluation of technologies showing the greatest promise for significant energy savings in buildings while maintaining levels of illumination and air quality adequate for human comfort and health. Specific projects

focus on developing the technology base for new energy-saving opportunities in fluorescent lamps, advanced windows, novel building insulation, analysis of federally assisted housing, residential and commercial building analysis and performance studies, analysis of appliance energy efficiency, and site-planning studies to minimize summer heat-island effects.

Building simulation experts expect to use the new Berkeley Lab supercomputing facilities to tackle important computational fluid dynamics problems and perform lighting simulations and visualizations that previously have been impractical with existing computing resources. Increased effort is focused on providing more "user friendly" access to the technologies and methodologies developed at Berkeley Lab. Examples include a graphical user interface to computer codes such as DOE-2, expert systems to aid energy-efficient building design, and electronic kiosks for information transfer. Another growing effort involves providing technical assistance to the Federal Energy Management Program (FEMP) as that program seeks to increase the energy efficiency of federal buildings. A third new focus is an emphasis on the development and understanding of integrated building systems, and on assuring their performance (energy, and occupant health and productivity) throughout the life cycle of the building. These projects are undertaken in close collaboration with the building industry and utilities. There is an additional emphasis on supporting the U.S. government's commitment to reducing green-house gas emissions to 1990 levels by the year 2000, by accelerating implementation of new energy-efficient technologies and processes.

Both domestic and international studies of economic impacts of alternative energy policies are expected to grow. The purpose of surveying the conservation policies of other developed countries is to enable the U.S. to compare progress in this area and perhaps adopt some of these countries' effective efficiency measures.

Federal Energy Management Program

Berkeley Lab's In-House Energy Management Program, supported by FEMP, pursues opportunities to significantly reduce energy costs at Berkeley Lab. The program involves surveys and studies of existing conditions, retrofit projects, new construction support, utility cost management, and facilities maintenance support. Retrofit projects have improved the efficiency of mechanical systems, lighting, and utility systems, resulting in approximately $1.4 million in annual savings by the end of FY 1995.

Office of Fossil Energy

Berkeley Lab conducts research directed toward making coal more usable, including studies on conversion to gaseous and liquid fuels and reduction of emissions. One current effort focuses on the low-temperature catalytic gasification of graphite and other forms of carbon. A flue-gas chemistry project is directed toward methods of simultaneous removal of SO_2 and NO_x, and other new processes are being developed to remove H_2S from gas streams, such as those produced during coal gasification. Another project is studying the erosion and corrosion of materials used in systems developed for coal conversion and use.

In the oil and gas area, Berkeley Lab is completing a study on the development of methods for characterizing heterogeneous and fractured reservoirs through a combination of geological, geophysical, and hydraulic studies. Heuristic methods are used to determine the systematic patterns of conductive features that result from the geologic processes. Improved seismic and electromagnetic methods are being developed for imaging these features from boreholes. Both of these types of information are used to obtain an improved model of reservoir performance to enhance our ability to manage reservoir production. Berkeley Lab is continuing development of advanced inversion codes and interpretation methods. This work has active industrial support.

The Earth Sciences Division of Berkeley Lab has taken the lead in forming DOE–industry cost-shared research alliances with California-based oil and gas producers, mainly those facing difficult and costly production problems from the diatomite reservoirs in Kern County. Although these reservoirs contain about 10 billion barrels of light oil in place, recoveries are low (2.5 to 6.0%), due to the very impermeable nature of the rock. Production is impeded by the chemical/mechanical nature of the rock, which leads to a high

rate of production-induced rock deformation and well failures. Berkeley Lab has started four new projects under the DOE/FE Oil Recovery Technology Program (ORTP), each with cost-sharing from industry. ORTP is one of several technology programs under FE's Natural Gas and Oil Technology Partnership, a partnership program started by SNL and LANL in 1989 and expanded to include Berkeley Lab and LLNL in 1994.

The partnership program was significantly expanded by the Offices of Fossil Energy and Energy Research in FY 1995 through the Computational Technologies (CT) program, a major 1995 thrust under the Domestic Natural Gas and Oil Initiative. CT was designed as a major technology development program to assist the domestic oil and gas industry in finding and producing more oil and gas at a lower cost and with lower financial and environmental risks. CT focuses on the vast, state-of-the-art computational capabilities at the national laboratories, including hardware, software, and their array of other enabling technologies. The main rationale for CT is to reduce the nation's increasing dependence on imported oil, now the largest contributor to the U.S. foreign trade deficit. Working with major and independent producers, oil-field service companies, and universities, Berkeley Lab received DOE approval for five projects. These ER-LTA funded projects cover advanced geophysical exploration for subsalt imaging in the Gulf of Mexico, drill-site analysis of drill cuttings for rock properties, visualization and virtual reality techniques for the reservoir engineer, control of production-related ground subsidence, and optimization of fluid injection for better production from low-permeability reservoirs. In addition, the Geosciences program in the Office of Energy Research is supporting three continuing projects.

Berkeley Lab is exploring the major factors that will affect the economic and technical success of cogeneration in China, the goal being to promote cost-effective application of that technology in China. Berkeley Lab is also exploring selenium's presence in San Francisco Bay and its effects on the Bay's water quality, as well as assessing whether oils refined in the region are sources of selenium contaminants.

Environmental Management

The Laboratory is implementing site projects for restoration and waste management consistent with DOE's National Environmental Management Program. Through direct involvement at Berkeley Lab and other DOE and DOD sites, Berkeley Lab intends to identify major technology gaps in environmental restoration. These gaps will then be addressed and resolved in close cooperation with industry. In addition, and as described in greater detail in Section V, the existing and budgeted site projects address specific conditions at the Laboratory, including facilities and operating programs for corrective actions, environmental restoration, and waste management.

In support of the Office of Technology Development in DOE's Environmental Management Program, and to facilitate the development of underlying science conducted in the Offices of Basic Energy Sciences and Health and Environmental Research, Berkeley Lab is putting together a multidisciplinary research and development program directed at improving the effectiveness and cost/risk benefits of environmental restoration technologies. This development is based upon the Laboratory's basic research in actinide chemistry, geophysical imaging technologies, and field research in microbial heterogeneity in collaborations with PNL, ORNL, Notre Dame, and Purdue. The program has four components:

- Improved characterization of subsurface environments, including better measurement of their biological, chemical, and physical properties, and better definition of the associated contaminant transport processes.
- Development of methods for assured containment and control of subsurface biological, chemical, and radiological contamination.
- Development of advanced remediation technologies, including instrumentation for cost-effective measurements and treatment methods appropriate to complex and heterogeneous subsurface environments.
- Improved risk assessment and prioritization systems to allow better allocation of remediation funds.

The methodologies used in the program will include field testing and tracking contaminant fronts; developing descriptive and predictive mathematical models; characterizing heterogeneous underground

systems; designing, demonstrating, and testing containment and cleanup systems at specific contaminant sites; and determining the underlying chemical, biological, and thermodynamic properties involved in mixed contamination. As program plans are developed, they will be reviewed for NEPA and CEQA documentation requirements.

In a specific direction, Berkeley Lab has joined with LLNL and SNL to form a joint project called the California Environmental Enterprise. Formed in FY 1994 with initial funding from the Office of Technology Development, the project will help facilitate the cleanup of the many contaminated properties in California by utilizing the environmental remediation expertise developed at the DOE laboratories. Berkeley Lab's role in the California Environmental Enterprise project will be to use the special expertise within its Earth Sciences, EH&S, Engineering, and Information and Computing Sciences Divisions for the following activities: (1) to assist small environmental technology businesses gain access to information about technologies being developed within Berkeley Lab and other federal laboratories; (2) to broker technologies developed within the DOE programs to companies in California; and (3) to help design and develop a better information system that will give businesses, regulators, and laboratories access to a wider range of information than is currently available from a single source.

Environment, Safety, and Health

Berkeley Lab is continuing its strong programs in analytical methods development and statistical studies of environmental and epidemiological factors supported by the Office of Epidemiology and Health Surveillance. The Population at Risk to Environmental Pollution Project focuses on the collection, analysis, and interpretation of data pertaining to relationships between human health and environmental pollution. Computational techniques are developed for the analysis of ecological data, especially small-area geographic data, to investigate alleged departures from expected disease rates, to generate etiologic hypotheses, and to plan clinical trials or cohort studies. The role of the Comprehensive Epidemiologic Data Resource (CEDR) Project is to provide exposure and health data on DOE workers to research epidemiologists both within and outside DOE. CEDR includes work on past and current epidemiologic studies by DOE and the Department of Health and Human Services, and is being expanded to include current epidemiologic monitoring data on DOE employees. Other data sets of interest, such as Radiation Effects Research Foundation summary tables and dose reconstruction data from the Nevada Test Site, are included. The goal of the program is to encourage independent review and augmentation of existing findings on DOE worker health effects, in response to criticism that DOE research has not been viewed as impartial by the public. The availability of CEDR data has been increased by posting the information on the World Wide Web and providing access through Gopher and various graphical interfaces.

Other DOE Programs

Civilian Radioactive Waste Management

Berkeley Lab continues a strong multidisciplinary program of interrelated geoscience and geological engineering research important to the safe, long-term underground storage of high-level nuclear wastes. This research includes characterization of deep geologic formations, determination of the physical and chemical processes occurring in the repository rocks, analysis of hydrologic and chemical transport mechanisms, and development of predictive techniques for repository performance. Coupled with ongoing basic research, Berkeley Lab is contributing to technology and applied development research at DOE's Yucca Mountain Project as well as to international projects in cooperation with Sweden, Switzerland, Canada, and Japan.

Experimental work involves testing of rock samples to determine fundamental chemical, mechanical, and hydrologic parameters under a suite of anticipated repository conditions. Complementary research is conducted on the solubilities of actinides and the characteristics and processes that control radionuclide transport in host rocks. Related efforts involve the understanding of processes and the development of methods for predicting the response of geologic systems to repository development and the performance of

geologic environments for various repository containment designs. These expanding research activities draw upon Berkeley Lab's expertise in chemistry, earth science, computing, and numerous engineering fields.

Policy, Planning, and Analysis

Berkeley Lab undertakes analysis activities in support of policy issues of concern to DOE. Recent efforts include analysis of "feebates" (an imposition of fees and concomitant offering of tax incentives to encourage energy-efficient technologies) as a policy approach to increase auto fuel economy, combustion pollution exposure that takes place indoors, the development of data and models for developing projections of energy demand under a variety of policy cases, and evaluation of a variety of policies as an input to DOE's assessment of U.S. energy strategies.

Berkeley Lab is supporting (along with Battelle/Pacific Northwest Laboratory) the creation of the Beijing Energy Efficiency Center. This center has the mandate to influence Chinese policy to promote energy efficiency, to carry out training and educational programs, and to promote trade and joint ventures in energy-efficiency products. Berkeley Lab also has a strong and diverse program of its own on energy efficiency in China. Current work involves production of a major energy data bank for China; analysis of energy efficiency in the Chinese cement industry; oversight of a major project in China to produce an energy-efficient refrigerator as a means of transforming the entire refrigeration market in that country; and economic/financial analysis of energy efficiency and renewable energy projects in China.

In 1994, the U.S. government initiated a program to provide technical assistance to developing countries in their efforts to find ways to reduce the growth of greenhouse gas emissions. Although the program is government-wide, DOE's Policy Office is playing a leading role in organizing this enterprise. Berkeley Lab has been selected to coordinate the technical assistance effort, using our own expertise and that of other organizations. This will begin with assistance to 47 developing countries and is expected to expand to about as many more countries over time.

Other DOE Contractors

Berkeley Lab contributes to the research programs at other DOE national laboratories and facilities through such activities as management and design for the STAR project for the Relativistic Heavy-Ion Collider at BNL, laser-material interactions for LLNL, development of specialized object-scanning CCD cameras, the investigation of advanced windows and energy-conservation strategies for the Bonneville Power Administration, and environmental research and technology development at DOE sites.

Work for Others

Berkeley Lab annually receives in excess of $40 million in sponsored research funding from non-DOE sponsors. The National Institutes of Health (NIH) have sponsored the most non-DOE funded research at Berkeley Lab over the past ten years. Their annual support to Berkeley Lab exceeds $15 million for a variety of research projects in the biomedical field. Other sponsors supporting large research projects at Berkeley Lab include the office of Naval Research, which is expected to fund the Molecular Design Institute for research on the synthesis of novel materials at the molecular lithographic level. Large industrial sponsors include Amgen, which continues to fund a large project in automated sorting of cDNA libraries.

National Institutes of Health

The success of the DOE biosciences and environmental sciences programs at Berkeley Lab has depended not only on DOE support but also on complementary NIH-supported research that is closely coupled to these programs. Several critical technologies recently identified as being of high priority for advancement by NIH—specifically genome sequencing, molecular medicine, biotechnology, and structural biology—are all major components of the life sciences program at Berkeley Lab. These technologies build on the unique facilities and expertise available at Berkeley Lab and point toward a growing interaction of DOE- and NIH-funded research in pursuing new goals in biology and medicine.

NIH applies Berkeley Lab's unique resources to investigations of the human genome and of carcinogenesis and mutagenesis. The Laboratory is central to the *Drosophila* genome project in partnership with NIH. Repair and recombination in yeast and the genetic effect of carcinogens will continue to be major focuses. Cell nuclei are studied by circular dichroism and related techniques. The Laboratory's capability in culturing human mammary epithelial cells is used to study breast cancer.

NIH supports programs on radionuclides, NMR, diagnostic image reconstruction, and radio-pharmaceuticals related to advanced instrumentation and disease treatment. Other major NIH-funded programs involve lipoproteins and their relationship to cardiovascular disease, biological structure analysis by electron crystallography to characterize cell-membrane proteins and viruses, the intracellular molecular structure of DNA and sickle hemoglobin, the molecular basis of cell senescence, and initiation of carcinogenesis by chemicals and radiation. Additional studies are funded to investigate how normal growth and cancer cells are controlled by their microenvironments.

The National Tritium Labeling Facility conducts research into the labeling of compounds with tritium. Berkeley Lab also conducts a program on intermediate-voltage biological electron microscopy under NIH sponsorship. NIH also supports research on oxygen radicals and aging, environmental tobacco smoke, soil transport of gas pollutants, and ecotoxicology assays.

In the life sciences, research on human lipoproteins, genetics, and dietary response are supported by the National Dairy Board through Children's Hospital in Oakland. The UC California Tobacco Research Institute supports research on carcinogenesis.

Department of Defense

The Center for X-ray Optics (CXRO) has received funding from ARPA for the past six years (FY 1991–96). The ARPA funds have been used for construction of two beamlines at the Advanced Light Source (one for EUV interferometry and one for EUV metrology), construction of the Nanowriter (an advanced e-beam writer), and supporting research activities. The funding of lithography research in the U.S. is currently uncertain. The Semiconductor Industry Association (SIA) and its members are urging support for EUV lithography through ARPA and DOE/DP. They are also considering direct research support, including the possibility of the CXRO EUV Lithography program at LBNL. In FY 1995, CXRO received $281 K in direct support from Intel and 380 K in 1996. Discussions about FY 1997 funding are in progress with all of the above-mentioned parties.

ARPA funds the MAGIC gigabit testbed, a project to combine high-speed, wide-area-network technology, distributed image-storage systems, and high-speed graphics with aerial and satellite images, to present a user with a virtual reality that corresponds to what he or she would see while traveling through the actual terrain. Berkeley Lab is doing the research and development for the high-speed distributed-image server system that will supply the imagery to the terrain-visualization application providing the real-time view of the landscape.

The Laboratory conducts research on the nanoscale synthesis and characterization of materials at its Institute for Molecular Design. The Laboratory also conducts a program of Bioremediation Education Science and Technology (BEST) for the U.S. Army Corps of Engineers in partnership with Jackson State University and the Ana G. Méndez University System in Puerto Rico.

National Aeronautics and Space Administration

The space radiation environment and what it means to continue human presence in space is one of the most unique of NASA's problems. In order to address the health hazard aspect of this problem, Berkeley Lab investigators are conducting multidisciplinary research at the molecular, cellular, and tissue levels. In consortium with Colorado State University, Fort Collins, Berkeley Lab is now the recognized NASA Specialized Center for Research and Training in the area of human health. The purpose of the training is to produce the next generation of space radiation scientists.

The Berkeley Lab Astrophysics Group has been instrumental in the development of the Differential Microwave Radiometer installed on the Cosmic Background Explorer (COBE), which has detected anisotropies in the cosmic microwave background. These anisotropies show the primordial seeds of modern structures such as galaxies, clusters of galaxies, and larger-scale patterns. These seeds were produced by particle interactions at the creation of spacetime. Data analysis is continuing to improve statistics and to refine our understanding of the early universe.

Other NASA projects at Berkeley Lab include studies on gravitational effects on combustion and low-noise electronics for detectors. These studies have applications in atmospheric and astrophysics research.

Environmental Protection Agency

Berkeley Lab conducts research on the hydrogeological transport of contaminant plumes from deep underground injection disposal. In the area of global environmental effects, Berkeley Lab is characterizing the emissions of energy technologies, improving global energy projections, fostering international awareness of global trends, studying effects of tropical deforestation, and gathering information on the potential effect of global climate change on U.S. natural resources. Berkeley Lab, along with other national laboratories, is working to develop new programs in partnership with the Environmental Protection Agency (EPA) that advance national environmental goals, including the more efficient use of energy to reduce greenhouse gas emissions.

Department of the Interior

Laboratory scientists are investigating the geochemistry of selenium and other trace elements at Kesterson Reservoir, which has been a terminus of agricultural drainage water in California's San Joaquin Valley. Continuing collaborative investigations are under way to evaluate remediation techniques for the area's soil. Related research is being conducted at Stillwater Marsh, Nevada.

Agency for International Development

The Agency for International Development is supporting a multiyear effort in which Berkeley Lab will perform research in support of improving the efficiency of energy use in developing countries.

Other Agencies/State and Private

The Laboratory conducts research for the Electric Power Research Institute (EPRI). Chemistry-related research includes studies on reducing oxidation and scale formation, and on oxygen depletion in compressed-air storage. Another EPRI project is the study of surface modification with metal plasma techniques.

The Gas Research Institute supports databases on the influence of clays on seismic-wave attenuation in reservoir rocks. The California Air Resources Board is sponsoring an analysis of polycyclic aromatic hydrocarbons in indoor air.

Berkeley Lab's expertise in building technologies is recognized by the California Energy Commission and the energy utilities. Much of the support is through the California Institute for Energy Efficiency (CIEE), a joint effort of the California energy utilities, Berkeley Lab, the University of California, and the California Energy Commission and Public Utilities Commission. CIEE manages a focused research program, with the research being carried out by California universities and DOE national laboratories located in the state. CIEE's overall research framework is determined by a research board consisting of high-level executives from the utilities, the University, the commissions, DOE, the Gas Research Institute, and EPRI. A planning committee with members from these same institutions approves individual research projects within this framework. CIEE serves in effect as a Work-for-Others (WFO) agency that evaluates and funds proposals from Berkeley Lab, along with those from other California research institutions. Particular Berkeley Lab projects funded by CIEE include the study of efficient systems for thermal distribution in buildings, integrated

envelope and lighting technologies, end-use technology performance data, urban landscape modifications to reduce energy use and air pollution, and advanced combustion devices to reduce nitrogen oxide emissions.

Additional utility support is as follows: Southern California Edison supports computer tool development; Pacific Gas and Electric Company supports a study of end-use energy intensifiers in commercial and residential buildings; and the Sacramento Municipal Utilities District supports energy-saving studies of shade trees and other surfaces.

Laboratory Directed Research and Development

This program contributes to scientific staff capability and vitality through the support of new research programs of merit and potential. Examples of project areas eligible for support include:

- Work in forefront areas of science and technology that enrich Laboratory research and development capabilities.
- Advanced study of new hypotheses, new experiments, and innovative approaches to development of new concepts or knowledge.
- Experiments directed toward proof of principle for initial hypothesis testing or verification.
- New-device studies to explore possible application to instrumentation or experimental facilities.

Recent achievements sponsored by the Laboratory Directed Research and Development (LDRD) program in the energy sciences include research on structure and chemistry of adsorbates at semiconductor interfaces, near-field scanning optical microscopy/spectroscopy of low-dimensional systems at 50-nm resolution, laboratory studies of microbial transformation of petroleum hydrocarbons in transient subsurface environment, electron-beam lithographic fabrication of submicron junctions for Coulomb blockade arrays and high-T_c SQUIDS, soil carbonate sorptive properties for trace elements, chemistry of etching, a low-temperature AFM for imaging current flow in nanostructures, improved estimation of in-use pollutant emissions from motor vehicles, thermodynamic temperature scale in the mK region, nanometer magnetism by using the Surface Magneto-Optic Kerr Effect (SMOKE), broad-band high-resolution microcalorimetry, combinatorial synthesis of high-T_c superconductors, catalytic routes to a cleaner environment, and ultrafast surface dynamics with atomic resolution. Recent achievements in the general sciences area include femtosecond x-ray pulse generation, global gravitational anomalies in three dimensions, integrated instrumentation system for drift chambers and TOF/Cerenkov/silicon detectors, and high-resistivity charge-coupled devices for imaging. Recent achievements in the biosciences area include electron crystallography of selected membrane proteins, biological dosimetry for genetically damaged hemopoietic stem cells, creation of transgenic mice containing a library of P1 clones encompassing the Down's Syndrome region from chromosome 21, variations in susceptibility to environmental oxidants, isolation of genetic supressor elements in human mammary epithelial cells, studies on hyperthermophilic microorganisms, and microchemical methods for biological assays. The FY 1995 *Report on Ernest Orlando Lawrence Berkeley National Laboratory, Laboratory Directed Research and Development Program* is available on the World Wide Web at http://www.lbl.gov/Publications/LDRD/. Planning documents that indicate program directions and projected resources are prepared annually.

