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ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 2000—FY 2004

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Ernest Orlando Lawrence
Berkeley National Laboratory
Berkeley, California 94720

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PREFACE

The FY 2000-2004 Institutional Plan provides an overview of the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab, the Laboratory) mission, strategic plan, initiatives, and the resources required to fulfill its role in support of national needs in fundamental science and technology, energy resources, and environmental quality. To advance the Department of Energy's ongoing efforts to define the Integrated Laboratory System, the Berkeley Lab Institutional Plan reflects the strategic elements of our planning efforts.

The Institutional Plan is a management report that supports the Department of Energy's mission and programs and is an element of the Department of Energy's strategic management planning activities, developed through an annual planning process. The Plan supports the Government Performance and Results Act of 1993 and complements the performance-based contract between the Department of Energy and the Regents of the University of California. It 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 Berkeley Lab's scientific and support divisions.

The Berkeley Lab FY 2000-2004 Institutional Plan reflects and complements the Department of Energy's own Strategic Plan (September 1997), the Energy Research Strategic Plan (1997), the Office of Science 1999 Strategic Plan (1999), and the Strategic Laboratory Missions Plan Phase I (July 1996). The Laboratory Missions and Core Competencies section identifies the specific strengths of Berkeley Lab that contribute to the missions in general and the Integrated Laboratory System in particular. The Laboratory Strategic Plan section identifies the existing contributions of Berkeley Lab's Core Business Areas, potential research trends and management implications, and long-range conditions that will influence Berkeley Lab. The Initiatives section describes some of the specific new research programs representing major long-term opportunities for the Department of Energy and Berkeley Lab. The Operations and Infrastructure Plan section describes our strategic thinking in the areas of human resources; work force diversity; communications and trust; worker, public, environmental, and asset protection programs; management practices; and site and facility needs. The Resource Projections are estimates of required budgetary authority for Berkeley Lab's research programs.

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I. DIRECTOR'S STATEMENT

As we plan for the 21st century, Berkeley Lab is addressing the great scientific challenges that have emerged at the end of this century: shaping computation to serve as a vital tool of scientific discovery, understanding the genome and developing a more predictive science of biology, harnessing fusion for global benefits, understanding complexity of structure and function down to atomic scale, and defining the fundamental properties of the universe. Addressing these challenge is at the heart of our strategic roles for the Office of Science and the Department of Energy, and its is the basis for our vision for the year 2010.

This year's planning advances the goals, objectives and strategies of the Strategic Plan of the Office of Science and related plans for DOE technology programs. The Laboratory continues to support the DOE Strategic Missions Plan and updated Laboratory Profile, placing key emphasis on the importance of the Laboratory's principal, fundamental science role in computing, energy science, biological and environmental research, and high energy and nuclear physics.

Supporting the mission of the Office of Science and fulfilling our scientific vision for 2010 is reflected in this institutional plan. This vision is aligned with the Office of Science strategic goals to Provide Extraordinary Scientific Tools, Explore Matter and Energy, Fuel the Future, and Protect our Living Planet. The Laboratory is applying its competencies toward implementing the Research Portfolio of the Office of Science, and national plans and roadmaps, including those being developed to address complex systems, high energy and nuclear physics, global change, and the emerging consensus for fusion energy science. It is our vision that national laboratories work in partnership with other research performers to develop consensus-based scientific roadmaps that further chart scientific directions. Critical outcomes of the Laboratory's planning, management, and scientific efforts are:

- **Implement the Scientific Simulation Initiative.** We will apply our fundamental capabilities in computational science of scale to address the national challenge for accelerated climate prediction, combustion modeling, subsurface transport, genomics, accelerator physics, and other research areas. These computational capabilities are integral to the Laboratory's scientific divisions and apply the resources of the National Energy Research Scientific Computing Center (NERSC) and the Energy Sciences Network (ESnet).
- **Achieve dramatic new levels of scientific productivity at the Advanced Light Source (ALS).** We will move forward with the ALS Science Roadmap. The number of users has tripled in two years to more than 800. New scientific opportunities are being pursued in areas such as highly correlated materials, the crystallography of macromolecules, and environmental molecular sciences, making the ALS vital to understanding complex systems. More than 220 scientists are using the Macromolecular Crystallography Facility, for example.
- **Develop forefront inertial confinement fusion science experiments and research facilities to deliver to the nation a scientifically well-founded basis for a fusion energy supply.** We are continuing experimentation to answer scientific questions on use of heavy-ion accelerators as fusion energy drivers. The Laboratory's accomplishments and plans support the recommendations of the national Fusion Energy Science Advisory Committee for an integrated research facility to understand beam and target physics.
- **Develop an astrophysics satellite that will define the fundamental properties of the universe through the observations of supernova.** The observation of sufficient numbers of supernova events to measure the mass density, energy density, and curvature of the universe, addresses fundamental questions that have been posed since the formulation of the theory of relativity. Beginning a DOE-NASA partnership for this satellite mission would be a near-term critical outcome for this effort.
- **Advance a broad front of post-genomics science that can provide a more predictive and quantitative basis for understanding and controlling biological systems.** This includes