Laboratory Directed Research and Development Program

Category	FY 1994 Actual	FY 1995 Actual	FY 1996 Authorized	FY 1997 Projected
Funding ($M)	5.2	6.4	7.7	9.0
Projects Approved	52	49	59	—

Science and Technology Partnerships

Berkeley Lab builds new partnerships with industrial, university and nontraditional partners where capabilities and technology derived from the Lab's research can be applied to solving important customer problems and at the same time strengthen DOE's basic science mission. Berkeley Lab's science and technology partnerships are managed by the Technology Transfer Department (TTD). Berkeley Lab is also home to National User Facilities hosting over 3,000 scientific personnel each year.

In leveraging the multidisciplinary of the Berkeley Lab in particular and the entire national laboratory system in general, there are new significant efforts in the Department of Energy for encouraging cross-cutting programs between the DOE's offices. It is by taking advantage of the full capabilities in place among the national labs that practical solutions to the nation's problems can be developed. Directions where Berkeley Lab can make special contributions include:

- **Environmental Science Initiative.** The DOE, through its Energy Management Office, is encouraging innovative and fundamental research to support the management and disposal of DOE's radioactive, hazardous chemical, and mixed wastes. This research will contribute to environmental management and restoration actions that would decrease risk for the public and workers, provide opportunities for major cost reductions, reduce time required to achieve Energy Management's mission goals, and, in general, should address problems that are considered intractable without new knowledge. Specific areas Berkeley Lab can support are: advanced characterization methods relating to high-level wastes, *in situ* characterization of dense nonaqueous phase liquid, characterization of heterogeneous wastes, nondestructive and *in situ* characterization landfill hazards, emission-free destruction of organic wastes, plutonium behavior in mixed matrices, waste stabilization of spent nuclear fuel, specialized waste forms, ecology, and biomarkers and sensors of contamination exposures.
- **Industries of the Future.** The Office of Energy Research can support the Office of Energy Efficiency and Renewables in encouraging high-quality research on the fundamental issues that will underpin future vehicular technologies and conversion of energy and pollution intensive industrial processes to more environmentally sound and energy-efficient processes. Berkeley Lab has numerous strengths in the frontier research vehicular technologies such as modeling and simulation of energy processes, fundamental understanding of surfaces and interfaces, relevant nano-science, energy relevant materials, advances in sensors and control methodology, and understanding catalytic and electrochemical processes. For industrial processes, Berkeley Lab can also make important contributions in areas of frontier research. Examples of these areas are reduction of energy consumption, pollution from energy production, and pollution-intensive manufacturing processes.
- **Energy Research/Energy Technology Cross-cuts.** The Energy Coordinating Committee and Laboratory Energy R&D Working Group have examined areas of crossing-cutting technologies which the national labs can address important issues. The six areas identified are: (1) biosciences research relative to biomass energy crop productivity and bioconversion; (2) high-efficiency, photovoltaic battery and fuel-cell engineered materials and devices; (3) miniaturization for energy applications; (4) corrosion research; (5) sequestering carbon dioxide emissions; (6) and enabling energy technologies through advanced computation and communications. Berkeley Lab is to coordinate discussions in the last area, which will examine imaging, visualization, modeling techniques, and networks.

Technology Transfer

Patent and Software Licensing

Berkeley Lab seeks to patent and license its intellectual property to maximize the use of the inventions by industry and to promote the research and technology transfer interests of the Laboratory and its research staff. In FY 1995 Berkeley Lab reported 63 inventions, 26 U.S. patent applications filed and 14 patents issued. The trend for patents in the 1990s shows Berkeley Lab averaging 60 reported inventions, 25 patents filed, and 15 issued annually.

Fiscal Year 1995 saw income from both patent and nonpatent intellectual property more than double from FY 1994 figures. We expect to see further growth as the program matures. That year also saw a large increase in options and licenses signed, which should lead to higher income in future years. At the end of FY 1995, Berkeley Lab added to its licensing staff, expanding from one full-time licensing executive to two full-time licensing executives and a paralegal. The impact of these changes should materialize in FY 1997 income.

One example of Berkeley Lab's licensing successes is that researchers developed a cost-effective technique to quicken the pace of production and screening of new advanced materials by as much as 10,000-fold. The technology was licensed to Symyx, a Sunnyvale, CA start-up company that expects to create 80 jobs in the next 4 years developing advanced materials such as superconductors, phosphors for flat panel displays, dielectric materials, zeolites, and magnetic materials. The license agreement has ushered in a new way for the Laboratory to do business. It is the first license-for-stock agreement arranged by a UC-managed laboratory. Obtaining a license with stock can be an attractive alternative for small companies who are not yet able to generate sufficient cash to pay for relatively large license issue fees. It is also a way by which Berkeley Lab can fulfill its mission to help small businesses.

Other Technology Transfer Department Efforts

In addition to patent and licensing efforts, the Technology Transfer Department (TDD) handles marketing, small business partnerships, and industrial outreach. TTD's marketing efforts foster industry and non-DOE-sponsored interest in Laboratory research capabilities. TTD promotes technologies available for licensing and collaboration, produces publications, attends trade shows, responds to Laboratory inquiries, and arranges corporate visits. It also manages World Wide Web marketing efforts with online groups such as DTIN (DOE Technology Information Network), UCACCESS, a University of California-wide technology transfer information service, and FLC Webmasters. Small businesses are a major source of new jobs, economic growth, and technological innovation in our economy. Berkeley Lab is committed to helping small businesses leverage their R&D resources; over 60% percent of our partnerships are with small businesses. Industrial outreach brings together industry and Berkeley Lab to work on projects of mutual interest. An example of a successful partnership is our CRADA with Intel to develop new tools at the Advanced Light Source that support the future needs of the semiconductor industry. This collaboration is especially noteworthy because it matches industrial needs as outlined in the "Semiconductor Industry Roadmap" developed by the Semiconductor Industry Association. The Technology Transfer Department also provides management for the ER-Laboratory Technology Research (ER-LTR) Program, which was established to enhance U.S. industrial competitiveness through beneficial collaborations between the national Energy Research laboratories and industry.

ORTA Activity

	FY 1995	FY 1996[a]	FY 1997[a]	FY 1998[a]	FY 1999[a]	FY 2000[a]	FY 2001[a]	FY 2002[a]
Funding ($K)								
ORTA Activity	420	431	442	453	464	475	486	497
Patent/Licensing Activity	736	852	872	894	1000	1030	1061	1093
Total ($M)	1.2	1.3	1.3	1.3	1.5	1.5	2.0	2.0
Staffing (FTE) (No.)								
ORTA Activity	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Patent/Licensing Activity[b]	8.0	8.0	8.0	8.0	8.5	8.5	8.5	8.5
Total	13.0	13.0	13.0	13.0	13.5	13.5	13.5	13.5

[a]Estimate.
[b]"Patent/Licensing Activity" covers invention identification, patent/copyright acquisition costs, and marketing.

Licensing Income and Use

Category	FY 1995	FY 1996 (est.)	FY 1997 (est.)	FY 1998 (est.)	FY 1999 (est.)
New Licenses (No.)[a]	24	25	30	30	30
License Income ($K)[b]	163	140	200	250	250

[a]Includes options.
[b]Cash-in only (i.e., not including fair market value of noncash income).

Use of Licensing Income:

Invention & ORTA Administration: 15% of gross income plus patenting costs.
Scientific or Applied R&D: 50% of net income.
Awards & Inventor Payments: 50% of net income.
Education/Training: 0.
Other (Specify): 0.

User Facilities

Berkeley Lab is the home of four major DOE user facilities: the Advanced Light Source, the National Energy Research Scientific Computing Center and Energy Sciences Network, the 88-Inch Cyclotron, and the National Center for Electron Microscopy.

Advanced Light Source (ALS). The Advanced Light Source (ALS) at Berkeley Lab is the world's brightest source of x-rays with long wavelengths (soft x-rays). The ALS is the first U.S. member of a new generation of synchrotron-light sources that use advanced accelerator and magnet technology to produce x-ray beams so bright that they resemble beams from lasers. A new facility that began operating for users in October 1993, the ALS offers unprecedented opportunities for research by American scientists from industrial, academic, and government laboratories.

Soft x-rays are an ideal tool for probing the secrets of matter at the level of individual atoms and molecules, owing to their ability to penetrate into samples and to the many ways in which they interact with atoms and molecules once inside. For example, the laser-like beams of the ALS make possible x-ray microscopes for direct visualization of structures. Almost all of the commonly observed properties of

matter depend directly on the atomic structure (i.e., where the atoms are) and on electronic structure (e.g., chemical bonding).

Research conducted at the ALS covers an exceptionally wide variety of subjects, encompassing both fundamental research and new technologies critical to maintaining U.S. competitiveness. Subjects for study range from the semiconductors that are the foundation of the electronics revolution, to magnetic materials used in computer-storage disks, to molecules undergoing rapid reactions in combustion and other industrially important processes, to structures within biological cells that determine how well drugs can fight disease-causing agents such as viruses.

National Energy Research Scientific Computing (NERSC) Center and Energy Sciences Network (ESnet). The NERSC Center offers unsurpassed high-end computational capability to support aggressive science-of-scale projects. Associated with this is high-performance access to online and near-line high-capacity storage systems. Computing resources range from desktop workstations and administrative support computers to the most advanced high-performance scientific computer systems such as the Cray C-90 and Cray J90/T3D systems. Communications resources include local area networks as well as the national Energy Sciences Network (ESnet).

ESnet is a high-quality, high-speed, and versatile communications network, a critical component of all aspects of computational science. The core of computing, storage, collaboration, and remote instrumentation as applied to science is based on computer networking and high-quality connectivity between users and systems.

NERSC and ESnet support a broad program in areas that help to reveal and realize the potential of computer science for the scientific community. The research program spans the areas of: Network Research, Heterogeneous Distributed Systems, System Architectures, Large-scale Scientific Data Management, Object-Oriented System-Independent Data Management Support, Network-Based Storage Systems and Scaleable Input/Output, Scientific Visualization.

88-Inch Cyclotron. The 88-Inch Cyclotron is a versatile and reliable accelerator supporting forefront scientific research programs in the areas of nuclear structure, nuclear astrophysics, fundamental symmetries, and space applications. It is operated by Berkeley Lab as a national facility in support of the U.S. Department of Energy programs in nuclear science. The research is carried out by scientists and engineers who come from Berkeley Lab as well as other national laboratories, universities, foreign institutions, and industrial organizations. The 88-Inch Cyclotron is the site of the major initiative of the nuclear structure research community—Gammasphere, a new high-resolution gamma-ray detector array. Gammasphere is presently the most powerful detector in the world for gamma rays with energies around a million electron volts. It is currently operating with 90 of the 110 germanium detectors planned. When completed in mid-1996, this array will be about 100 times more powerful than its predecessors. It already attracts a large worldwide community of users. The Cyclotron plays an important role in the education and training of young scientists at the undergraduate, graduate, and postdoctoral stages of their careers. For example, 49 postdocs, 61 graduate students, and 13 undergraduate students were involved in research at the facility in FY 1995.

The Cyclotron is a sector-focused, variable-energy cyclotron that is fed by either of the two Electron Cyclotron Resonance (ECR) high-charge-state ion sources producing beams from hydrogen to uranium. This versatile combination produces heavy-ion beams from helium to oxygen with energies of up to 32 MeV/nucleon. For heavier ions the maximum energy per nucleon decreases with increasing mass. Typical ions and maximum energy (MeV/nucleon) are argon (23), krypton (14), xenon (8), and bismuth (5). Most metallic ions and all gaseous ions up to mass 150 either have been accelerated or can be developed as needed, with energies high enough for nuclear physics studies. To date, 41 elements have been accelerated including every element from hydrogen to zinc. The high efficiency of the ECR sources makes it economically feasible to accelerate rare expensive isotopes. Light ions—p, d, ^{3}He and ^{4}He—are produced up to total energies of 55, 65, 135, and 130 MeV, respectively. Polarized protons and deuterons at intensities of up to 0.5 micro ampere are also available.

National Center for Electron Microscopy (NCEM). Electron microscopy is a unique and indispensable tool for materials characterization because it is the only technique that provides information on the inner

structure of materials at a high spatial resolution. In a transmission electron microscope, a high-energy electron beam penetrates an extremely thin slice of material to form a transmission image of the sample's interior structure. The resulting micrographs carry quantitative information on the property-controlling characteristics of materials such as internal interfaces, defects, structure, bonding, and composition. Electron microscopy is used to characterize advanced materials, establish the link between microstructure and properties, detect causes for failure, and discover new materials and phenomena in fundamental materials science.

The NCEM is a national user facility for electron microscopy sited at DOE's Berkeley Lab. The facility provides state-of-the-art equipment and expertise in microcharacterization of materials at high spatial resolution. Its users are materials scientists from universities, government laboratories, and industry. The NCEM is home to two unique high-voltage electron microscopes—the 1 MeV atomic-resolution microscope (ARM) reaches the highest resolution in the United States, and the 1.5 MeV high-voltage electron microscope (HVEM) provides the highest energy. In addition, the Center houses several smaller mid-voltage microscopes, including a 200 keV analytical electron microscope (AEM) and a 200 keV high-resolution electron microscope (HREM). A 200 keV *in-situ* microscope (ISM) has recently been added, and a computer-facilitated one-Ångstrom microscope (OÅM) is being acquired. Facilities for specimen preparation, image processing, and data analysis are also available to NCEM users.

Experimenters at Designated User Facilities — 1995

	Labs[a]			University			Industry			International			Other		
	Exp	Org	% of Use	Exp	Org	% of Use	Exp	Org	% of Use	Exp	Org	% of Use	Exp	Org	% of Use
ALS	70	8	–	76	26	–	13	8	–	54	23	–	–	–	–
NERSC[b]	264	19	89	166	66	9	31	21	2	2	2	0	–	–	–
88-Inch Cyclotron	102	4	62	78	18	23	30	8	10	52	17	5	–	–	–
NCEM	86	9	51	51	16	30	18	12	11	13	14	7	–	–	–

[a]Labs are all federal government labs (not just DOE). Berkeley Lab/UCB joint appointments typically are given in Labs rather than University.

[b]NERSC experimenter figures based on principal investigator's accounts. There are approximately nine times as many individual users as principal investigators.

University and Science Education Programs

The Center for Science and Engineering Education (CSEE) develops and implements programs that utilize Berkeley Lab resources to provide authentic science education opportunities to improve the quality of mathematics, science, and technology education in the United States. The Center, in concert with other DOE laboratories, is prepared to provide greater technical and operating support to the Office of Science Education Programs. On an annual basis, CSEE educational activities reach thousands of students and faculty. CSEE programs are funded primarily by the Department of Energy, with additional funding from the National Science Foundation and the National Institutes of Health. The program and activity areas match the needs of the target audiences and the resources of the Laboratory. New initiatives include (1) greater outreach to the diverse California student population to ensure a diverse science and engineering workforce for the Department of Energy; and (2) expansion of the successful Teacher Research Associate Program and Hands-On Universe models through partnerships to increase national science knowledge and skills.

Laboratory Cooperative Education provides students and faculty from across the country with research experience in Berkeley Lab's scientific and engineering programs. Both summer and academic-year programs offer long-term, close mentor relationships that provide participants with in-depth exposure to the world of scientific research and development. Successful partnerships with the California community colleges, California state universities, and the University of California will be targeted for expansion. Berkeley Lab proposes to take a central coordination role in an expanded NSF/DOE high school and middle school faculty research associate program.

Partnerships in Education and Systems support will continue for professional development of educators and curriculum implementation in the Oakland Unified School District through the Bay Area Science and Technology Education Collaboration (BASTEC).

The Science Consortium is a collaboration of three entities—Berkeley Lab, Jackson State University in Mississippi, and the Ana G. Méndez University System in Puerto Rico. These three organizations work together to promote computer and science education in the academic institutions through collaboration with Berkeley Lab scientists. The development of initiatives in bioremediation research and high-performance computing and networking for competitive research grant development will continue.

The Native American Renewable Energy Education Program (NAREEP) carried out though the UC Berkeley Energy Resources Group, provides for the development of curricula and energy utilization education at tribal community colleges.

Hands-On Universe and Authentic Science Education Outreach will expand the opportunity for students to participate in ongoing science research beyond the current automated supernova search at Berkeley Lab. The Hands-On Universe project is carried out collaboratively with the Berkeley Lab Physics Division and the Institute for Nuclear and Particle Astrophysics. Currently in the development, testing, and early evaluation phase, Hands-On Universe is an international partnership consisting of over 10 museums, 30 teachers, 1000 students, and leading science education specialists across the country. The Hands-On Universe model and network will be used to coordinate the educational efforts of various research divisions at Berkeley Lab to promote and deliver materials for the nation's classrooms via the World Wide Web. Examples of programs under development include: Microworlds, based on the work at the ALS, with its embedded assessment tools and curriculum materials; the Human Genome Project's Ethical Legal and Social Issues; and the Whole Frog Project, with its Frog Dissection Kit. Berkeley Lab will extend its outreach to the nation's classrooms through the use of the World Wide Web. As an expansion of this area, partnerships are being developed with the Far West Laboratory for Educational Research and Development, the California Math and Science State Systemic Initiative, and other state-wide mathematics and science education programs organized under the UC Office of the President.

University and Science Education

Programs	FY 1995 Total	FY 1995 Minorities[a]	FY 1995 Women	FY 1996 Totals	FY 1996 Minorities[a]	FY 1996 Women
Undergraduate Students	88	28	39	84	36	49
Undergraduate Faculty	255	50	132	351	66	169
Student/Faculty Teams	2	2	0	5	3	1
Precollege Students	204	58	72	116	28	28
Precollege Faculty	467	112	279	45	7	23
Special Programs: BASTEC Teachers (Systemic Initiative)	1,272	579	890	380	118	216
Special Programs: BASTEC Students (Systemic Initiative)	17,464	12,790	8,557	5,250	4,375	2,560
Special Programs: Berkeley Lab Outreach (Northern California)	25,000	10,000	9,000	15,000	15,000	7,500

[a]Minority numbers are for underserved groups only.

V. CRITICAL SUCCESS FACTORS

Berkeley Lab's strategic planning focuses on aligning the Laboratory's management and operational systems so as to support DOE national research programs and achieve Vision 2000. A number of organizational systems have been identified as critical factors for measuring the Laboratory's performance. The systems directly support DOE's Quality Leadership Group plan: "The Quality Transformation: A Catalyst for Achieving Energy's Strategic Vision." This section describes the quality management and operational systems that support Berkeley Lab's programs and are a key to successful research management and institutional planning.

HUMAN RESOURCES

Berkeley Lab's strategic plan supports a major human resources initiative in clearly communicating performance expectations and empowering the staff to pursue these goals in an atmosphere of mutual trust and respect. This endeavor undergirds DOE's efforts for aligning human resources with agency priorities. We are seeking an increase in the diversification of work force organizations — with streamlined management, the utilization of continuous process improvement tools in systems analysis and review, and empowered employees — all of this occurring with less regulatory oversight so that Berkeley Lab and the Department of Energy can respond to today's technology-demanding economy.

The Human Resources Strategic Plan has resulted in the creation of a set of operating principles and expected outcomes concerning the delivery of services in the areas of compensation, employee relations, labor relations, benefits, training, reception center, and staffing. In each of these areas, we are challenged to deliver valuable services to our customers.

The principles that guide our performance require us to establish a consultative partnership with our clients. Our efforts will support institutional goals and directives that are situationally rather than structurally based. We need to be flexible and offer a market-based compensation program focusing on duties and responsibilities. We will deliver training that is skilled and is behavioral and value based, and that incorporates the "Laboratory culture." We expect a bipartisan employee relations climate that balances management's perspective with the employee's perspective, where our Employee Relations staff is valued for its objectivity and quality consulting.

During the past fiscal year, the Berkeley Lab implemented a reduction in force that resulted in over 130 administrative support positions being eliminated. Human Resources worked collaboratively with DOE to obtain approval of the Lab's Work Force Restructuring Plan. Further, Human Resources staff worked with management in implementing the reductions and organizing the outprocessing of staff. Over 100 of these former employees enrolled in the outplacement workshops designed to help them in the transition to new employment. These reductions were made possible as a result of redesign and reengineering efforts to analyze processes and make them more efficient. Thus, the Laboratory is able to accomplish its mission while eliminating nonvalue added work.

A team from Operations has made significant progress in designing and developing an Administrative Services Department that will provide support to the research divisions. This approach will be set up on a regional service center concept that will allow for clear, consistent performance standards with service being delivered in a responsive manner. The Administrative Services Department will provide improved career choices for administrative support staff while engaging the staff in a variety of daily assignments. Ultimately, this approach will allow the Lab to deliver support in a more cost-effective manner.

Overall, Human Resources performance has been extremely effective. Here is a brief summary of some key Human Resources initiatives during the past year:

- Designed, developed, and implemented 24 exempt and 22 nonexempt administrative job classifications.
- Designed, developed, and implemented a pilot Spot Recognition Award Program that allows supervisors to promptly recognize individuals and teams for accomplishments that support the Laboratory's mission.
- Proceeded with the mid-year roll out of PeopleSoft Human Resources Information/Payroll System.
- Human Resources functional disciplines developed training modules that explain Laboratory policy for hiring and selection, compensation, performance evaluation, employee relations, and labor relations.
- Continued increased emphasis on supervisory training and leader effectiveness as a part of the Laboratory's training plan.
- Placed increased emphasis on affirmative action outreach and gained broader support from the Berkeley Lab Diversity Committee.
- Concurrently, Human Resources dedicated specific personnel to support the NERSC transition to the Berkeley Lab.
- Merged the Compensation and Benefits Units under one manager to reinforce cross training and to eliminate "silos" that get in the way of quickly shifting resources as projects demand.

Berkeley Lab's initiatives, designed to optimize the way we work, are high priorities. The Berkeley Lab is committed to obtaining the highest quality results at the minimal cost. The principal components of Berkeley Lab's human resources planning effort are discussed below and are also summarized in Section III, "Laboratory Strategic Plan."

Laboratory Personnel and Programs

Berkeley Lab's most valuable resource is its people—the scientists, engineers, and support staff who contribute their many diverse skills to advance the Laboratory's research programs. The Laboratory's scientific and engineering staff are known for a wide range of accomplishments and honors. Nine Berkeley Lab scientists have become Nobel laureates, sixteen have won Lawrence Awards, and four have won Fermi Awards. Of its present staff, 55 have been elected to the National Academies of Sciences and Engineering. Much of this success is founded on the Laboratory's ability to create highly effective teams of scientists, engineers, technicians, and students—then to orchestrate their efforts to produce a rich yield of basic knowledge and applied technology. From scientific leadership to technical expertise to administrative support, all parts of the team are necessary if we are to succeed.

To reinforce our successes, the Outstanding Performance Award (OPA) Program has been developed to recognize and reward individuals and teams that support the Laboratory's strategic plan. Examples of areas of achievement include technology transfer, total quality management, and work force diversity. During FY 1996, a spot recognition program was introduced to facilitate immediate acknowledgment of employees for key contributions to successful efforts.

A large part of the Laboratory's success is also due to the many graduate and undergraduate students who contribute their efforts each year, as well as the many senior staff scientists jointly appointed as faculty on the UC campuses, primarily at UC Berkeley. This relationship with UC provides a unique ability to interact with the broader university community, and helps to attract and retain a professional staff of high caliber. All of these factors contribute to Berkeley Lab's mission to promote excellence in education and training, both for its own employees and for the greater scientific community. Our ultimate goal is to offer exceptional opportunities for professional growth, in an environment where achievement is recognized and rewarded at every level.

The Laboratory's Human Resources programs are administered in a manner consistent with the Prime Contract with the University of California and the Department of Energy. The Laboratory has adopted a compensation philosophy with the following objectives:

- To provide a level of compensation that, within available funds, attracts, motivates, and retains the quality work force necessary for the achievement of Laboratory goals.
- To recognize and reward performance and productivity while maintaining a competitive market position and providing internal Laboratory equity.

In its administering of the Human Resources programs, the Laboratory strives to deliver Human Resources systems in a cost-effective manner; develop and maintain work force excellence; strengthen the Laboratory's commitment to achieving work force diversity; and guide Human Resources programs and operations in accordance with the Laboratory's quality strategies and initiatives.

Human Resources programs and initiatives that are planned for the next fiscal year include:

- Developing and maintaining an applicant pool that is diverse, current, and highly qualified.
- Streamlining the hiring and recruitment process, with more scientific and engineering activity occurring in the research divisions and more administrative hiring occurring centrally.
- Providing affirmative action guidelines and resources.
- Implementing a career development program and an integrated management program with defined skill sets for each management level.
- Implementing supervisory training programs that reinforce and support Laboratory quality initiatives.
- Developing a proactive role for Employee Relations and Labor Relations staff that balances employee concerns with management needs.
- Developing programs that effectively coordinate the Laboratory's employee resources.
- Developing and implementing alternative rewards programs, including nonmonetary rewards, spot awards, and employee-initiated awards.

Laboratory Staff Composition (Full- and Part-Time Personnel—FY 1995)

Group	Doctoral	Master's	Bachelor	Other	*Total*
Professional Staff					
Staff Scientists	782	36	31	7	856
	(23.6)	(1.1)	(0.9)	(0.2)	(25.9)
Engineers	124	132	149	47	452
	(3.7)	(4.0)	(4.5)	(1.4)	(13.7)
Management/Administrative	30	87	117	249	483
	(0.9)	(2.6)	(5.3)	(7.5)	(16.4)
Support Staff					
Technicians	14	94	232	573	913
	(0.4)	(2.8)	(7.0)	(17.3)	(27.6)
All Other	1	107	325	113	546
	(0.0)	(3.2)	(9.8)	(3.4)	(16.5)
Total	*951*	*456*	*854*	*989*	*3250*
	(28.7)	*(13.8)*	*(27.6)*	*(30.0)*	*(100.0)*

Training and Development Programs

Through a combination of on-the-job training, in-house training programs, and attendance at programs/courses provided by non-Laboratory institutions, the technical skills of the Laboratory's employees are constantly upgraded to keep current with rapid technological advances. The Employee Development and Training Unit (EDT) continues to offer management and supervisory development courses. The roll out of Zenger Miller's Frontline Leadership is in its third year. To date, nearly 300 managers and supervisors from Operations, Scientific Divisions, and the Directorate have attended the training.

The roll out of Managing Within the Law continues, as does Knowing the Law. Both courses are taught by attorney and noted author, Rita Risser. Four hundred thirty-three managers and supervisors across Berkeley Lab have attended Managing within the Laws while 792 employees have attended Knowing the Law.

EDT also provides consulting and facilitation services to requesting divisions. Various divisions throughout the Laboratory have asked for and received training in Team Building, Time Management, Instructional Design, Effective Meetings, and Effective Presentations. Additionally, this year Berkeley Lab EDT has reached an agreement with UC Berkeley EDT that enables all managers and employees access to the extensive course offerings on the UC Berkeley campus.

More than 30 development courses and seminars are offered on site each year. Scheduled on-site training and programs are conducted in environmental safety and health and in management, personnel, computer, and workstation skills. Berkeley Lab also provides support for off-site training and education, including baccalaureate and advanced degrees as well as other professional training credentials. The Laboratory has an educational assistance and tuition reimbursement program to aid employees in obtaining advanced training and education through approved employee development plans.

In addition to providing training, the Laboratory maintains an Employee Assistance Program in conjunction with UC Berkeley, which offers counseling to employees with problems that often impact job retention, personal well being, and effective job performance. These resources and programs are available through the Human Resources Department's Employee Relations and Labor Relations offices and the Health Services Department. The long-range goal is to outsource this program, thereby offering comprehensive services for employees through a competent external organization.

Work Force Diversity

As we move into the next century, one of the more dramatic changes affecting employers is the increasing diversity of both the state of California and the nation at large. The challenge for Berkeley Lab will be to continue to expand our efforts to create a climate in which diversity in the work force is valued. This means actively seeking such diversity and fully supporting the contributions and changes that it brings about. By recognizing, creating, and celebrating a diverse culture, the Berkeley Lab will provide an environment that is accessible, equitable, and hospitable to all its employees and guests. Creating a workplace where diversity can thrive will also enable us to attract the qualified staff that we need to continue to conduct world-class science. In more recent years, the term "work force diversity" has been recognized at the Laboratory to mean that there is a broader set of issues than the traditional focus on affirmative action compliance. In effect, there is a new emphasis on harnessing diversity to the cause of scientific excellence. The term is used to describe essentially a new workplace culture in which a fundamental set of guiding principles and values form the community context in which diversity is practiced. Five key principles form the basis of the Laboratory's definition of diversity.

- Differences in ethnicity, culture, gender, age, and lifestyle are valued for the variety of perspectives they bring to the workplace. New perspectives and old perspectives are equally important.
- Differences are not only welcomed but actively sought.
- Management takes these differences into account in setting policies, motivating people, and giving rewards.

- The sense of being valued motivates all employees to put forth their best efforts and therefore leads to higher productivity.
- The spirit of mutual regard and cooperation leads to synergism — the state in which working together yields results greater than the sum of individual efforts.

In addition to these key principles, the Laboratory's Work Force Diversity Office, in partnership with senior management, will undertake the following specific programmatic initiatives, as well as a wide range of programs that will enhance our ability to attract and retain qualified individuals:

- Aggressively seek women, people of color, and individuals from other protected classes who have the potential to achieve excellence at Berkeley Lab. Initiate new recruitment methods that identify potential candidates early in their educational careers.
- Mentor employees so that they can achieve excellence.
- Ensure a working atmosphere that is supportive and gives a sense of belonging to employees from all cultures.
- Provide resources to help managers and supervisors implement the Laboratory's affirmative action program.
- Develop new capabilities for the Laboratory and each division to review its performance with regard to affirmative action issues.

Accomplishments in 1995–1996

At the beginning of FY 1995, the Laboratory had achieved aggregate work force representation comparable to availability for women and minorities by reducing underutilization during the preceding Affirmative Action Plan (AAP) year. Further progress was made by the Laboratory in eliminating areas of underutilization in several occupational categories, representing 9 of 26 (34.6%) of underutilized job groups at the end of FY 1995. Progress also was demonstrated in the reduction of underutilization in 16 of 26 (61.5%) of job groups that were underutilized. Also at the end of FY 1995, an additional 3 (10 total) of 33 job groups were fully utilized. Women were fully utilized by the Laboratory in 22 of 33 EEO job groups. An additional 1 (20 total) of 33 EEO job groups were fully utilized for people of color and an additional 3 (11 total) of 33 were fully utilized for every minority group. As a result of retention, placement, and promotion of women and people of color, 14 areas eliminated undertutilization in FY 1995. The specifics of this progress, accomplished despite significant reduction-in-force losses in this period, are given in Section 14 of the FY 1996 Affirmative Action Program document and in response to Performance Objective #3 of the Human Resources Appendix F measures for the UC contract.

In addition, the following is a representation of several programmatic achievements that occurred in FY 1995:

Child Care Center Working Group. In late 1993, the Child Care Center Working Group (CCCWG), chaired by Deputy Director Pier Oddone, developed a survey designed to gauge employees' interest in an on-site child care center. The survey was distributed to Laboratory employees in December 1993 with a return deadline of March 1994. The survey was conducted and the results compiled by the UC Survey Research Center. Based on the positive response of Laboratory employees, in June the CCCWG developed a business plan for an on-site child care center.

The business plan was reviewed in an all-day, on-site review in September by representatives from Argonne National Laboratory, Brookhaven National Laboratory, and Lawrence Livermore National Laboratory. The review was generally favorable, and following the review the Laboratory Director identified the on-site child care center as a high priority for the Laboratory. The Laboratory is in the process of identifying funding sources for the center.

College Relations Program. The Laboratory is in the process of developing a college-level relations program aimed at addressing underrepresentation in the Research Associates classification series. It is expected that this program will be implemented in FY 1996.

Diversity Training. The Laboratory implemented a pilot Diversity Training Program for Environment, Health and Safety Division's supervisors and managers. The training program focuses on increasing awareness to create a work environment that is inclusive and welcoming to all employees and on enhancing and developing skills to effectively manage differences. The Program is being piloted for more than 30 managers and supervisors in EH&S before it is offered Laboratory-wide as part of the ongoing Employee Develpment and Training Unit's on-site program.

Employment Law Training. Employment law training was completed by Operations managers and employees. "Managing Within the Law" was provided to supervisors and managers, and "Rights and Responsibilities: Knowing the Law" was provided to employees. The Laboratory's scientific division directors completed "Managing Within the Law." Scientific managers and supervisors will attend this course in FY 1996.

Berkeley Lab Postdoctoral Fellowship Program. The Laboratory has developed its own year-round Postdoctoral Program aimed at improving diversity and developing promising scientists and engineers for career employment opportunities. It is anticipated that the Program will be implemented in 1996. The Laboratory will continue to participate in the UC President's Postdoctoral Fellowship Program.

Management Skills Assessment Program (MSAP). MSAP is a week-long residential career development program that has at one of its goals increasing the representation of individuals in underutilized areas. Participants gain a better understanding of their strengths and weaknesses and develop an action program for continued development of their management skills. The Laboratory sends four employees to participate in each annual session.

Mentor Program. The Laboratory's Committee on Diversity recommended that a broad-based mentoring program be established for employees. In 1994, the Laboratory implemented a pilot Mentor Program in the Engineering Division. The Program provides a deliberate pairing of a skilled and experienced employee mentor with a less skilled and experienced person protégé with the intent to transfer knowledge and experience. The goals of the formal Mentor Program for the Engineering Division is to provide Engineering Division employees with a mentoring resource to develop and sustain skills and capabilities critical to current and future programmatic needs and opportunities; increase exposure to diverse skills, knowledge, and abilities; and collaborate with other Berkeley Lab staff to utilize their knowledge and experience. Discussions are under way with others in the Laboratory who are interested in establishing a mentor program in their areas.

Nuts & Bolts HR Practices. In FY 1996, human resource managers are providing supervisory training on hiring, compensation, performance management, employee relations, and labor relations to Operations managers and supervisors.

Professional Skills Assessment Program (PSAP). PSAP is a week-long residential career development program. Participants are given the opportunity to increase their knowledge about their career-related skills and on-the-job potential, as well as develop a plan for future career growth. Modeled after the highly successful Management Skills Assessment Program, PSAP has been designed to meet the needs of staff who wish to increase their preparation for assuming responsibilities at the professional level. The Laboratory sends three employees to participate in each annual session.

Science Exploration Camp (SEC). The Laboratory's Work/Family Committee, which grew out of the Laboratory's Child Care Center Working Group, headed by Deputy Director Pier Oddone, implemented a pilot two-week summer camp program during July–August 1995. Thirty-two youngsters of Laboratory employees, ranging from grades one through seven, participated in a variety of science activities, including hands-on experiments, demonstrations, field trips, and recreational activities. The science camp is run by a nonprofit corporation formed by Laboratory employees. The SEC directors hire staff and volunteer their time to organize the camp and participate in the program to support paid staff. It is expected that the Laboratory will host the second SEC on-site at the Laboratory in July-August 1996.

Zenger-Miller Programs. Zenger-Miller's FrontLine Leadership Program, with its emphasis on core leadership skills and Zenger-Miller's Quality Workshops Program, was provided in 1994 primarily to supervisors and managers in Operations and Administration, and to some supervisors and division

administrators in the scientific divisions and in the Directorate. The Program will continue to be offered to supervisors and managers in Operations and areas outside of Operations.

The Operations Frontline Leadership Program will be completed in FY 1996. The program will also be completed in the scientific divisions in FY 1996 as well. The program will continue to be offered to new managers and supervisors.

UC President's Postdoctoral Fellowship Program. The Regents established the UC President's Postdoctoral Fellowship Program in order to improve the quality and diversity of UC faculty and to enhance the competitiveness of outstanding people of color and women Ph.D. degree holders for appointments at UC campuses and the DOE laboratories. The Laboratory hosts two fellows annually, and each fellowship is for a 12-month period, renewable for a second year pending evidence of satisfactory progress. Three postdoctoral fellows are currently in the program.

Affirmative Action Program

The Laboratory's Affirmative Action Program outlines activities, such as special recruitment, training, and employee development programs, aimed at improving access to the workplace for people in underrepresented groups. It also serves as a working document that describes current policies, practices, and results in the area of affirmative action. It represents the Laboratory's framework for an affirmative approach that will increase the representation of people of color and women in segments of our work force where they have been underrepresented. The program also is a vehicle for increasing the employment of persons with disabilities and special disabled and Vietnam-era veterans. The Program describes the hierarchy of responsibility for Laboratory affirmative action; the mechanisms that exist for full Laboratory participation in the Affirmative Action Program; the policies and procedures governing recruitment at all levels, the Laboratory's plan for monitoring, reporting, and evaluating affirmative action progress; and a description of special affirmative action programs and plans the Laboratory has used and will use in its efforts to increase the representation and retention of groups historically underrepresented in our work force.

The Laboratory also establishes measures to ensure that basic equal opportunity/affirmative action efforts have been incorporated into standard division procedures, such as the inclusion of AA/EEO responsibilities in supervisors' performance reviews, development of recruitment plans when vacancies exist, equity review of salary actions, and participation in related training programs. The following activities are part of the Laboratory's good faith efforts that have expanded steadily over the last four years.

Short-Range Plans

Berkeley Lab is committed to pursuing the following goals:

- Improving the utilization of women and people of color in underutilized job groups.
- Making good-faith efforts to ensure that the composition and viability of candidate pools reflect availability.
- Assessing supervisors' AA/EEO contributions in their annual performance reviews.
- As vacancies appear during 1996, continuing to target openings to promote diversity by ethnicity and gender throughout the Laboratory, with special emphasis on professional and technical positions.
- Giving special attention to the coupling of recruitment and outreach efforts to key (significant) areas of underutilization.
- Enhancing employment opportunities for individuals with disabilities and covered veterans.
- Continuing efforts to educate and sensitize the work force to diversity awareness, goals, and objectives.
- Through the Work Force Diversity Office, continuing to implement the recommendations contained in the Laboratory Committee on Diversity Report, as approved by the Laboratory Director.

- Continuing to make efforts to encourage and obtain active top management support of diversity considerations, including affirmative action and educational outreach efforts.
- Through the Work Force Diversity Office, continuing to develop affirmative action reports so that division directors can assist department heads to manage their affirmative action responsibilities, and assessing how well divisions use available opportunities to improve and meet their work force affirmative action goals.
- Targeting line management for greater participation in affirmative action recruitment for vacancies as they occur in the divisions. Managers will attend job fairs and related events and speak directly with qualified individuals interested in work in their specific area of operations.

Long-Range Plans

Our goal is to increase the representation of women and people of color in our mid- and senior-management-level job groups. Community outreach activities, university and college relations initiatives, and refined and selective recruitment efforts will be utilized for this purpose.

With the help of the new Human Resources Information System (HRIS) database to be installed in CY 1996, monitoring activities will be expanded and/or refined.

The Laboratory will direct proactive efforts toward reduction and/or elimination of underutilization in job groups and/or classifications through the use of training programs, employment pools, and targeting of management-level positions. In this way, the Laboratory will attain all of its work force statistical goals.

The following two tables are compiled from the Laboratory's 1991 and 1996 Affirmative Action Programs and are based on FY 1990 and FY 1995 data of career-status employees who are covered under the University of California retirement system. Over this reporting period, the Laboratory work force increased with respect to the representation of women (19.57%) and people of color (8.31%). For affirmative action reporting purposes, this accomplishment occurred during a period when the Laboratory experienced reduction-in-force activity (a 9.0% reduction between FY 1994 and FY 1995), particularly in nonscientific and technical support areas. Representation of women increased 8.82% for Officials and Managers and 58.48% for Scientific and Engineering Professionals. Representation of people of color increased 56.10% in the Officials and Managers and 24.24% for Scientific and Engineering Professionals.