developing rapid throughput systems for determining macromolecular structure, understanding the molecular machinery of cells, and quantitatively modeling intracellular and intercellular dynamics that are the basis of gene expression and disease.

- **Serve as Partners of Choice in national and international science collaborations.** Our record is solid in delivering on time and on budget for the BaBar Detector and Low-Energy Rings for SLAC, for the STAR detector at RHIC, and for the Sudbury Neutrino Observatory. The Laboratory has the opportunity to deliver computational capability for the ATLAS experiment as well as accelerator R&D for the Large Hadron Collider in Europe. We are addressing proof-of-principal studies for neutrino physics experiments that could observe the low fluxes of high-energy neutrinos from very distant and energetic cosmic objects such as active galactic nuclei.

The Laboratory's competencies are serving the National Laboratory System in an integrated way: Berkeley Lab serves in close partnership with Oak Ridge, Brookhaven, Argonne and Los Alamos for the design and fabrication of the Spallation Neutron Source, and with Los Alamos on the Dual Axis Radiographic Hydrodynamic Test Facility. We are also a key partner with Stanford and Livermore on the Next Linear Collider R&D efforts. The Laboratory's geoscience capabilities are being deployed to address the fundamental science needed for sequestering carbon. Our geosciences leadership is also being utilized by DOE to address the critical national problem of nuclear waste disposal through the Site Suitability Assessment that has been conducted at Yucca Mountain.

Berkeley Lab has a distinguished record of its research being transferred from the laboratory to create products in the marketplace that use energy more efficiently or reduce energy-related emissions. Successes include low-emissivity windows, high frequency ballasts for fluorescent lamps, and efficient fixtures for compact fluorescent lamps. The Laboratory proposes to develop the next generation of energy-efficient technologies for carbon dioxide emissions reduction, and to evaluate systems for sequestering carbon to reduce atmospheric concentrations. The Laboratory's capabilities in computation and energy analysis can contribute to improved electric reliability through modeling and better technology.

We have established outreach, training, and retention programs to encourage and fully respect diversity, and we encourage excellence through the Office of Work Force Diversity. The School to Work program is reaching out to urban schools and colleges to bring new students to the laboratory in planned programs that offer improved prospects for career employment. New educational partnerships with Oakland and Berkeley Schools promise local and national benefits from DOE technology and scientific resources. We are engaged in proactive involvement with our community and have recently entered an automatic aid agreement with the City of Berkeley Fire Department to provide first response to fires in the vicinity of the Laboratory; have advanced a plan for monitoring tritium; and are conducting a vegetation management program in concert with our neighbors. We have also taken many steps to assure the security of information at Berkeley Lab, and are recognized for our cyber security systems.

Berkeley Lab's institutional distinction is built on our University-based management, proximity to the University of California at Berkeley, and close working relationships with campuses, government, and industry. As the Ernest Orlando Lawrence Berkeley National Laboratory charts its course for the 21st century, we will continue our contribution to DOE's missions as a vital element of an integrated National Laboratory System. Our goal is to serve as valuable resources for DOE, the nation, and the community at large.

Charles V. Shank,

Director

II. LABORATORY MISSION

Berkeley Lab is a multi-program national research facility operated by the University of California for the Department of Energy. As an integral element of DOE's National Laboratory System, Berkeley Lab supports DOE's missions in fundamental science, energy resources, and environmental quality. Berkeley Lab programs advance four distinct goals for DOE and the nation:

- To perform leading multidisciplinary research in the energy sciences, general sciences, biosciences, and computing sciences in a manner that ensures employee and public safety and protection of the environment.
- To develop and operate unique national experimental facilities for qualified investigators.
- To educate and train future generations of scientists and engineers to promote national science and education goals.
- To transfer knowledge and technological innovations and to foster productive relationships among Berkeley Lab's research programs, universities, and industry in order to promote national economic competitiveness.