Lawrence Berkeley National Laboratory 1990

Federal Occupational Category	Total		Caucasian		Minority									
					Total		Black		Hispanic		Asian		Nat. Am.	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
OFFICIALS & MANAGERS	86	23	75	19	11	4	5	1	3	1	3	2	0	0
	78.90%	21.10%	68.81%	17.43%	10.09%	3.67%	4.59%	0.92%	2.75%	0.92%	2.75%	1.83%	0.00%	0.00%
PROFESSIONALS														
Scientists & Engineers	873	148	714	119	159	29	12	3	19	1	127	25	1	0
	85.50%	14.50%	69.93%	11.66%	15.57%	2.84%	1.18%	0.29%	1.86%	0.10%	12.44%	2.45%	0.10%	0.00%
Administrative	57	132	38	94	19	38	4	14	5	9	10	15	0	0
	30.16%	69.84%	20.11%	49.74%	10.05%	20.11%	2.12%	7.41%	2.65%	4.76%	5.29%	7.94%	0.00%	0.00%
TECHNICIANS	285	53	217	35	68	18	20	9	18	1	30	7	0	1
	84.32%	15.68%	64.20%	10.36%	20.12%	5.33%	5.92%	2.66%	5.33%	0.30%	8.88%	2.07%	0.00%	0.30%
OFFICE SERVICES	19	223	10	120	9	103	7	60	0	22	2	20	0	1
	7.85%	92.15%	4.13%	49.59%	3.72%	42.56%	2.89%	24.79%	0.00%	9.09%	0.83%	8.26%	0.00%	0.41%
SKILLED CRAFTS	203	2	163	2	40	0	13	0	12	0	11	0	4	0
	99.02%	0.98%	79.51%	0.98%	19.51%	0.00%	6.34%	0.00%	5.85%	0.00%	5.37%	0.00%	1.95%	0.00%
SEMI-SKILLED	48	9	22	3	26	6	14	6	11	0	1	0	0	0
	84.21%	15.79%	38.60%	5.26%	45.61%	10.53%	24.56%	10.53%	19.30%	0.00%	1.75%	0.00%	0.00%	0.00%
SERVICE WORKERS	50	15	26	6	24	9	7	4	10	4	7	1	0	0
	76.92%	23.08%	40.00%	9.23%	36.92%	13.85%	10.77%	6.15%	15.38%	6.15%	10.77%	1.54%	0.00%	0.00%
Total All Categories	1621	605	1265	398	356	207	82	97	78	38	191	70	5	2
	72.82%	27.18%	56.83%	17.88%	15.99%	9.30%	3.68%	4.36%	3.50%	1.71%	8.58%	3.14%	0.22%	0.09%

Source: 1991 LBL Affirmative Action Plan. Figures are based on end of fiscal year 1990 (9/30/90).

Lawrence Berkeley National Laboratory 1995

Federal Occupational Category	Total		Caucasian		Minority									
					Total		Black		Hispanic		Asian		Nat. Am.	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
OFFICIALS & MANAGERS	104	31	82	24	22	7	9	3	3	1	10	3	0	0
	77.04%	22.96%	60.74%	17.78%	16.30%	5.19%	6.67%	2.22%	2.22%	0.74%	7.41%	2.22%	0.00%	0.00%
PROFESSIONALS														
Scientists & Engineers	771	230	603	169	168	61	12	7	16	1	140	53	0	0
	77.02%	22.98%	60.24%	16.88%	16.78%	6.09%	1.20%	0.70%	1.60%	0.10%	13.99%	5.29%	0.00%	0.00%
Administrative	50	135	37	95	13	40	4	14	4	7	5	18	0	1
	27.03%	72.97%	20.00%	51.35%	7.03%	21.62%	2.16%	7.57%	2.16%	3.78%	2.70%	9.73%	0.00%	0.54%
TECHNICIANS	322	58	256	36	66	22	18	7	19	4	29	11	0	0
	84.74%	15.26%	67.37%	9.47%	17.37%	5.79%	4.74%	1.84%	5.00%	1.05%	7.63%	2.89%	0.00%	0.00%
OFFICE SERVICES	41	228	20	127	21	101	7	62	7	17	6	22	1	0
	15.24%	84.76%	7.43%	47.21%	7.81%	37.55%	2.60%	23.05%	2.60%	6.32%	2.23%	8.18%	0.37%	0.00%
SKILLED CRAFTS	118	0	89	0	29	0	9	0	12	0	6	0	2	0
	100.00%	0.00%	75.42%	0.00%	24.58%	0.00%	7.63%	0.00%	10.17%	0.00%	5.08%	0.00%	1.69%	0.00%
SEMI-SKILLED	19	4	7	4	12	0	6	0	5	0	1	0	0	0
	82.61%	17.39%	30.43%	17.39%	52.17%	0.00%	26.09%	0.00%	21.74%	0.00%	4.35%	0.00%	0.00%	0.00%
SERVICE WORKERS	41	20	22	6	19	14	7	8	8	4	4	2	0	0
	67.21%	32.79%	36.07%	9.84%	31.15%	22.95%	11.48%	13.11%	13.11%	6.56%	6.56%	3.28%	0.00%	0.00%
Total All Categories	1466	706	1116	461	350	245	72	101	74	34	201	109	3	1
	67.50%	32.50%	51.38%	21.22%	16.11%	11.28%	3.31%	4.65%	3.41%	1.57%	9.25%	5.02%	0.14%	0.05%

Source: 1996 LBL Affirmative Action Plan. Figures are based on end of fiscal year 1995 (9/30/95).

Future Efforts

The initiatives and programs mentioned here are by no means intended to be an all-inclusive list but merely illustrate the direction and support of affirmative action and equal employment opportunity at Ernest Orlando Lawrence Berkeley Laboratory. The Laboratory is committed to the idea and intent of equal employment opportunity for all people. To that end, it works to ensure equal employment opportunity for everyone and will pursue the concepts of EEO within the Laboratory at all times. Berkeley Lab will continue to implement new initiatives to further affirmative action and equal employment opportunity throughout the year.

While the Laboratory is strongly committed to recruit women and people of color into its work force, equally important is the retention of its employees. In positioning the Laboratory to compete effectively in the marketplace to recruit promising scientists to the Laboratory, it has restructured its scientist and engineer classification and pay program. This new structure, along with the recent establishment of scientist and engineer leadership positions, provides more clearly defined career paths in the areas of both scientific accomplishment and scientific management, formalizes accountabilities, and improves succession planning capabilities. The Laboratory is directing its recruitment program toward three goals: (1) ensuring a breadth of experience, (2) maintaining a strong scientific and technical base in the work force, and (3) committing to its diversity goals. Berkeley Lab is active in recruiting promising scientists and engineers through its divisional fellow and postdoctoral associate programs, and each division is accountable for affirmative action/equal employment opportunity action-oriented programs aimed at achieving a diverse work force. Berkeley Lab has effected the following specific steps to achieve these goals:

- Strengthened the Laboratory's competitiveness in the recruitment marketplace, including an active advertising campaign, strong representation at job fairs, and training programs.
- Created outreach recruitment progams, including a widely distributed job listing, professional seminars, and search committees, with extensive participation of managers and supervisors.
- Created special employment and internship programs, including summer student and youth employment programs, as well as education programs for members of groups historically underrepresented in the science and engineering fields.

Additionally, since its beginning the Laboratory has had a strong commitment to train the next generation of scientists and engineers. The education programs of the Center for Science and Engineering Education are instrumental in encouraging young people, especially women and people of color, to enter careers in science and engineering, better positioning them to attain their career goals. Berkeley Lab is now exploring ways to maintain contact with these students after they have completed a Laboratory program and as they progress through the educational system. In this way, the Laboratory can continue to encourage and assist them in achieving their goals and address its own future human resource needs.

ENVIRONMENT, SAFETY, AND HEALTH

Berkeley Lab's environment, safety, and health programs, which are integral to program performance, fully support DOE's strategies for ensuring the safety and health of workers and the protection and restoration of the environment. Excellence and timely implementation of environmental, safety, and health activities are critical to the success of each of Berkeley Lab's—and DOE's—core business areas. Berkeley Lab strongly endorses DOE's vision that the highest priority of all our activities is daily excellence in the protection of the worker, the public, and the environment. Berkeley Lab's EH&S programs correspond to and cooperate with the DOE goals in support of this vision. EH&S priorities are set and followed in accordance with DOE's EH&S Management Plan. The programs described below are fundamental to the attainment of this vision and represent the performance commitment of Berkeley Lab employees to trust, communications, and continuous improvement in all Berkeley Lab activities.

ES&H Goals and Objectives

It is the policy of Lawrence Berkeley National Laboratory to integrate environment, safety, and health (ES&H) performance into all of its operations to ensure employee and public safety and the protection of the environment. The Laboratory has developed institutional ES&H goals to guide its integrated ES&H program. These goals are the following:

- Berkeley Lab will provide employees with a safe workplace.
- Berkeley Lab will design and operate facilities and research activities to minimize adverse impact on public health and the environment.
- Berkeley Lab will produce and use only materials that can be disposed of safely and will minimize waste.
- Berkeley Lab will promptly communicate the known hazards of our activities and the related methods necessary for safety and health protection.
- Berkeley Lab will use available technology, engineered safeguards, and responsible science to mitigate all significant risks arising from its research and related activities.

The objectives of ES&H in the conducting of research activities are to ensure the integrity of human health and safety and the environment in which we operate, to manage resources with a value-added perspective, to maintain a capability that is not currently supported by other Laboratory programs, to provide opportunities for staff development, to build new competencies that could prove useful to future Laboratory and DOE ES&H programs, and to support the Laboratory's technology transfer mission.

Underlying these goals is a commitment to ES&H performance through quality management of the Laboratory's programs and in its conduct of operations. Berkeley Lab's current efforts respond to the management initiatives of the DOE Office of Energy Research (ER). The Laboratory has also developed an ES&H Management Five-Year Plan. These efforts include a renewed commitment to ES&H through self-assessment and an effective Corrective Action Plan.

The Laboratory's ES&H Performance Measures are utilized to improve performance and institute a more quantitative framework for Berkeley Lab's ES&H trends and activities. For employee health and safety, representative measures include those that document occupational radiation doses and accidental frequency and severity rates (expressed as cases or days lost per 200,000 hours worked). In accordance with the requirements of Contract 98, Berkeley Lab has embarked on a course of continuous improvement in ES&H performance over prior years.

Environmental Performance Measures include monitoring public radiation doses from Berkeley Lab operations, waste minimization activities, and the Toxics Release Inventory. One goal is to manage waste disposal more effectively and efficiently, including significantly reducing the total amount of hazardous wastes generated when compared to prior years. Waste minimization indicators include the percent of Laboratory office waste recycled, and the total number of waste streams recycled. Performance Measures include those that count the number of waste pick-up requisitions rejected because waste is nonhazardous (waste minimization), the number of complaints received by a group leader (waste management operations), and the number of requisitions received and processed with average turnaround time for each requisition (waste management operations). In addition, the Laboratory is establishing procedures to assure that there will be no excess discharge of heavy metals and toxic chemicals into the sewer system. The goal is to keep all discharges below established standards.

Current Conditions

Programmatic Directions and Potential Hazards

As indicated in Section IV, Berkeley Lab's scientific and technical programs primarily support DOE's Office of Energy Research (64%). The multiprogram charter includes programs in Basic Energy Sciences,

Nuclear Physics, High Energy Physics, and Health and Environmental Research. Energy Efficiency and Renewable Energy (7%) supports studies in building energy conservation, energy storage, and solar and geothermal energy. Other DOE-sponsored programs (13%) include research supported by Civilian Radioactive Waste Management, and Fossil Energy. Work for Other Agencies and Institutions (16%) is primarily for the National Institutes of Health (NIH), the Department of Defense (DOD), states, and private industry.

Berkeley Lab's potential ES&H risks are characteristic of accelerator operations, shops, and a diversity of laboratories for chemical, biological, materials science, and technology development, as well as other facility support operations. Hazards arise from both radiological and nonradiological activities. Radiation protection for workers and the public is required for accelerators, x-ray units, sealed sources, and radioisotope use. The nonradiological hazards include electrical systems, sources of ignition and combustible materials, rotating and reciprocating machinery, hoisting and rigging operations, lasers, oxygen-deficient atmospheres, chemicals, biohazards, moving vehicles, construction activities, and natural phenomena such as storms and earthquakes.

Berkeley Lab monitors the levels of chemicals, biohazards, and radioactivity discharged from operations at the Laboratory, and evaluates their impact on the environment and to the public health. Radiological operations include particle accelerators, gamma irradiators, laboratories conducting research using radionuclides and radiopharmaceuticals, and the National Tritium Labeling Facility. Nonradiological sources and discharges include chemicals from research operations, fabrication shops, automotive shops, paint shops, water treatment facilities, and the Hazardous Waste Handling Facility. Current trends in Laboratory activity indicate the following environmental and safety hazards that must be mitigated:

- **Chemistry and Materials Research.** Programs in materials and chemical research, including new hazardous materials management requirements, create demands on many ES&H programs. Examples include managing chemical acquisition and inventories, chemical monitoring systems, fume hood monitoring, laser safety training, respiratory protection programs, and hazards communications. The ALS, a controlled facility, expands the use of x-rays on site, and is operated with complete ES&H systems and management protocols in place.
- **Biological Research.** Berkeley Lab biological research programs have grown recently. Berkeley Lab's biological hazards control program continues to be expanded. Biological research programs often utilize radiolabeled materials, and the delivery of low-level radioisotopes has increased in the last few years. The radioactive and mixed wastes derived from these operations present a special challenge because of the restrictions on their disposal.
- **Radiobiology Experimental Programs.** Berkeley Lab radiological research at the Bevalac has ended, but the use of isotopes continues in many applications, including at the new Biomedical Isotope Facility.
- **Construction.** Berkeley Lab's construction activity has increased during the past decade, resulting in potential additional accident risk. Oversight for construction contractors and tradespersons has become increasingly important, including, but not limited to, the need to ensure the stability of excavations and management of drainage systems.
- **Nuclear Physics and Nuclear Chemistry.** The nuclear physics experimental programs at the Bevalac were curtailed in FY 1993. However, the 88-Inch Cyclotron has expanded research with the Gammasphere detector and supports a more diversified scientific program.

Increased resources have been provided to serve research program areas that have potential hazards, such as those employing toxic chemicals, lasers, new x-ray sources and beamlines, and radiolabeled compounds. Space for staff and equipment must be provided to meet service demands and logistics needs. Reporting functions have been formalized to optimize use of staff. Automated systems to track chemicals from procurement to disposal and to automate all monitoring and analytical activities are under development. Berkeley Lab is committed to meeting all regulatory requirements in a cost-effective, risk-based fashion that deals with real risks and environmental concerns as the top priority.

EH&S Activities and Accomplishments

The division undertook a major reengineering effort and melded the following disciplines: emergency management, radiation safety, industrial hygiene, safety engineering, security, fire protection, fire services, EH&S training, and risk/hazards management into interdisciplinary/customer service-oriented technical support groups under a new organization known as the **Field Support Operations Department**. Many noteworthy accomplishments and strategic initiatives have emerged.

Hazards Management. An integrated hazards management activities continue to provide a proactive effort to identify and assess risks in various areas:

- *Activity Hazards Document Program.* Modifications to the structure of the program resulted in an increased participation of the customer and reduction of review time.
- *Necessary & Sufficient Pilot.* A pilot program to define the work processes and to identify the hazards and select standards appropriate for the hazard level was conducted for the National Tritium Labeling Facility. The success of the pilot was used as a basis for the development of a program to apply the process to other similar DOE laboratories.
- *Safety Reviews for Research Proposals.* The process of safety reviews for research proposals was simplified and streamlined resulting in a reduction of proposal processing time and a review more appropriate for the level of hazards.
- *Preliminary Hazard Review Process.* A Preliminary Hazard Review process was developed and implemented to formally identify hazards and assure mitigation.
- *Safety Documentation.* A Safety Analysis Document was prepared for the National Tritium Labeling Facility which concluded that potential accident scenarios would result in negligible off-site affects and minor on-site affects.

Emergency Management. Emergency preparedness and readiness at LBNL continues to improve as the program matures. The Master Emergency Plan (MEP) remains the basis document for the program. A comprehensive drill-and-exercise program continues to be the centerpiece, Berkeley Lab Emergency Command Center operations were improved, and coordination between LBNL emergency planners and state and local government also continues to improve.

Radiation Protection Program. The radiation protection program has been structured to meet and implement the requirements of 10 CFR 835 (Radiation Protection of the Worker), meet the needs of the Laboratory research community, and meet the objectives of the Laboratory Mission. The management of the radiation protection program integrates the program across groups internal to EH&S and research divisions through the Radioactive Work Authorization Program, Sealed Sources Management Program, Radiation Protection Data Base Management (RADAR), Radiation Work Permit Program, Training, Dosimetry, and Safety Documentation areas.

Industrial Hygiene. In the area of Ventilation Safety, major advances were made in the safety performance of existing hoods. In the area of Chemical Exposure Evaluation, more than 99 percent of the measured exposures were below one-half the occupational health standard.

Safety Engineering. The principal mission of the Safety Engineering function is to assist Laboratory Divisions in obtaining low accident rates and in achieving compliance with Laboratory safety standards, OSHA regulations, and other safety standards. During the last year, much emphasis was placed on creating additional awareness of injuries among the various divisions, resulting in a significant drop in injury rates. Between April 1995 and April 1996, the 12-month moving average dropped from 6.9 to 2.8 injuries per 200,000 hours worked.

Fire Protection. The Sitewide Fire and Life Safety Systems Upgrade Project Phase I is currently under construction. Twenty-eight buildings are being retrofitted to eliminate the fire and life safety deficiencies as well as upgraded to meet the latest codes and standards. As a result of good engineering efforts and construction practices, the project is currently under budget. Thus, the extra saving can be applied to more retrofitting work in buildings that were excluded from the original Phase I project. In addition, the

Building 70 Hazardous Materials Safeguard Project — Phase I has been completed. The building was upgraded to meet the current building and fire codes for use of hazardous chemicals.

Vegetation Management. Administratively, the Lab is a charter member of the East Bay Hills Emergency Forum, where we participate in the coordination, collection, assessment and sharing of information on East Bay hills fire hazards and build interagency consensus on development of fire safety standards and codes, incident response and management protocols, public education programs multi-jurisdictional training, and fuel reduction strategies. We are also actively involved in the Vegetation Management Consortium and have proactively utilize the wildland Fire Hazard Mitigation Program and Fuel Management plan developed by this group to aggressively direct our vegetation management program.

ES&H Plans and Initiatives

To promote integration of strategic and program planning, the Laboratory maintains a Comprehensive Planning Calendar that defines annual planning requirements and provides a schedule that identifies necessary information exchange and preparation responsibilities. This process defines the responsibilities and information requirements that will incorporate environmental, safety, and health concerns into institutional and program planning elements. Examples of planning products include those for program plans and for ES&H support functions:

- **ES&H planning and initiatives.** The EH&S Division has realigned its mission in sync with the broader mission of the Laboratory. To this end, the Division effectively manages environment, health, and safety in a way that minimizes interference with new or ongoing scientific research. Creating value for the economy and contributing to the community through partnerships with industry are another part of the Laboratory's mission. The EH&S Division is developing creative solutions for environment, safety, and health problems that can be transferred into the private sector for broader application.
- **ES&H management and operations planning.** Berkeley Lab manages and coordinates its ES&H programs through strategic plans that define activities, source needs, staffing, and regulating responsibilities. These plans include, as examples, the ES&H Management Plan, the Self-Assessment Implementation Plan, NEPA programs planning, and waste minimization plans (see below). Other examples are the Environmental Protection Implementation Plan, the Environmental Monitoring Plan, and the Groundwater Protection Management Plan.
- **Berkeley Lab emergency preparedness and response planning.** This includes maintaining and updating a Master Emergency Plan, building and facility emergency plans, and individual equipment emergency plans. Berkeley Lab is revising and strengthening these plans and implementing programs to ensure that resources and trained staff are available to address all credible emergencies.
- **Research program planning.** As an example of this program planning, early in the formulation of the heavy-ion fusion accelerator research area (see Section IV), the underlying ES&H criteria for the Berkeley Lab facility were established, as documented in a Conceptual Design Report. The safety systems and procedures for this facility are being designed to meet all standards for the expected occupancy. Safety management operations have been integrated with program plans and are included in cost estimates. The National Environmental Policy Act (NEPA) document preparation schedule and the requirements for Operational Safety Procedures were also planned from the outset. The Human Genome Laboratory underwent a similar review and documentation process.
- **Site development planning.** The Site Development Plan integrates ES&H objectives and needs in all facilities-related programmatic building support projects. Site-planning goals, existing conditions, and planning analysis integrate ES&H planning information, including NEPA and CEQA requirements. Specific references are made to environmental monitoring, environmental impact studies, and the health and safety of facilities. To provide adequate ES&H support facilities, two general-purpose building initiatives are proposed within the period covered by this plan. Current Laboratory support service facilities are inadequate and inefficient because of obsolete design and substandard construction.

- **Strategic and Environmental Planning.** Berkeley Lab's Environment, Safety and Health Division, with the Office of Planning and Communications, has incorporated a comprehensive planning mechanism to integrate strategic and environmental planning. In support of this integration, an environmental compliance calendar and a Comprehensive Planning Calendar have been created.
- **Tiger Team Assessment Corrective Action Plan.** Completed in September 1991, the plan addressed the findings and concerns of the 1991 Tiger Team as well as the 1989 Technical Safety Appraisal. The Laboratory and DOE/OAK developed 409 tasks with subsidiary milestones to correct the findings and concerns and eliminate the underlying root causes. Berkeley Lab has implemented all tasks from the Corrective Action Plan.

Environment, Safety, and Health Management Plan

The Laboratory has developed and utilizes a prioritized Management Plan for Environment, Safety & Health Activities that includes the existing core program of environment, safety, and health activities, additional basic support, and specific projects to fully meet all Berkeley Lab and DOE environmental, safety, and health goals. Berkeley Lab contributed to the development of the ER prioritization system to rank activities based on quantitative risk reduction criteria for the purpose of allocating funds.

In response to the requirements of the Corrective Action Plan, and to emphasize safety and health issues, Berkeley Lab has significantly increased its spending on core environment, health, and safety programs since 1991. Conscientious application of prioritization methodology to these issues will allow the Laboratory and DOE to allocate appropriate funding each year, and to assure that serious and urgent issues are addressed appropriately in light of resource limitations.

Management Plan Projections (M)[a]

Category	1996	1997	1998	1999	2000	2001	2002
Operating							
Core/Compliance	47.9	32.9	31.2	30.4	30.3	23.6	18.4
Improvements	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Op.	47.9	32.9	31.2	30.4	30.3	23.6	18.4
Cap. Equip.	0.0	0.1	1.2	0.2	0.0	0.0	0.0
GPP	6.7	0.8	3.2	0.3	0.7	0.0	0.0
Line Item	4.8	0.0	2.4	4.1	0.8	3.8	5.8

[a]Includes MEL-FS, programmatic and overhead funding.

Waste Minimization Plan

Berkeley Lab's waste minimization program is an organized, comprehensive, and continual effort to systematically reduce hazardous, radioactive, and mixed waste generation. The DOE Waste Minimization and Pollution Prevention Awareness Program and California Senate Bill 14 (HazWaste Source Reduction and Management Review) are designed to eliminate or minimize pollutant releases to all environmental media from all areas of the site's operations.

In support of DOE's voluntary commitments to the EPA, Berkeley Lab is committed to reducing EPCRA hazardous wastes 33% by calendar year 1997, and 50% by calendar year 2000. In addition, the Laboratory has developed waste minimization goals for the following streams:

- Waste streams comprising 5% or more of the total hazardous waste generated by Berkeley Lab (SB14 goals).
- Nonautomotive waste oils, spent empty drums, waste mercury, and process wastewater (SB14 goals).

- Acids, coolants, contaminated solids, and total aggregate wastes (Contract 98, Appendix F, Performance Measures).
- Low-level radioactive wastes, low-level mixed (radioactive and hazardous) wastes, RCRA and CA-only hazardous wastes, and sanitary wastes (DOE Waste Reduction Plan).

Specific waste reduction goals for these streams can be found in Appendix D of the Berkeley Lab Waste Minimization and Pollution Prevention Awareness Plan. These efforts offer increased protection of public health and the environment. They will yield the following additional benefits:

- Reduction of waste management and compliance costs.
- Reduction of resource usage.
- Reduction or elimination of inventories and release of hazardous chemicals.
- Reduction or elimination of civil and criminal liabilities under environmental laws.

The program reflects the goals and policies for waste minimization for Berkeley Lab and represents an ongoing effort to make waste minimization/pollution prevention part of the site's operating philosophy. Berkeley Lab's overall efforts include assessment of waste minimization opportunities and the development of source reduction plans. The projected budget authority goals of the waste minimization program, as included in the Environmental Restoration and Waste Management Program, are indicated in the following table for Berkeley Lab's unconstrained funding case.

Waste Minimization Management Program
Resource Requirements (FY BA $M)[a]

Category	1995	1996	1997	1998	1999	2000	2001	2002
Operating	0.5	0.4	0.6	0.6	0.6	0.6	0.6	0.6

[a]Estimated ERWM (EX) Budget Authority for unconstrained funding case.

National Environmental Policy Act Planning

The Laboratory has a program that supports DOE's full compliance with the National Environmental Policy Act (NEPA) and UC's compliance with the California Environmental Quality Act (CEQA). Consistent with the Office of Energy Research's goals for adherence to the principles of the National Environmental Policy Act, Berkeley Lab's NEPA Program, in concert with other Berkeley Lab Environment, Health and Safety programs, strives to: (1) prevent and eliminate damage to the environment from Berkeley Lab activities; (2) attain beneficial uses of the Berkeley Lab environment and site without degradation; (3) reduce the risk of undesirable or unintended environmental consequences of Berkeley Lab activities; and (4) thus, achieve productive harmony between Berkeley Lab's mission and the environment.

Berkeley Lab's general plan of action for projects includes preparation of NEPA/CEQA forms specifying NEPA and CEQA documentation recommendations for Field Task Proposals and capital projects, Field Work Proposals, Work for Others proposals, Cooperative Research and Development agreements, and LDRD proposals. The forms are completed by principal investigators and are forwarded by division administrators to the Berkeley Lab Office of Planning and Communications, where NEPA recommendations are made and forwarded to DOE for a NEPA determination. The Laboratory and DOE are striving to further improve the efficiency of this activity, fully consistent with DOE policies.

During 1995, DOE issued a finding of No Significant Impact for the construction and operation of a Genome Sequencing Facility in Building 64 and for the Induction Linac System experiments in Building 51.

Environmental Restoration and Waste Management

Berkeley Lab environmental management site projects supported through the DOE Office of Environmental Restoration and Waste Management (EM) are essential to correct and restore environmental conditions at the Laboratory and to improve the management of waste handling operations in support of DOE's national environmental objectives. The corrective actions achieve and maintain required low exposure and risk levels. The environmental restoration program includes the assessment and characterization of contamination and the closure of the existing Hazardous Waste Handling Facility. Increased support for the waste management program is necessary for the proper management of radioactive and hazardous waste. The waste management program supports the construction of a new Hazardous Waste Handling Facility. Representatives from these two programs meet regularly to ensure compliance with DOE and other federal regulations, as well as requirements established by state and local agencies.

The Environmental Restoration and Waste Management programs have been developed in conjunction with DOE, state, and federal reviews. The resource projections below and in Section VI reflect existing guidance in Activity Data Sheets. These resources do not include additional corrective action planning requirements, maintenance projects, and other upgrades funded through Berkeley Lab institutional resources. The resources also do not include the cost for decommissioning the Bevalac, following acceptance by EM.

Environmental Restoration and Waste Management Resource Requirements ($M)[a]

Category	1996	1997	1998	1999	2000	2001	2002
Environmental Restoration							
Operating	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line Items	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Waste Management							
Operating	6.0	6.8	7.9	8.3	8.6	8.7	8.7
Capital Equipment	0.0	0.2	0.3	0.3	0.3	0.3	0.3
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line Items	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.0	7.0	8.2	8.6	8.9	9.0	9.0
Total EM Funding	10.2	11.2	12.4	12.8	13.1	13.2	13.2

[a]Actual-year Berkeley Lab Budget Authority. The funding level shown for FY 1995 reflects the actual approved budget, for FY 1996 reflects the President's budget request to Congress, and for FY 1997 reflects the target (EM requested) budget level.

Landlord Funded ES&H

ES&H (other than Waste Management and Site Restoration) currently is funded mostly through Laboratory overhead. In addition, the MEL-FS program provided $5,087,000 in FY 1995. Of this, $4,047,000 went towards the construction of a hazardous waste handling facility, the fire and safety systems upgrade project, and the safety upgrading of electrical utility systems. The remaining $1,040,000 went to support operations in the areas of wildland-fire fuel management, seismic upgrades, DOELAP certification, underground storage tank abatement, and pollution prevention. The ES&H Management Plan makes the distinction between core activities and additional funding necessary to fully implement an ES&H program that will address needed Laboratory improvements. This year's Activity Data Sheet submissions are summarized in the table "Management Plan Projections" on page 5-16.

MANAGEMENT PRACTICES

A key element of Berkeley Lab's strategic plan addresses the need for efficient and effective management practices that focus on performance and accountability. Berkeley Lab is working with DOE and the UCOP to fully implement performance-based contracting and to streamline management systems. Berkeley Lab fully supports DOE's Strategic Plan, which addresses the numerous separate systems for managing its operations and improving the Department's flexibility. Berkeley Lab is working with DOE through Process Improvement Teams and through other management and communications systems to achieve DOE goals to become a more streamlined and agile organization. Berkeley Lab is taking specific steps to address DOE's defined need for change in information systems, procurement and contracting, planning and budgeting, financial management, and site and facilities management.

Quality Assurance and Self-Assessment Programs

Berkeley Lab has a strong tradition of research productivity and quality, maintaining a commitment to the success of DOE's mission and its research program. The Laboratory is committed to continuous improvement in program performance and environment and safety management, and to the execution of best business practices. Berkeley Lab has developed a strategy for programs to improve performance based on nationally recognized criteria and Total Quality Management principles, and is working with DOE on implementation of these programs.

The Laboratory is responsible for maintaining the infrastructure for effective financial and administrative performance. Berkeley Lab is committed to best business practices and continuous improvements in all areas of administration, including human resource development and training, finance and contractual relations, materials management and procurement, and facilities maintenance and engineering. The University and the Laboratory emphasize the application of performance measures in key functional areas, and are committed to working in partnership with DOE for continuous performance improvement for national research institutions.

Berkeley Lab's Operating and Assurance Program (OAP) Plan, developed and administered by the Office of Assessment and Assurance, is the institutional document that specifies the Quality Assurance requirements for the Laboratory. Berkeley Lab's OAP was developed using the guidance provided in the *Implementation Guide for QA Programs for Basic and Applied Research* (DOE-ER-STD 6000-92), and is intended to optimize the long tradition of Berkeley Lab excellence in science by applying required management controls to support research activities in an integrated and cost-effective way. In the context of Total Quality Management, the extent and detail of the management systems are commensurate with the scale, cost, complexity, and hazards of the work being performed.

Berkeley Lab has also instituted a program for self-assessment as a systematic way to identify Berkeley Lab's strengths and weaknesses, and to implement corrective actions if needed. Each Berkeley Lab Division develops its own program to evaluate itself against performance objectives established by the Laboratory. This continuous process of information gathering enables Berkeley Lab to assess performance in a systematic and uniform manner, and to target areas that may need improvement. Targeted areas of improvement are the subject of formal root cause analysis performed by teams of management representatives and technical specialists. Areas of improvement in the past have included waste management practices and hazard communication (training). Corrective actions that address root causes are identified and tracked on the Laboratory's tracking database to ensure accountability and timely implementation. The Office of Assessment and Assurance documents the Laboratory's self-assessment activities in an annual report. The Office of Assessment and Assurance also performs independent assessments of selected Berkeley Lab functions and processes within specific organizational units, as well as across organizational boundaries.

Administrative Management

Financial and Business Services

The Berkeley Lab Chief Financial Officer (CFO) is responsible for the financial and procurement functions of the Laboratory. These functions include planning, utilization, and accounting of the funds provided to Berkeley Lab to carry out its research and development programs and the acquisition of supplies, services, and construction necessary to support the Laboratory. There are three major areas in the CFO organization: CFO/Finance, CFO/Budget, and CFO/Business Services. CFO/Finance is responsible for conducting and overseeing financial operations in a manner that is responsive to the Laboratory's research mission, and that complies with UC and DOE regulations, Generally Accepted Accounting Principles, and Federal Cost Accounting Standards. CFO/Budget is responsible for budget formulation and execution; program budget planning and analysis; planning and monitoring of indirect, plant, and capital equipment budgets; and the administration of sponsored research including the negotiation and securing of funds for non-DOE contracts. CFO/Business Services is responsible for procurement, property, and travel services.

The Laboratory's financial systems are being continuously improved through the streamlining of data-handling processes. We have moved from laborious, time-consuming, multistage hard-copy inputs to the use of interactive electronic computer workstations. Results are reflected in the amount of time it takes to complete actions—e.g., the time to complete some 20,000 annual general ledger account changes was reduced in individual instances from as long as six weeks to overnight. The Laboratory has developed and implemented an employee electronic time reporting system, the Laboratory Employee Time System (LETS) that has eliminated the physical handling of over 100,000 time cards per year. Improved networking systems provide for the transfer of timely information to external locations as well.

An Accounts Payable system has been implemented utilizing electronic data handling to interface with the newly implemented electronic Purchasing–Receiving system. Other ongoing Laboratory projects include developing a general ledger system to process its 750,000 ledger transactions; conversion activities to prepare for the handling of approximately 5,600 transactions a year now processed by the DOE's Financial Information System; a new Work for Others Financial Tracking System; and a new UNIX/Oracle-based system to replace the existing Payroll and Personnel system.

As part of the Laboratory's budget formulation and execution processes, the CFO conducts an annual budget workshop for research divisions that is supplemented with a budget preparation handbook; validates the budget proposals for adequate justification; and coordinates the Laboratory Director's formal review-discussion process.

The Laboratory's indirect cost structure and rates have been revised in recent years to comply with federal Cost Accounting Standards.

The Procurement Department has replaced the Laboratory's previous purchasing system with a new electronic Oracle purchasing system. The new system includes requisitioning, purchasing, receiving, and accounts payable, and transfers more of the activities in the acquisition process to the users. Procurement also has implemented a low value field buying program and a corporate credit card (Procard), which allows users/requisitioners to do their own buying within prescribed limits. Previous methods of purchasing are being phased out by modern methods of electronic and deployed purchasing.

Property Management and Property Accounting have been merged for better efficiencies, and CFO staff are working with the Laboratory divisions to shift greater responsibility for property management directly to divisional staff.

Laboratory travelers are now able to deal directly with the Laboratory's new contract travel agency in making travel reservations and ticketing. Travel Expense Reports are now online, with the near-term goal being that Laboratory travelers submit their expenses and receive reimbursements electronically.

Internal Auditing

The Berkeley Lab Internal Audit Services Department, established during FY 1993, provides independent, objective reviews and analyses to assist management in achieving internal control objectives. Audit efforts are proactive, and the independent appraisal process determines if management has established and maintained adequate systems of accounting and management controls over programs and administrative functions to provide assurance that: (1) programs and operational objectives are conducted efficiently and effectively in accordance with program direction and funding requirements; (2) costs and obligations are in compliance with applicable laws; and (3) funds, property, and other assets are safeguarded against waste, loss, mismanagement, unauthorized use, or misappropriation. Topics considered for evaluation encompass all facets of the Laboratory, including: Financial Management; Procurement Management; Human Resources Management; Construction and Facilities Management; Information Management; Environmental Health and Safety; Data Processing Systems; Property Management; Planning and Budget Management; and Support Services and various research programs.

In past years, the Berkeley Lab Internal Audit Services Department has initiated the development and implementation of an Internal Audit Peer Review Program for DOE management and operating contractors. This program provides assurance that professional auditing standards are complied with and acts as a forum for the exchange of Best Practices to assist in meeting the challenges imposed by changes in strategic direction, increased public scrutiny, and limited DOE resources. During the current year, the Berkeley Lab Internal Audit Services Department has developed a uniform risk assessment model in conjunction with the University of California Office of the President to quantify high-risk areas of financial exposure and liability to the institution. The formal assessment of institutional risks will ensure that the Berkeley Lab Internal Audit effort and resources are allocated appropriately. Berkeley Lab is a participant in the DOE Cooperative Audit Strategy, emphasizing improved communication and coordination among the DOE Offices of Inspector General, DOE Field Offices, and internal audit staffs. This quality initiative should result in greater reliance on the work of internal audit staffs, and in reduced DOE audit effort and oversight.

Site and Facilities

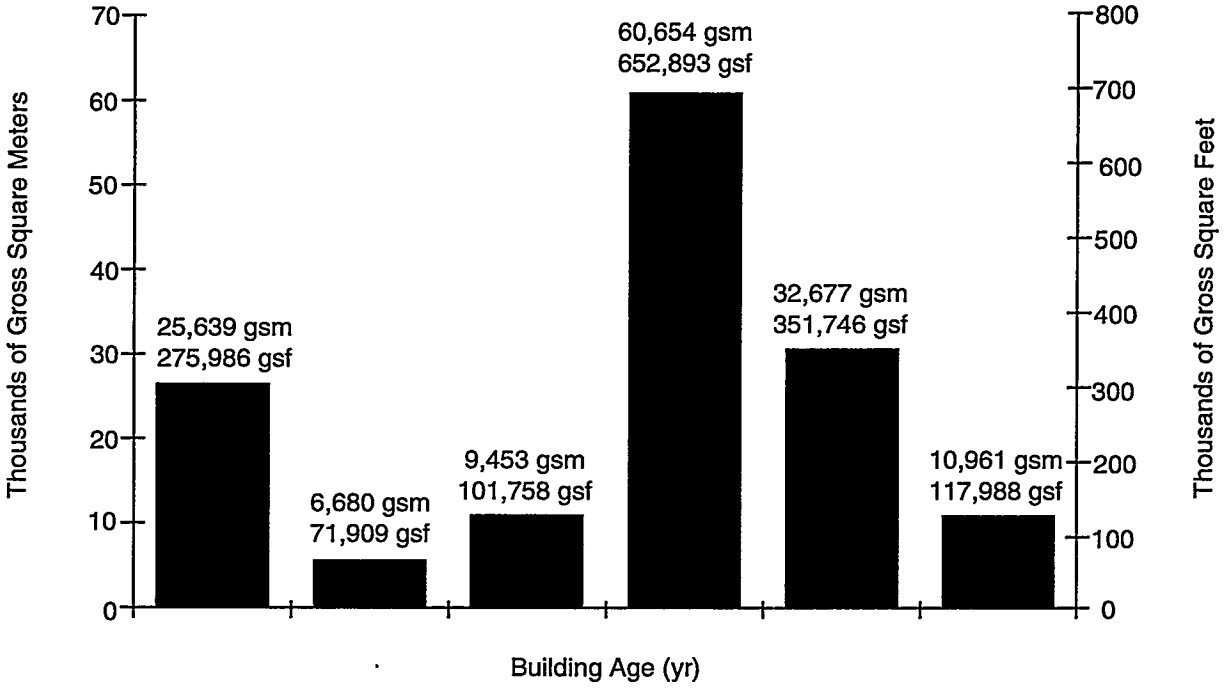
The Laboratory has a unique location in the hills above the UC Berkeley campus, on a 54-hectare (134-acre) site overlooking the San Francisco Bay. The Laboratory strongly supports strategic planning activities that are now taking place as part of a national effort to restore and maintain the nation's scientific infrastructure, and has made these activities an integral part of its own site development process. In addition, Berkeley Lab is continually vigilant about creating conditions that protect the Berkeley Lab staff, the public, and the environment.

Berkeley Lab facilities include approximately 183,018 gsm (1.97 Mgsf) located on- and off-site. See the Berkeley Lab Space Distribution table, below. The vast majority of space utilized by Berkeley Lab research and support staff is located in DOE-owned buildings on the main site (84%). However, Berkeley Lab also utilizes off-site leased space (10%), and space on the adjacent UC Berkeley campus (6%) available to DOE by long-term arrangement. Having space nearby at a major university facilitates continuous flow of scientific thought, and productive interactions between DOE laboratory and University communities.

Berkeley Lab Space Distribution

Location	Area (Ksm)	Area (Mgsf)	% of Total
Main site	154	1.66	84
UC Berkeley campus	10	0.11	6
Off-site leased	19	0.20	10
Total	183	1.97	100

In FY 1996, the main site included 76 permanent buildings and approximately 113 trailers and temporary structures. The first on-site building was constructed in 1940.



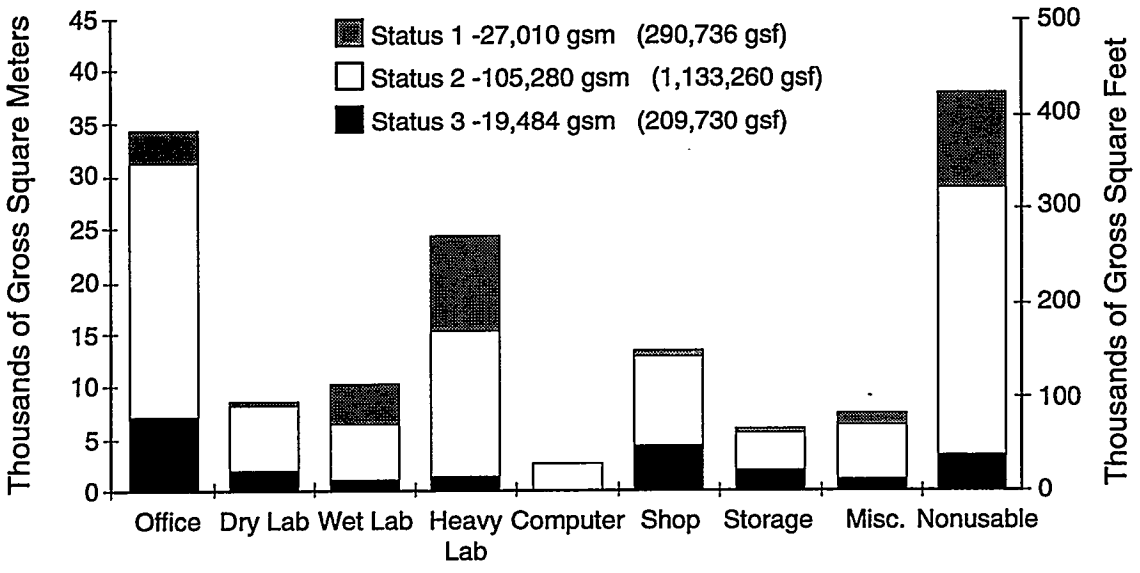
Age distribution of permanent main-site buildings.

Evaluation of building condition and usability is based on categories utilized in the former Strategic Facilities Initiative (SFI) that have been modified for present use. These categories are:

Status 1: **Adequate.** Structure, systems, and components are adequate for current use. Building utilities have adequate capacities, technological quality, and reliability to reasonably support functions required by occupants and processes. Structural and safety features are adequate to provide occupants, the public, and the environment with reasonable protection from natural and industrial hazards (equivalent to that required by applicable codes, statutes, and regulations). The extent of deterioration and technological obsolescence is limited to that which can be addressed by maintenance or minor alteration.

Status 2: **Functional, Can Be Economically Upgraded.** Structure, systems, and components are functional for current use but are approaching technological or functional obsolescence. Can be economically upgraded.

Status 3: **Substandard, Cannot Be Economically Upgraded.** Structure, systems, and components have been used beyond their normal lifespan, and cannot be economically upgraded.



Condition of main-site buildings, modulars, and trailers by space type.

At Berkeley Lab, Status 2 space (Functional, Can Be Economically Upgraded), is the focus of ongoing planning and construction efforts aimed at retaining full use of these facilities. Status 3 space (Substandard, Cannot Be Economically Upgraded), consists primarily of offices in aged "temporary" trailers, and older shop spaces. When functions in these temporary facilities are transferred to permanent buildings, about one-third of the Status 3 space will be eliminated.

The FY 1996 replacement plant value (RPV) of Berkeley Lab occupied facilities is estimated to be approximately $823 million. This includes DOE- and UC-owned buildings and occupied trailers, and leased facilities, on- and off-site. The RPV of site infrastructure, including site improvements, utilities, communication systems, and accelerators, is approximately $252 million. The RPVs were determined using Berkeley Lab-derived RPV unit costs.

FY 1996 Facilities Replacement Plant Value

Type	Value ($M)	% of Total
Buildings	823	77
Utilities	252	23
Total	1075	100

Facilities Plans and Options

Site Development Plans

Berkeley Lab's Site-Development Plan provides analysis and policy guidance for the effective use and orderly development of land and facilities. This planning effort is critical to all of the Laboratory's programs. First, it is critical because facilities require rehabilitation to avert safety hazards, shutdowns, and failures. Second, it is critical to optimize use of the Laboratory's limited land and building resources. In addition to the site development plan, department-wide planning efforts are integrated into the total site-planning effort. The objectives of the site-planning effort are as follows:

- Evaluate future mission projections and anticipate DOE national research facility needs.
- Ensure a safe and healthy workplace in full compliance with building and fire codes.
- Protect the environment and buffer activities to enhance adjacent land uses.
- Protect the national investment in government-owned research and support assets.
- Consolidate research and support services through proper siting of new buildings and maintenance of functional units.
- Make efficient use of unique Laboratory assets and adopt and reuse similar facilities with potential to support Laboratory missions.
- Improve access and communications within and to the Laboratory.
- Promote cost reductions and energy conservation through efficiencies in building design and location, operation and maintenance, and parking and transportation.

Resources to improve the Laboratory's facilities are provided through Multiprogram Energy Laboratory Facilities Support (MEL-FS), General Plant Projects (GPP), In-House Energy Management, and General Purpose Equipment (GPE). Adequate funding from these resources is a critical element of Berkeley Lab's ability to provide DOE with an effective multiprogram Laboratory that can meet environmental and safety standards. A major effort is under way to provide conditions that meet accepted standards for Berkeley Lab's environment, health, and safety programs, including providing adequate monitoring and sample processing laboratories, emergency command and response facilities, and sufficient space for on-site offices for industrial hygiene, environment, and other essential EH&S staff.

Berkeley Lab's facilities planning is coordinated through specific Laboratory management activities and DOE initiatives. Berkeley Lab has established a prioritization framework for its multiprogram capital projects and incorporates a safety and environmental program. Operating funds have been provided through the MEL-FS General Purpose Facilities KG01, KG02, and KG03 subprograms to support infrastructure, the Condition Assessment Survey, vegetation management, and other planning activities. The Laboratory's ten-year In-House Energy Management Plan represents significant opportunities for cost savings. All proposed projects undergo NEPA and CEQA review procedures for full compliance with DOE and UC guidelines. Institutional planning acts to couple site-management planning activities to program planning and other strategic management processes. For FY 1995, a complete 20-year infrastructure program has been developed consistent with DOE guidelines and the Laboratory's Vision 2000 strategic planning.

The Site Development Plan (SDP) is based on five Berkeley Lab site-master-plan concepts. These concepts accommodate facilities improvement needs within existing geophysical, environmental, and operational conditions. They provide a basis for understanding and evaluating the more detailed elements of specific projects, planned locations, and other site-improvement projections. These site-planning concepts are:

- Consolidation of activities within seven functional planning areas to enhance efficiency and effectiveness and to provide specialized research facilities.

Condition of Main-Site Buildings, Modulars, and Trailers by Space Type

	Space Type (Square Meters)										
Condition of Space	Office	Dry Lab	Wet Lab	Heavy Lab	Computer	Shop	Storage	Misc.	Non-usable	Condition Subtotals	% of Total
Rehab Status 1 (Adequate)	2,791	360	3,431	8,511	92	391	375	981	10,078	27,010	18
Rehab Status 2 (Functional, Can Be Economically Upgraded)	25,243	5,886	8,016	15,075	2,366	10,798	3,518	6,506	27,873	105,280	69
Rehab Status 3 (Substandard, Cannot Be Economically Upgraded)	6,475	1,674	672	1,098	103	3,781	1,604	564	3,514	19,485	13
Space Type Totals	34,509	7,920	12,119	24,683	2,561	14,970	5,496	8,051	41,465	151,775	100

Condition of Main-Site Buildings, Modulars, and Trailers by Space Type

	Space Type (Square Feet)										
Condition of Space	Office	Dry Lab	Wet Lab	Heavy Lab	Computer	Shop	Storage	Misc.	Non-usable	Condition Subtotals	% of Total
Rehab Status 1 (Adequate)	30,038	3,871	36,934	91,610	988	4,213	4,033	10,563	108,486	290,736	18
Rehab Status 2 (Functional, Can Be Economically Upgraded)	271,727	63,361	86,283	162,267	25,471	116,231	37,865	70,028	300,027	1,133,260	69
Rehab Status 3 (Substandard, Cannot Be Economically Upgraded)	69,701	18,016	7,229	11,821	1,109	40,696	17,264	6,073	37,821	209,730	13
Space Type Totals	371,466	85,248	130,446	265,698	27,568	161,140	59,162	86,664	446,334	1,633,726	100

- Redevelopment of obsolete buildings and deteriorated infrastructure, elimination of temporary structures used for permanent functions, and improvement of building arrangements to increase safety and energy efficiency.
- Concentration of development along the east–west circulation and utilities axis to enhance transportation and service systems, e.g., development of off-road parking and improvement of pedestrian pathways.
- Improvement and maintenance of perimeter and internal buffer zones to screen noise-generating activities and minimize potential incompatibility between adjacent operations.
- Providing of off-site facilities for receiving, warehousing, and other support and research activities suitable for decentralization.

Facilities planning includes exploring such options as the potential interim use of off-site facilities for administrative and other support functions. Over the past three decades administrative requirements have been increasing as safety, accounting, environmental, and other requirements are addressed. Berkeley Lab is exploring long-term options, such as reconfiguration of some existing space, new additions to office and support buildings, and removal of temporary office structures. These temporary office structures proliferated during the past several decades as a result of limited construction for offices and support buildings.

If the full programmatic capability of the site is developed to meet anticipated national needs in energy technology and supporting research, per the Twenty-Year Plan, the sites and new buildings would result in a net increase of 37,000 gsm (0.4 Mgsf) to the existing main site, for a total of approximately 186,000 gsm (2.0 Mgsf). For comparison, the 1995 total, including current construction, consists of 149,500 gsm (1.66 Mgsf) at the main site. The Laboratory's on-site space is at an approximate 73% net-to-gross area efficiency. The usable on-site space is approximately 112,000 gsm (1.2M net square feet). The building utilization efficiency is not projected to change significantly, although the efficiency of land use is expected to improve with the replacement of obsolete single- and two-story buildings with three- to five-story structures.

General Purpose Facilities Plans

Multiprogram Energy Laboratory Facilities Support. This modernization program addresses needs primarily related to the many buildings and utilities that are 30 to 50 years old. Individual projects are evaluated against generic Laboratory site-development priorities such as safety, environmental protection, reliability, maintainability, design standards and obsolescence, and delivery of research and support services.

Safety and Health Improvements. Health and safety improvements are needed in safety services, radiation protection and monitoring, and other safety systems (see the "Environment, Safety and Health" subsection in this section). Many of these projects were initiated as MEL-FS projects. Examples of important funded projects include a Fire and Life Safety Systems Upgrade Project (Phase I) and the Hazardous Materials Safeguards Program.

Mechanical Utilities. The Laboratory's mechanical/utility systems are up to 40 years old. Mechanical utilities consist of domestic- and cooling-water; storm-drain and waste; and natural-gas, compressed-air, and vacuum systems. Full implementation of Berkeley Lab's plans would minimize the possibility of program disruption by loss of essential utilities and equipment.

Electrical Utilities/Safety. Berkeley Lab's power-distribution system consists of 24 substations and 32 kilometers (20 miles) of 12-kV primary distribution cable. Much of the distribution equipment and cables are obsolete, resulting in reduced reliability and increased maintenance. The electrical rehabilitation projects have been prioritized into several phases based on the expected failure rates of equipment and the importance to site-wide facilities demands. Phases one and two, the Grizzly Peak Substation and Original Labsite Substation, have been completed. Phase three, the East Canyon Electrical Safety Project, was funded in FY 1992, and is now under construction. The remaining phase four, Electrical Systems Rehabilitation (Blackberry Canyon Switching Station and Replacement), is our

top MEL-FS priority for FY 1998. The upgraded switching and distribution system will provide the reliability, flexibility, and expansion necessary for efficient Laboratory operation and future growth.

Building Replacement and Modernization. The MEL-FS building replacement and modernization plan responds to the needs for safety, support, and research infrastructures, and for general-purpose engineering facilities. Improvements in substandard space conditions, as part of a long-term modernization program, will facilitate the achievement of the Laboratory's mission. Included in the long-range plan is the removal of substandard facilities that cannot be economically upgraded.

General Plant Projects

GPP funds are required to address a number of the essential strategic and site-planning objectives of the Department of Energy and the Laboratory. Realization of these objectives requires capital funds as facility improvements are accomplished. GPP funds are the sole appropriate choice when the cost of these capital projects is below the MEL-FS threshold. The Laboratory applies GPP funds to important environmental, health, safety, and building modernization project needs in an expeditious and cost-efficient manner. GPP funds support achievement of objectives in many areas, including projects to upgrade high efficiency particulate air (HEPA) filtration systems on glove-box exhaust stacks and to upgrade environmental monitoring equipment capable of documenting the care taken to preserve and protect the environment, to improve slope stability, and to correct existing noncompliance problems in order to conform with fire and life safety codes. Additional GPP projects include those to modernize and enhance utility infrastructure, to maintain and advance facility utilization through adaptive reuse of existing assets, and to modernize buildings in order to realize the benefits of automation and technological advances.

The Laboratory has a significant backlog of projects, in the amount of approximately $30 million. This backlog is not being reduced, as approximately $3 million of new project needs are identified annually whereas the Laboratory's GPP funding has remained at a similar level for a number of years. In addition, the recent application of overhead burdens further reduces available funds. The Laboratory reviews all candidates on an annual basis, and projects are ranked and reviewed using the DOE-developed CAMP and RPM criteria. Increasing GPP funding to $6 million annually would ensure achievement of critical strategic and site-planning objectives and reduce the backlog of projects.

General-Purpose Equipment

Essential support equipment has been funded through DOE. Berkeley Lab's Five-Year GPE Plan identifies needs based on a range of criteria, including environment, safety, and health; legal requirements; failed, worn, inefficient, or obsolete equipment; substandard performance; or increased workload and demand. The current funding level of $1.9 million/year is inadequate to meet the Laboratory's needs. As noted in the new DOE/UC contract, "a continuing, active and affirmative program of supplementing and replacing such equipment is essential to scientific progress." Currently, there is a $19 million equipment backlog for environmental monitoring, building services, data processing, and communications.

Maintenance Plans

Maintenance plans and budgets are developed annually within an overall five-year planning and safety management strategy. The Laboratory has improved its current maintenance scheduling system and backlog of maintenance projects through its site-wide Plant Inspection Program and condition assessment program. Requirements are identified by periodic reviews and inspections, and new priorities are developed during the fiscal year.

The operating expenses for maintenance include physical-plant maintenance, mobile-equipment maintenance, and noncapital alterations related to maintenance. In addition, specialized maintenance related to shop, computer, and telecommunications facilities is also performed.

The current strategy for improving maintenance relies on strengthening the capital outlays, continuing the operating-cost efforts, and implementing the maintenance-planning system. This allows the Laboratory to sustain DOE facilities while planning for maintenance cost economies. These economies can be achieved

through the replacement of existing obsolete and high-maintenance-cost facilities with modern facilities and equipment supported by increased MEL-FS, operating, GPE, and GPP funds.

Programmatic Facilities Plans

The new programmatic research buildings and facilities identified in the table serve the national interest in several research areas where Berkeley Lab has established programs. Several major scientific facilities form the core of Berkeley Lab's plans to contribute to DOE's research capabilities. The Human Genome Laboratory, ALS Structural Biology Support Facilities, and the Elise accelerator are recently funded projects. Proposed are the ALS Roadmap Initiative and expansion of the National Center for Electron Microscopy–Electron Beam Microcharacterization Facility. Completion of the second floor of the ALS building for users is essential to meet ALS program requirements.

Facilities Decommissioning Plan

The development of new national program directions for nuclear physics resulted in the shutdown of Berkeley Lab's Bevalac nuclear physics program during FY 1993. A stand-down-and-secure of the facility was completed in FY 1994. Berkeley Lab is currently working with DOE/ER and DOE/EM for cost-effective and timely recovery of the space previously required for Bevalac operations and experimental programs.

The key element of Berkeley Lab's plan is a waste minimization initiative for reuse of the Bevalac shielding blocks at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. This project has significant cost savings for DOE because it obviates the need for disposal as low-level waste of 13,440 cubic meters (480,000 cubic feet) of shielding block. The shipment began in FY 1995 and will continue through FY 1998.

Berkeley Lab has developed and submitted several proposals to the Inactive and Surplus Facilities Program (I&SFP; ER-7). These proposals are for the cleanup and cleanout for eventual reuse of nonactivated Bevalac equipment and peripheral spaces, permitting a gradual return of these spaces to productive Laboratory and programmatic use. Aside from the Bevalac, the Laboratory conducts periodic reviews of facilities that may become inactive. Other facilities to be decommissioned include gamma irradiators.

Facilities Decommissioning Plan ($M)

Category	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Bevalac:						
Surveillance and Maintenance (OER)	0.15	0.15	0.16	0.16	0.17	0.17
Block Reuse at BNL (OER/EM)	1.08	0.36	—	—	—	—
Inactive & Surplus Facilities Program (ER-80)	0.16	0.16	0.16	0.16	0.16	0.16
D&D Base Program (OER)	0.60	—	—	—	—	—
Total	1.99	0.67	0.32	0.32	0.33	0.33

Facilities Resources Requirements

A five-year construction plan for programmatic and general purpose facilities is provided in the Lawrence Berkeley National Laboratory Construction Plan table for FY 1996 to FY 2001 (see page 5-30). MEL-FS proposed projects are listed in a prioritized order of sequence. All budget information as indicated is actual-year authority.

Assets Management

Berkeley Lab utilizes its assets to the fullest extent. Space is limited and in high demand; therefore, no divestiture of assets is anticipated. However, if a facility were to become surplus, it would be proactively managed on an individual basis to return it to productive use. Full advantage would be taken of DOE-sponsored programs such as the *Surplus Facilities Inventory and Assessment (SFIA), Inactive and Surplus Facilities Program (I&SFP),* and *Return on Investment (ROI) Program* to set reuse priorities and procure funding. Various portions of non-activated Bevalac space were cleaned-up under *I&SFP*. Bevalac shielding blocks are currently being shipped to and reused at Brookhaven National Laboratory's Relativistic Heavy-Ion Colllider (RHIC) as the key element of LBNL's *ROI* project, saving DOE over $100 million in low-level waste burial costs. (See preceding section on *Facilities Decommissioning Plan.*)

Berkeley Lab Construction Plan

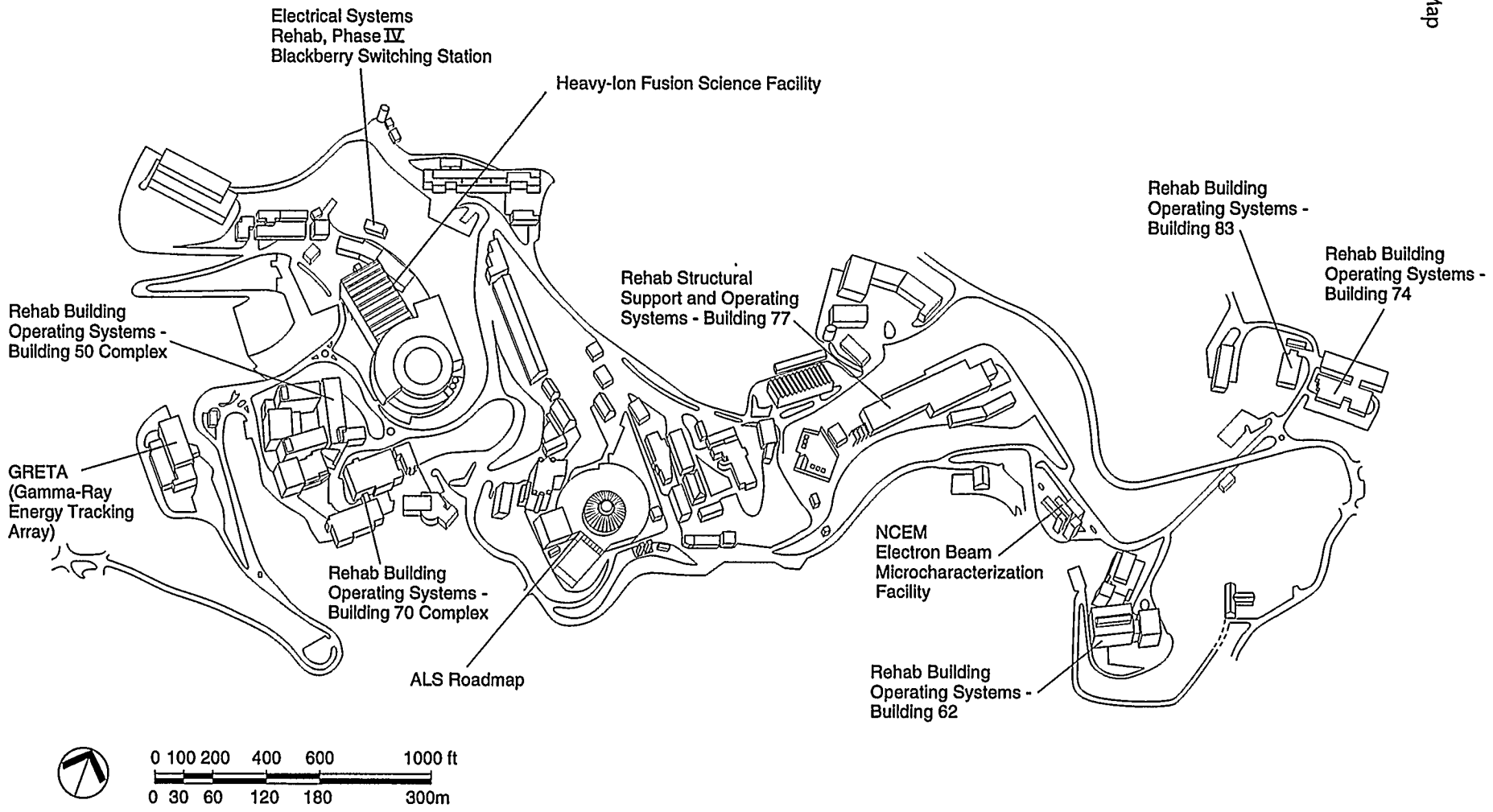
FY 1997–FY 2002

Plan for programmatic and general purpose facilities, including funded, budgeted, and proposed construction (FY BA, $M)

Project	Scope	TEC	Prior†	1997	1998	1999	2000	2001	2002	2003
FUNDED PROGRAM RELATED PROJECTS:										
Human Genome Laboratory (KP)	3,809 gsm (41,000 gsf)	24.700	23.700	1.000						
ALS Structural Biology Support Facilities	1,031 gsm (11,100 gsf)	7.900	7.900							
SUBTOTAL - FUNDED PROGRAM RELATED		**32.600**	**31.600**	**1.000**						
FUNDED MEL-FS PROJECTS (KG):										
Fire & Safety Systems Upgrade Proj. Ph I		4.600	4.600							
Hazardous Materials Safeguards, Ph. I		4.720	4.720							
SUBTOTAL - FUNDED MEL-FS PROJECTS		**9.320**	**9.320**							
FUNDED ERWM PROJECTS:										
Hazardous Waste Handling Facility	1,198 gsm (12,900 gsf)	12.625	12.625							
SUBTOTAL - FUNDED ERWM PROJECTS		**12.625**	**12.625**							
TOTAL FUNDED		**54.545**	**53.545**	**1.000**						
BUDGETED MEL-FS PROJECTS (KG)										
Sanitary Sewer Restoration, Phase 1	1,036 m (3,400 ft)	2.400	2.400							
TOTAL FUNDED and BUDGETED		**56.945**	**55.945**	**1.000**						
PROPOSED PROGRAM RELATED PROJECTS:										
ALS Roadmap (KC)	1,877 gsm (20,200 gsf)	39.5				9.2	16.5	9.2	4.6	
NCEM Electron Beam Microchar Facility (KC)	900 gsm (10,000 gsf)	17.5				1.0	8.5	7.0	1.0	
TOTAL - PROPOSED PROGRAM RELATED		**57.0**				**10.2**	**25.0**	**16.2**	**5.6**	
PROPOSED MEL-FS PROJECTS:‡				**97**	**98**	**99**	**00**	**01**	**02**	**03**
No Funding Available (FY 1997)										
Elect. Sys. Rehab, Phs IV		6.5			2.4	4.1				
Mechanical Systems Modernization		4.7			0.5	2.2				
Rehab Building Operating Systems - B 74		5.5				1.1	3.0	1.4		
Rehab Struct. Support and Operating Sys. - B 77		6.2				0.7	2.7	2.8		
Rehab Building Operating Sys - B 50 Complex		6.3					0.7	2.0	3.0	0.6
Mechanical Utilities Upgrade, Phs 1		4.1					0.7	2.5	0.9	
Rehab Building Operating Systems - B 62		4.6						0.6	1.8	2.2
Struct. Modifications to Bldgs. for Seismic Safety		4.2						0.7	2.0	1.5
Rehab Bldg Operating Sys. - B 70 Complex		4.7							0.9	1.9
Fire & Safety Systems Upgrade, Phs 2		5.3							0.8	2.4
Rehab Building Operating Systems - B 83		5.8								0.9
Sewer System Restoration		3.1								0.9
SUBTOTAL - PROPOSED MEL-FS PROJECTS		**61.0**		**0.0**	**4.9**	**8.1**	**7.1**	**10.0**	**9.4**	**10.4**
TOTAL FUND, BUDGET & PROP MEL-FS PROJECTS (Excludes Program and ERWM Related Projects)		**72.72**	**11.720**	**0.0**	**4.9**	**8.1**	**7.1**	**10.0**	**9.4**	**10.4**

†Prior costs for previous years.

‡This list has been significantly changed from the list presented in the previous plan. As MEL-FS funds had been available for only a single new project for FY 1994 through FY 1997, the former plan required significant revision to ensure that the most urgent among the many urgent needs were appropriately prioritized. Berkeley Lab has reviewed all MEL-FS needs to develop this list. The individual high-priority items that comprise this list will be reviewed further through 1996, and the TECs may be adjusted during this process.



Proposed major construction projects (FY 1997–FY 2002)
(Site-specific projects only)

Information Management Program

Berkeley Lab's Information Management (IM) program includes both research and operational activities. Research is discussed in the Computational and Technology Research subsection of Section IV. Operational activities involve the integration of these new technologies into a seamless information technology infrastructure that supports the mission of the NERSC Center and the research and administrative requirements of the Laboratory.

All scientific programs at Berkeley Lab make essential use of the Laboratory's information resources for the collection and analysis of data and the modeling and visualization of physical process; for numerous administrative support functions; and for communication with colleagues—both on an individual basis through e-mail, fax, and telephone services, and through hardcopy and electronic (e.g., via the World Wide Web) publications, conferences, and video conferences.

Objectives

The major goal of Berkeley Lab's efforts in Information Management is to provide cost-effective, technologically appropriate support for the programmatic mission and administrative functioning of the Laboratory. To achieve this goal, the following objectives have been developed:

- **For corporate data:** To implement a data-warehouse-based environment where data are entered only once, and then made conveniently available to all authorized users; to reduce the Laboratory's dependence upon paper reports to a minimum, and to provide appropriate protection for and disposition of all data and records.
- **For the dissemination of scientific and technical information:** To increase the use of generally accessible electronic media such as the World Wide Web, and to encourage the development of a paperless exchange of scientific and technical results, reports, and journal articles.
- **For telecommunications:** To provide reliable full connectivity and ample bandwidth to every staff member. (Note: The interpretation of what constitutes "ample" bandwidth is changing rapidly. Our current standard is megabits-to-the-desktop, but increasing use of desktop video, remote control of experiments, and other elements of the collaborative-laboratory concept, is rapidly rendering this insufficient.)
- **For the staff:** To provide state-of-the-art and transparent computing and communications resources for DOE programs and services to every scientific, engineering, and administrative employee. These services include advanced network communications technology that keeps pace with demand, workstation support services and technical support for telecommuting and telework, transparent access to computing resources, upgraded central computing and mass storage facilities, and proper control of access to sensitive files.

These goals underpin Berkeley Lab's mission for research and development, design and operation of user facilities, education and training, and technology transfer. Together with the human and facilities resources of the Laboratory, the information resources provide a flexible and responsive operating environment for the implementation of DOE programs. Effective information management is vital to the success of this mission, and will require the allocation of adequate DOE resources for effective implementation.

Information Management Resource Requirements (FY BA, $M)

Category	1997	1998	1999	2000	2001	2002	Total
Recharge	15.7	17.0	18.5	20.0	21.0	22.0	114.2
Overhead	9.9	10.1	10.3	10.5	10.7	10.9	62.4

Strategies

In addition to the programmatic efforts described above, Berkeley Lab's IM strategy includes focused support for improving the nation's computing and communications infrastructure, assistance to DOE in the development of IM policies and plans, and development of Berkeley Lab's computing and communications infrastructure to support the Berkeley Lab/DOE multiprogram Energy Research Laboratory mission. Berkeley Lab's strategies directly support IM objectives described above to provide state-of-the-art, transparent computing and communications resources; accessible corporate information management systems; effective scientific and technical information services; and a secure records management program. These strategies are:

Improve National Computing Infrastructure. Berkeley Lab has provided continuing support to the Office of IM Policy to develop DOE's Information Management strategies. This includes review of existing strategies and policies and the development of new policies to cope with the changing IM environment. Berkeley Lab is an active participant in DOE's effort to streamline the directives that apply to Information Management. The Laboratory strongly supports DOE development of a planning process that is driven by programmatic need rather than report requirements. Berkeley Lab is also active in several branches of the standards-development process that are of particular interest to DOE. These include participation in technical committees dealing with network issues, the planning and development of ESnet, and the Internet Engineering Task Force. In addition, Berkeley Lab also supports the development of the national communications infrastructure through its ESnet service, a major element in DOE's nationwide communications infrastructure.

Enhance the Berkeley Lab Work Environment's Access to Corporate Information. A new institutional strategic change to achieve Berkeley Lab Vision 2000 is improved definition and management of corporate and institutional data. Berkeley Lab's site strategy encourages the integration of appropriate information technology into individual work environments. The process of creating an integrated Laboratory approach to information management has begun, and will extend over several years.

Convert to a Primarily Electronic Information Environment. Berkeley Lab has made a number of steps towards creating an information environment that is primarily online rather than paper-based. These include administrative applications (such as electronic time reporting), digital photography, the exchange of scientific and general-interest information through the World Wide Web, access to remotely located computational and experimental resources through ESnet, the expansion of online library services, and video conferencing, both desktop and studio-based. Over the next several years we will continue to build upon this foundation to provide tools that enable all staff to have convenient online access to essentially all the information they need, whether of a scientific or administrative nature. It is expected that this new online environment will materially change the way in which intellectual and administrative work is accomplished in the years ahead.

Scientific and Technical Information Management. As a DOE national laboratory, Berkeley Lab has a responsibility to conduct leading-edge research and to publish the results of that research in appropriate scientific and technical media. Until quite recently, these media were almost exclusively paper based. For many years, Berkeley Lab has had a set of policies in place to provide effective management of scientific and technical information (STI) through its entire life cycle: from creation, through publication and dissemination, to eventual retirement and archival. This STI program is driven by the scientific programs, primarily through the Field Work Proposal (FWP) process. The FWP process is the normal funding mechanism at Berkeley Lab, and requires explicit line-item entries to document the preparation and publication of suitable reports describing the results of the programmatic efforts. In addition, many groups at Berkeley Lab are making increasing use of the Internet and the World Wide Web, an Internet client–server information retrieval system, as communications and information distribution media. We believe that these electronic media have created nearly unbounded information channels and require a nontraditional (and noncentralized) type of management. Berkeley Lab is developing policies to operate in this new environment.

Advanced High-Speed Networking. To meet projected traffic and demand, Berkeley Lab anticipates that expanded communications and networking infrastructures will be required. The Laboratory has

embarked upon a multiyear LBLnet Upgrade Project that will extend high-speed (100 Mbs and beyond) network access to the majority of Berkeley Lab workstations. In addition, network backbones and server systems will need to be upgraded or replaced.

Other Initiatives and Infrastructure Investments. As a separate initiative, and in common with other federal facilities, Berkeley Lab has begun an examination of options to satisfy the impending narrowed bandwidth requirements for radio systems. Conversion to narrow bandwidth telecommunications using a trunk-based system will require expenditures over the next several years, beginning in FY 1996. This program is to be coordinated among the DOE laboratories in response to the DOE requirements.

Throughout the period covered by this Institutional Plan, the Laboratory will continue its program of support for development of the information infrastructure, including the formation of a cadre of experts skilled in preparation of multimedia presentations and documents; the introduction of virtual reality concepts into the analysis of complex data; and a sophisticated mechanism for the indexing, storage, and retrieval of visual information using visual and textual search techniques.

COMMUNICATIONS AND TRUST

A key element of Berkeley Lab's strategic plan (discussed in Section III) is a broad initiative to strengthen communications at all levels and to build a trusting relationship with the Laboratory's public and private constituents. This effort focuses on enhanced internal communications, improved communications with DOE and federal and industrial partners, and a strengthened identity in the community and the region. Berkeley Lab has prepared a report defining communications issues, strategies, and actions to meet specific objectives.

Strengthening Communication

Strengthening communications at all levels, internal and external, to build trust with the public and Berkeley Lab employees is among the key elements of the Berkeley Lab Strategic Plan. This emphasis parallels the Department of Energy's goal to change its culture to one of openness, communication, and trust.

A Laboratory-wide Communications Plan was issued in 1995 and is being instituted as resources allow. A major commitment to this plan was a Laboratory-wide Open House for the general public, conducted in the Fall of 1995. The Plan provides a foundation for development of unifying and consistent written and graphic symbols of Berkeley Lab's identity. One element of the identity program will be signage for a more welcoming and negotiable campus. Consistent graphics and publications guidelines will also lend a sense of unity and familiarity to Berkeley Lab products and vehicles.

Berkeley Lab will continue to enhance two-way interactions between management and the work force through training programs for Laboratory leadership, increased opportunities for employee development and feedback, and improved communication mechanisms and programs. Integration of electronic communications systems and networks will be essential for effective linkage of Berkeley Lab personnel and programs, and the development of World Wide Web-based technologies to share information will be among the Laboratory's top planning priorities. A well-informed Laboratory citizenry leads to a more rewarding and safe workplace that nurtures creativity, rewards achievement, and is results-oriented and enjoyable.

Public Information

How Berkeley Lab is perceived by its most important external constituencies—Bay Area communities, Congress and the Department of Energy, the general and scientific news media, the University of California, and prospective business partners—will be essential to the fulfillment of its mission. Berkeley Lab supports

an aggressive program of publicity and promotion to heighten the Laboratory's profile and broaden understanding of and appreciation for its work.

Primary audiences include the Bay Area communities, in particular the neighborhoods of Berkeley and Oakland; the undefined "public" reached via the general news media; elected officials and regulatory agencies; the Department of Energy; the University of California; prospective business clients in technology and industry; and members of various scientific communities, reached through professional affiliations or the science press. Prospective employees, especially from minority and underrepresented communities, are particularly important targets to reach as Berkeley Lab strives to achieve its diversity goals.

Community Relations and Outreach

Being a "good neighbor" and a valued member of the surrounding community has never been more important to Berkeley Lab, and thus its communications and interactions with local government, agencies, citizens' groups, schools, the news media, and other stakeholders will be enhanced. This includes continuing efforts to cooperate in the planning of all projects that might involve environmental and cultural impacts on the city and county within which Berkeley Lab exists.

A comprehensive and effective community relations program requires regular interactions between the citizens of Berkeley Lab and the external environment. These connections, involving administrators, scientists, and staff members at the Laboratory, are encouraged through the Speakers' Bureau, the participation of employees in community-based projects and service groups, and the development of a more welcoming Laboratory environment. Visitor programs, special events, and targeted communications vehicles will be developed and promoted to project an inviting, cooperative, user-friendly image of openness and honesty. Goals of the Community Relations Program are identified as follows:

- Integration of community relations activities within the scientific divisions with the overall Berkeley Lab community relations effort, so that all issues of public concern may be addressed in a coordinated program.
- Continuation of a two-way communication with the public.

In particular, the local community is active in many environmental issues. Opportunities for public involvement are built into regulations, but Berkeley Lab will expand these opportunities by encouraging the public to participate in discussions at local community meetings about pertinent issues. Another, more focused goal is:

- Providing the community with accurate and timely information to increase the level of understanding of Berkeley Lab programs.

The local community, including elected officials, staff, Berkeley Lab employees, and site neighbors, is very interested in receiving more information about Berkeley Lab. Several vehicles to orient the public about Berkeley Lab programs are: site tours and open houses, information repositories, mailing lists, fact sheets and summaries of technical documents, a speakers' bureau, and meetings and presentations. The purpose of these is to:

- Respond to the different information requirements of specific groups, including elected officials, city staff, site neighbors, and employees. Activities include briefings for elected officials and attendance at local community meetings.
- Respond to the changing needs of the community.

Berkeley Lab values its relations with local communities and is committed to an expanding outreach effort. The benefits of a good community relations program can be seen in the burgeoning partnerships Berkeley Lab is now forming with the surrounding cities of Berkeley and Oakland. For example, Berkeley Lab has become an active participant with the city of Berkeley.

Operating under the philosophy that every Berkeley Lab employee is an ambassador for the Laboratory, the community relations program is directed internally as well. Noon-time lectures and films, nature walks around the Laboratory's scenic premises, ecology fairs, and other activities are held throughout the year, and all employees are encouraged to attend.

VI. RESOURCE PROJECTIONS

Resource projections for the Institutional Plan provide a description of the budget authority (BA) to implement the research programs. The resource tables also indicate actual FY 1995 BA and FY 1996 BA for comparison. These tables include:

- Resource Summaries (page 6-2);
- Secretarial Level Resources (pages 6-3 and 6-4);
- Program Office Resources (pages 6-5 through 6-8);
- Work for Others Resources (page 6-9); and
- Subcontracting and Procurement (page 6-10).

The FY 1997 estimate is based on FY 1997 DOE budget guidance, the President's Request, and assessments by Berkeley Lab Divisions. For fiscal years 1998 and beyond, operating cost projections are in FY 1998 dollars and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 1998 to FY 2002, the growth assumptions in program areas as tabulated range from 0% to 1.5% per year. These growth assumptions are based on the general direction indicated by DOE program personnel. Specific trend levels were established within each program activity.

The resource projections that follow include all funded and budgeted construction projects, the projected MEL-FS program, the approved Environmental Restoration and Waste Management program funding and construction, and operational costs for the Advanced Light Source. The new initiatives' resource projections are indicated in Section IV, and are not included in Section VI Resource Projections unless incorporated in budget submissions. Construction project costs are provided in Section V. The distribution of direct and indirect full-time equivalents is integrated with ES&H staffing planning, but is insufficient for full support of the 5-year ES&H Plan and Corrective Action Plan (see Section V), both of which require additional program support for full implementation.

Funding Summary (Fiscal Year Budget Authority, $M)

Category	1995	1996	1997	1998	1999	2000	2001	2002
DOE Operating	183.2	223.8	226.7	234.0	235.5	235.6	233.2	233.2
WFO Operating	34.7	40.8	43.7	44.2	44.2	44.2	44.2	41.6
Total Operating	**217.9**	**264.6**	**270.4**	**278.2**	**279.7**	**279.8**	**277.4**	**274.8**
Capital Equipment	33.4	40.6	27.0	27.7	27.8	27.9	28.0	28.1
Program Construction	29.0	27.0	7.2	5.1	6.6	13.3	17.8	7.6
MEL/FS-Revitalization	4.0	2.8	0.0	4.9	8.0	6.2	6.5	10.5
Environmental Restoration	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	3.4	4.0	3.5	3.5	3.5	3.5	3.5	3.5
General Purpose Equipment	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Total Lab Funding	**290.2**	**340.9**	**310.0**	**321.3**	**327.5**	**332.6**	**335.1**	**326.4**

Personnel Summary (Fiscal Year FTE)

Category	1995	1996	1997	1998	1999	2000	2001	2002
DOE Effort	1446	1437	1489	1551	1559	1574	1574	1574
WFO	348	349	367	367	367	367	367	367
Total Direct	**1794**	**1786**	**1856**	**1918**	**1926**	**1941**	**1941**	**1941**
Total Indirect	**782**	**644**	**668**	**687**	**690**	**696**	**696**	**696**
Total Lab Personnel	**2576**	**2430**	**2524**	**2605**	**2616**	**2637**	**2637**	**2637**

Secretarial Office Funding Summary (Fiscal Year Budget Authority, $M)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research								
Operating	129.2	179.3	178.8	186.1	188.0	188.1	185.7	185.7
Capital Equipment	16.0	30.7	18.6	19.3	19.4	19.5	19.6	19.7
Construction	33.6	31.4	9.7	12.5	17.1	22.0	26.8	20.6
Total	**178.8**	**241.4**	**207.1**	**217.9**	**224.5**	**229.6**	**232.1**	**226.0**
Energy Efficiency and Renewable Energy								
Operating	22.9	19.4	19.5	19.5	19.5	19.5	19.5	19.5
Capital Equipment	0.9	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Total	**23.8**	**20.0**	**20.2**	**20.2**	**20.2**	**20.2**	**20.2**	**20.2**
Fossil Energy								
Operating	2.5	2.7	2.5	2.5	2.5	2.5	2.5	2.5
Total	**2.5**	**2.7**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Office of Civilian Radioactive Waste Management								
Operating	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Environmental Management								
Operating	15.4	12.6	11.6	11.6	11.6	11.6	11.6	11.6
Capital Equipment	0.3	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**16.3**	**12.6**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**
Office of Environment, Safety and Health								
Operating	1.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	**1.2**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Human Resources and Administration								
Operating	0.5	0.4	0.3	0.1	0.1	0.1	0.1	0.1
Construction	2.8	2.4	1.0	1.0	1.0	1.0	1.0	1.0
Total	**3.3**	**2.8**	**1.3**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Policy								
Operating	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.3**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Office of Science, Education and Technical Information								
Operating	3.0	1.8	1.4	1.6	1.2	1.2	1.2	1.2
Total	**3.0**	**1.8**	**1.4**	**1.6**	**1.2**	**1.2**	**1.2**	**1.2**
Work for Other DOE Contractors								
Operating	5.8	7.0	12.0	12.0	12.0	12.0	12.0	12.0
Capital Equipment	4.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total	**10.6**	**11.0**	**16.0**	**16.0**	**16.0**	**16.0**	**16.0**	**16.0**
Total DOE								
Operating	183.2	223.8	226.7	234.0	235.5	235.6	233.2	233.2
Capital Equip. (inc.GPE)	22.0	35.3	23.6	24.3	24.4	24.5	24.6	24.7
Construction (inc. MEL)	37.0	33.8	10.7	13.5	18.1	23.0	27.8	21.6
Total	**242.2**	**292.9**	**261.0**	**271.8**	**278.0**	**283.1**	**285.6**	**279.5**
Work for Others	48.0	48.0	49.0	49.5	49.5	49.5	49.5	46.9
Total Lab Funding	**290.2**	**340.9**	**310.0**	**321.3**	**327.5**	**332.6**	**335.1**	**326.4**

Personnel By Assistant Secretary Level Office (Fiscal Year FTE)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research	1090	1126	1187	1249	1258	1273	1273	1273
Energy Efficiency and Renewable Energy	145	126	124	124	124	124	124	124
Fossil Energy	15	13	13	13	13	13	13	13
Office of Civilian Radioactive Waste Management	15	0	0	0	0	0	0	0
Office of Environment, Safety and Health	13	4	4	4	4	4	4	4
Environmental Management	59	50	45	45	45	45	45	45
Human Resources and Administration	2	2	2	1	1	1	1	1
Policy	4	1	0	0	0	0	0	0
Office of Sci., Edu.and & Tech. Information	8	5	4	4	3	3	3	3
Other DOE Contractors	95	110	110	110	110	110	110	110
Total DOE	**1446**	**1437**	**1489**	**1551**	**1558**	**1573**	**1573**	**1573**
Work for Others	348	349	367	367	367	367	367	367
Total Direct	**1794**	**1786**	**1856**	**1918**	**1925**	**1940**	**1940**	**1940**
Total Indirect	**782**	**644**	**668**	**687**	**690**	**696**	**696**	**696**
Total Personnel	**2576**	**2430**	**2524**	**2605**	**2615**	**2636**	**2636**	**2636**

Office of Energy Research Funding and Personnel (FY BA, $M)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
AT Fusion Energy								
Operating	5.8	4.9	5.4	3.3	3.4	3.5	3.6	3.6
Capital Equipment	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	**6.1**	**5.2**	**5.7**	**3.6**	**3.7**	**3.8**	**3.9**	**3.9**
Direct FTE	23	22	23	19	19	19	19	19
KA High Energy Physics								
Operating	19.8	20.1	21.0	23.0	23.0	23.0	23.0	23.0
Capital Equipment	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Construction	3.7	7.0	1.0	0.0	0.0	0.0	0.0	0.0
Total	**25.4**	**29.0**	**23.9**	**24.9**	**24.9**	**24.9**	**24.9**	**24.9**
Direct FTE	165	165	166	182	182	182	182	182
KB Nuclear Physics								
Operating	17.3	17.5	17.8	17.8	17.8	17.8	17.8	17.8
Capital Equipment	4.8	3.7	3.9	3.9	3.9	3.9	3.9	3.9
Construction	3.6	4.0	3.8	3.8	3.8	4.0	4.0	4.0
Total	**25.7**	**25.2**	**25.5**	**25.5**	**25.5**	**25.7**	**25.7**	**25.7**
Direct FTE	188	194	197	198	207	222	222	222
KC 02 Materials Sciences								
Operating	36.7	44.2	45.1	46.2	46.2	46.2	46.2	46.2
Capital Equipment	2.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Construction	1.8	3.8	3.8	3.8	5.3	11.8	16.3	6.1
Total	**41.4**	**52.9**	**53.8**	**54.9**	**56.4**	**62.9**	**67.4**	**57.2**
Direct FTE	342	350	350	359	359	359	359	359
KC 03 Chemical Sciences								
Operating	8.3	8.7	8.9	10.0	9.7	9.7	9.7	9.7
Capital Equipment	1.3	1.6	1.1	1.1	1.1	1.1	1.1	1.1
Total	**9.6**	**10.3**	**10.0**	**11.1**	**10.8**	**10.8**	**10.8**	**10.8**
Direct FTE	80	80	80	87	87	87	87	87
KC 04 Engineering, Math and Geosciences								
Operating	2.2	1.7	2.1	2.1	2.1	2.1	2.1	2.1
Capital Equipment	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
Total	**2.5**	**2.0**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**
Direct FTE	20	15	18	18	18	18	18	18
KC 05 Advanced Energy Projects								
Operating	0.7	0.6	0.5	0.6	0.5	0.5	0.5	0.5
Capital Equipment	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.8**	**0.7**	**0.5**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	4	3	1	1	1	1	1	1
KC 06 Energy Biosciences								
Operating	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Direct FTE	8	8	8	8	8	8	8	8

Office of Energy Research Funding and Personnel (FY BA, $M) (continued)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
KC 07 Applied Math Sciences								
Operating	4.6	48.4	45.3	46.6	46.6	46.6	46.6	46.6
Capital Equipment	0.4	14.6	3.1	3.8	3.9	4.0	4.1	4.2
Construction	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5.0**	**64.4**	**48.4**	**50.4**	**50.5**	**50.6**	**50.7**	**50.8**
Direct FTE	20	65	115	120	120	120	120	120
KC Basic Energy Sciences (Total)								
Operating	53.5	104.7	103.4	106.6	106.2	106.2	106.2	106.2
Capital Equipment	5.1	21.6	9.3	10.0	10.1	10.2	10.3	10.4
Construction	1.8	5.2	3.8	3.8	5.3	11.8	16.3	6.1
Total	**60.4**	**131.5**	**116.5**	**120.4**	**121.6**	**128.2**	**132.8**	**122.7**
Direct FTE	474	521	572	593	593	593	593	593
KG Multiprogram Energy								
Operating	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	4.0	2.8	0.0	4.9	8.0	6.2	6.5	10.5
Total	**5.2**	**3.8**	**0.9**	**5.8**	**8.9**	**7.1**	**7.4**	**11.4**
Direct FTE	35	33	33	33	33	33	33	33
KP Biological and Environmental Research								
Operating	22.3	23.6	25.0	29.2	29.2	29.2	29.2	29.2
Capital Equipment	3.8	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Construction	20.5	12.4	1.1	0.0	0.0	0.0	0.0	0.0
Total	**46.6**	**39.2**	**29.3**	**32.4**	**32.4**	**32.4**	**32.4**	**32.4**
Direct FTE	175	166	171	200	200	200	200	200
KT Science Education and Tech. Information								
Operating	3.0	1.8	1.4	1.6	1.2	1.2	1.2	1.2
Total	**3.0**	**1.8**	**1.4**	**1.6**	**1.2**	**1.2**	**1.2**	**1.2**
Direct FTE	8	5	4	4	3	3	3	3
KU Laboratory Technology Transfer								
Operating	9.4	7.5	5.3	5.3	7.5	7.5	5.0	5.0
Total	**9.4**	**7.5**	**5.3**	**5.3**	**7.5**	**7.5**	**5.0**	**5.0**
Direct FTE	20	30	25	25	25	25	25	25
Total OER								
Operating	129.2	179.3	178.8	186.1	188.0	188.1	185.7	185.7
Capital Equipment	16.0	30.7	18.6	19.3	19.4	19.5	19.6	19.7
Construction	33.6	31.4	9.7	12.5	17.1	22.0	26.8	20.6
Total	**178.8**	**241.4**	**207.1**	**217.9**	**224.5**	**229.6**	**232.1**	**226.0**
Direct FTE	**1090**	**1126**	**1187**	**1249**	**1258**	**1273**	**1273**	**1273**

Energy Efficiency and Renewable Energy Funding and Personnel (FY BA, $M)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
AK Electric Energy Systems								
Operating	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Total	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Direct FTE	2	2	3	3	3	3	3	3
EB Solar Energy								
Operating	1.5	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Total	**1.5**	**0.9**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Direct FTE	3	4	4	4	4	4	4	4
EC Building Sector								
Operating	15.6	13.5	14.0	14.0	14.0	14.0	14.0	14.0
Capital Equipment	0.8	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Total	**16.4**	**14.0**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**
Direct FTE	115	99	100	100	100	100	100	100
ED Industrial Sector								
Operating	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5
Total	**0.7**	**0.7**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	5	6	8	8	8	8	8	8
EE Transportation Sector								
Operating	2.7	3.3	3.5	3.5	3.5	3.5	3.5	0.0
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Total	**2.8**	**3.4**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**0.0**
Direct FTE	10	10	10	10	10	10	10	10
EK Utility Sector								
Operating	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Direct FTE	10	5	0	0	0	0	0	0
Total Energy Efficiency and Renewable Energy								
Operating	22.9	19.4	19.5	19.5	19.5	19.5	19.5	19.5
Capital Equipment	0.9	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Total	**23.8**	**20.0**	**20.2**	**20.2**	**20.2**	**20.2**	**20.2**	**20.2**
Direct FTE	145	126	124	124	124	124	124	124

Fossil Fuel and Other DOE Program Funding and Personnel (FY BA, $M)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
AA Coal								
Operating	0.6	0.7	0.5	0.5	0.5	0.5	0.5	0.5
Total	**0.6**	**0.7**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	4	4	3	3	3	3	3	3
AB Gas								
Operating	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	4	3	3	3	3	3	3	3
AC Petroleum								
Operating	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Direct FTE	7	6	6	6	6	6	6	6
Total Fossil								
Operating	2.5	2.7	2.5	2.5	2.5	2.5	2.5	2.5
Total	**2.5**	**2.7**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Direct FTE	15	13	13	13	13	13	13	13
DB Civilian Radioactive Waste Management								
Operating	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct FTE	15	0	0	0	0	0	0	0
HA Environment, Safety and Health								
Operating	1.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	**1.2**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	13	4	4	4	4	4	4	4
EX/EW Restoration & Waste Management								
Operating	15.4	12.6	11.6	11.6	11.6	11.6	11.6	11.6
Capital Equipment	0.3	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**16.3**	**12.6**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**
Direct FTE	**59**	**50**	**45**	**45**	**45**	**45**	**45**	**45**
WB Admin. & Human Resources Management								
Operating	0.5	0.4	0.3	0.1	0.1	0.1	0.1	0.1
Construction	2.8	2.4	1.0	1.0	1.0	1.0	1.0	1.0
Total	**3.3**	**2.8**	**1.3**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Direct FTE	2	2	2	1	1	1	1	1
PE Policy Planning								
Operating	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.3**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct FTE	4	1	0	0	0	0	0	0
Work for Other DOE Contractors								
Operating	5.8	7.0	12.0	12.0	12.0	12.0	12.0	12.0
Capital Equipment	4.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total	**10.6**	**11.0**	**16.0**	**16.0**	**16.0**	**16.0**	**16.0**	**16.0**
Direct FTE	95	110	110	110	110	110	110	110

Work for Others Funding and Personnel (FY BA, $M)

Office/Program	1995	1996	1997	1998	1999	2000	2001	2002
Other Federal Agencies								
AID	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct FTE	2	3	3	3	3	3	3	3
Defense	8.2	5.7	6.7	6.7	6.7	6.7	6.7	6.7
Direct FTE	58	45	50	50	50	50	50	50
EPA	2.2	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Direct FTE	12	12	12	12	12	12	12	12
DOI	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Direct FTE	6	6	6	6	6	6	6	6
NASA	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Direct FTE	24	24	24	24	24	24	24	24
NIH	14.4	14.4	15.0	15.5	15.5	15.5	15.5	15.5
Direct FTE	114	130	140	140	140	140	140	140
Other	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Direct FTE	4	3	4	4	4	4	4	4
Total Other Federal Agencies								
Operating	18.4	24.7	27.6	28.1	28.1	28.1	28.1	28.1
Capital Equipment	11.7	4.6	3.1	3.1	3.1	3.1	3.1	3.1
Total	**30.1**	**29.3**	**30.7**	**31.2**	**31.2**	**31.2**	**31.2**	**31.2**
Direct FTE	220	223	239	239	239	239	239	239
State/Private								
Operating	16.3	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Capital Equipment	1.6	2.6	2.2	2.2	2.2	2.2	2.2	2.2
Total	**17.9**	**18.7**	**18.3**	**18.3**	**18.3**	**18.3**	**18.3**	**18.3**
Direct FTE	128	126	128	128	128	128	128	128
Total Work for Others								
Operating	34.7	40.8	43.7	44.2	44.2	44.2	44.2	41.6
Capital Equipment	13.3	7.2	5.3	5.3	5.3	5.3	5.3	5.3
Total	**48.0**	**48.0**	**49.0**	**49.5**	**49.5**	**49.5**	**49.5**	**46.9**
Direct FTE	348	349	367	367	367	367	367	367

Subcontracting and Procurement ($M)

Recipient	FY 1994	FY 1995	FY 1996 (Projected)	FY 1997 (Projected)
Universities	15.6	15.0	11.6	10.2
All Other	79.8	87.9	105.5	92.8
Other DOE	3.6	3.4	2.3	2.1
Total	**99.0**	**106.3**	**119.4**	**105.1**

Procurement from Disadvantaged, Women Owned, and All Small Businesses

Business Category	FY 1994 $M (%)	FY 1995 $M (%)	FY 1996 (Projected) $M (%)
Disadvantaged	9.3 (12.3)	11.8 (12.3)	10.8 (10.0)
Women Owned	5.0 (6.6)	6.3 (6.5)	6.5 (6.0)
All Small	43.2 (57.1)	54.8 (57.1)	59.1 (55.0)

VII. ACKNOWLEDGMENTS

Institutional planning at Berkeley Lab is conducted as an annual management activity based on technical information contributed by the Laboratory's Divisions (see organization chart, Section II). Preparation of reporting documents is coordinated through the Office of Planning and Communications. Divisional staff coordinating information and assisting in preparation include:

Accelerator and Fusion Research	Christine Celata, Joseph Chew
Chemical Sciences	Linda Maio
Earth Sciences	Ellen Klahn
Energy and Environment	Donald Grether
Engineering	Laura Slusher
Environment, Health and Safety	Forrest Gee
NERSC and Information and Computing Sciences	David Stevens
Life Sciences	Huber Warner, David Gilbert
Materials Sciences	Jeri Edgar
Nuclear Science	Janis Dairiki
Physics	Pauline Fong
Structural Biology	James Bartholomew

The Deputy Directors' Offices provided review and comments, and scientific program leaders contributed to specific sections of the plan through division offices. In addition, elements of the documents are developed in conjunction with responsible support program administrators and staff:

Assessment and Assurance	Irene Kan
CFO/Budget	Patricia Jenkins
Educational Programs	Roland Otto, Eileen Kraskouskas
Facilities Planning	Laura Chen, Tina Loo
Laboratory Directed R&D	Todd Hansen
Technology Transfer	Bruce Davies
Work Force Diversity	Harry Reed, Christine Jue

The plan is prepared through the Technical & Electronic Information Department, Ruby Tebelak, Head. Julie McCullough edited the plan and provided composition and format for the plan's Web site.

Correspondence regarding the Institutional Plan can be directed to:

Michael A. Chartock, Head
Office of Planning and Communications
Lawrence Berkeley National Laboratory, MS 50A-4119
University of California
Berkeley, California 94720
(510) 486-6669; Fax: (510) 486-4553
MAChartock@lbl.gov

This plan is posted on the World Wide Web: http://www.lbl.gov/LBL-Publications/Institutional-Plan/

VIII. ACRONYMS AND ABBREVIATIONS

AA	Affirmative Action
AAP	Affirmative Action Plan
ACTI	Advanced Computational Technology Initiative
ACTS	Advanced Computational Testing and Simulation
AECR	Advanced Electron Cyclotron Resonance
AEM	Analytical Electron Microscope
AGS	Alternating Gradient Synchrotron
ALS	Advanced Light Source
AMTEX	AMerican TEXtile Partnership
ARIM	Accelerator and Reactor Improvements and Modifications
ARM	atomic resolution microscope
ARPA	Advanced Research Projects Agency
ATLAS	A Toroidal LHC Apparatus
BA	Budget Authority
BASTEC	Bay Area Science and Technology Education Collaboration
BES	Basic Energy Sciences (Office)
BGS	Berkeley Gas-Filled Separator
BEST	Bioremediation, Education, Science, and Technology (Program)
BNCT	Boron-Neutron Capture Therapy
BNL	Brookhaven National Laboratory
CAM	Center for Advanced Materials
CAMP	Capital Asset Management Plan
CCCWG	Child Care Center Working Group
CCSE	Center for Computational Science and Engineering
CDF	Collider Detector Facility at Fermilab
CEB	Center for Environmental Biotechnology
CEDR	Comprehensive Epidemiologic Data Resource
CEQA	California Environmental Quality Act
CERN	European Organization for Nuclear Research
CFC	chlorofluorocarbon
CFO	Chief Financial Officer
CIEE	California Institute for Energy Efficiency
COBE	Cosmic Background Explorer
CP	charge parity
CRADAs	Cooperative Research and Development Agreements
CSEE	Center for Science and Engineering Education
CT	Computational Technologies (Program)
CXRO	Center for X-ray Optics
DIRC	Detection of Internally Reflected Cerenkov Light
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE/EM	U.S. Department of Energy, Office of Environmental Research
DOE/ER	U.S. Department of Energy, Office of Energy Research
DOE/OAK	DOE Operations Office, Oakland
DOI	U.S. Department of Interior
DP	Office of Defense Programs
EBMF	Electron Beam Microcharacterization Facility
ECM	extracellular matrix
ECR	electron cyclotron resonance

EDT	Employee Development and Training (Unit)
EEO	equal employment opportunity
EH&S	Environment, Health and Safety Division (LBL)
EM	Environmental Management
EOS	Equation-of-State
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPRI	Electric Power Research Institute
EPU	elliptically polarizing undulator
ER	Office of Energy Research (see also OER)
ER-LTR	Energy Research–Laboratory Technology Research
ERWM	Environmental Restoration and Waste Management
ES&H	environment, safety, and health
ESnet	Energy Sciences Network
EUV	extreme ultraviolet
FE	Office of Fossil Energy
FEMP	Federal Energy Management Program
FNAL	Fermilab National Accelerator Laboratory
FTE	full-time equivalent
FWP	Field Work Proposal
FY	fiscal year
GFS	gas-filled separator
GPE	General Purpose Equipment
GPP	General Plant Projects
GRETA	Gamma-Ray Energy Tracking Array
gsf	gross square feet
gsm	gross square meters
HENP	High Energy and Nuclear Physics (Collaboratory)
HEPA	high-efficiency particulate air
HGC	Human Genome Center
HREM	high-resolution electron microscope
HRIS	Human Resources Information System
HVAC	heating, ventilating, and air-conditioning
HVEM	high-voltage electron microscope
ICSD	Information and Computing Sciences Division
I&SFP	Inactive & Surplus Facilities Program
IM	Information Management
INPA	Institute for Nuclear and Particle Astrophysics
IR	interaction region
IRM	information resources management
ISM	*in-situ* microscope
JAERI	Japan Atomic Energy Research Institute
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LDRD	Laboratory Directed Research and Development Program
LETS	Laboratory Employee Time System
LHC	Large Hadron Collider
LIGA	Lithographie Galvanoformung, Abformung
LLNL	Lawrence Livermore National Laboratory
M&O	maintenance and operations
MBone	Multicast Backbone
MEL-FS	Multiprogram Energy Laboratory Facilities Support
MEMS	microelectromechanical systems

MEP	Master Emergency Plan
MSAP	Management Skills Assessment Program
NABIR	Natural and Accelerated Biomediation Research
NAREEP	Native American Renewable Energy Education Program
NASA	National Aeronautics and Space Administration
NCEM	National Center for Electron Microscopy
NEPA	National Environmental Policy Act
NERSC	National Energy Research Scientific Computing
NIH	National Institutes of Health
NMR	nuclear magnetic resonance
NOW	Network of Workstations
NREN	National Resource and Education Network
NSF	National Science Foundation
OÅM	one-Ångstrom microscope
OAP	Operating and Assurance Program
OBES	Office of Basic Energy Sciences
OER	Office of Energy Research (see also ER)
OHER	Office of Health and Environmental Research
OPA	Outstanding Performance Award
ORNL	Oak Ridge National Laboratory
ORTA	Office of Research and Technology Applications
ORTP	Oil Recovery Technology Program
OSHA	Occupational Safety and Health Administration
PC	personal computer
PDSF	Parallel Distributed Simulation Facility
PEP	Positron–Electron Project
PET	positron emission tomography
PNGV	Partnership for a New Generation of Vehicles
PNNL	Pacific Northwest National Laboratory
PSAP	Professional Skills Assessment Program
RADAR	Radiation Protection Data Base Management
R&D	research and development
RDAC	Research and Development Associated with Construction
RHIC	Relativistic Heavy-Ion Collider
RNA	ribonucleic acid
ROI	Return on Investment
RPM	Risk Prioritization Matrix
RPV	replacement plant value
SDC	Solenoidal Detector Collaboration
SDP	Site Development Plan
SEC	Science Exploration Camp
SEMPA	Scanning Electron Microscope with Polarized Analysis
SFI	Strategic Facilities Initiative
SFIA	Surplus Facilities Inventory and Assessment
SIA	Semiconductor Industry Association
SLAC	Stanford Linear Accelerator Center
SLC	Stanford Linear Collider
SMOKE	Surface Magneto-Optic Kerr Effect
SNL	Sandia National Laboratories
SNO	Sudbury Neutrino Observatory
SPLEEN	Spin Polarized Low-Energy Electron Microscope
SPS	Super Proton Synchrotron
SQUID	superconducting quantum interference device
SSC	Superconducting Super Collider

SSRL	Stanford Synchrotron Radiation Laboratory
STAR	Solenoidal Tracker at RHIC
STI	scientific and technical information
SVX	silicon vertex
SXR	soft x-ray
TEC	total estimated cost
TOF	Time-of-Flight
TPC	Time Projection Chamber
TTD	Technology Transfer Department
UC	University of California
UCSF	University of California, San Francisco
UCOP	University of California, Office of the President
VOC	volatile organic compound
VUV	vacuum ultraviolet
WFO	work for others
YAC	yeast artificial chromosome
XANES	x-ray absorption near-edge structure spectroscopy