Berkeley Lab's programs, all unclassified, support DOE's mission for "a secure and reliable energy system that is environmentally and economically sustainable" and for "continued United States leadership in science and technology," as enunciated in DOE's Strategic Plan. These efforts support the Comprehensive National Energy Strategy to "work internationally on global issues," to "improve the efficiency of the energy system," and to "expand future energy choices through wise investments in basic science and new technologies."

SCIENTIFIC ROLE AND LABORATORY PROFILE

Berkeley Lab is unique among the multiprogram laboratories with its close proximity to a major research university, the University of California at Berkeley. The Laboratory's principal role for DOE is fundamental science, including developing powerful experimental and computational systems for exploring properties of matter, deepening understanding of molecular interactions and synthesis, and gaining insights into biological molecules, cells, and tissues. The Laboratory is a major contributor of research on energy resources, including the earth's structure and energy reservoirs, fusion, combustion of fuels, and keys to efficient energy storage and use. The Laboratory is extensively involved in environmental research, including subsurface contaminant transport, bioremediation and indoor air quality. User facilities include the Advanced Light Source, National Energy Research Scientific Computing Center, National Center for Electron Microscopy, 88-Inch Cyclotron, Biomedical Isotope Facility and National Tritium Labeling Facility. Our multidisciplinary research environment and unique location serve to strengthen partnerships with industry, universities and government laboratories. Partnerships include the Joint Genome Institute and programs in advanced accelerator and detector systems, x-ray lithography, high-speed networking and computer architectures, building and lighting systems, and science education. These principal, contributing and specialized participating roles support DOE's Strategic Laboratory Missions Plan, and are based on the core competencies described below.

Berkeley Lab complements the work at other national laboratories in several key national program areas. Its detector expertise deployed in the STAR detector now operating at the Relativistic Heavy Ion Collider complements accelerator efforts at Brookhaven National Laboratory. This is also the case for our work on the BaBar Detector for the Stanford Linear Accelerator Center (SLAC). Also complementary to SLAC is our work on storage rings through the completion of the Low-Energy Ring at the B Factory. Berkeley Lab's ion source efforts in developing the front end of the Spallation Neutron Source complement the experimental systems being developed at Oak Ridge National Laboratory, the linac work being conducted at Los Alamos National Laboratory, and the compressor ring design and development at

Brookhaven National Laboratory. Berkeley Lab's unique expertise in induction linacs also called for our complementary contributions to the Dual Axis Radiographic Hydrodynamic Test Facility. The Laboratory's research also lends itself to exploring accelerator-based methods for Boron Neutron Capture Therapy, complementing work at other labs that is based on reactors, such as at Brookhaven and Idaho. In the biosciences, Berkeley Lab's automation and genomics work complements the competencies at Los Alamos and Livermore Laboratories whose programs have come together at the Joint Genome Institute's Production Sequencing Facility, now among the most productive sequencing operations in the world.

CORE COMPETENCIES

The ability of Berkeley Lab to advance its strategic roles for DOE depends upon its "core competencies." These competencies are an integration of research disciplines, personnel, skills, technologies, and facilities that produce valuable results for our sponsors and customers. The core competencies also enable the Berkeley Lab to respond to rapidly changing national needs and new research problems.

- **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; scientific data management; network research; collaborative technologies.
- **Particle and Photon Beams:** Analysis and design of accelerators; induction linacs and neutral beams for fusion energy; beam dynamics; high-brightness ion, electron, and photon sources; advanced magnet design and research and development; rf technology; x-ray optics and lithography; ion beam sources for lithography and semi-conductor processing.
- **Bioscience and Biotechnology:** Structural biology; genome research; bioinstrumentation; medical imaging; biology of aging and human diseases; biomolecular design; environmental biology.
- **Characterization, Synthesis, and Theory 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.

DIVISION RESPONSIBILITIES

While the core competencies underpin the Laboratory's role for DOE, to achieve DOE programmatic goals the Laboratory is managed through divisions that implement DOE and other sponsors' research programs. These divisions have line and project management responsibility to assure that DOE programs are implemented within scope, schedule, and budget, and performed in a safe and environmentally protective manner. As indicated in the following organization chart [see Figure II(1)] the divisions are structured to serve multiprogram needs, and their strengths are summarized below. Importantly, many projects are staffed and supported through a matrix of divisions, with computational and engineering integrated across the biosciences, general sciences and energy sciences divisions.

Computing Sciences

- **Information and Computing Sciences:** Advanced software engineering; information management; network development; scientific imaging and visualization tools; collaborative technologies; biostatistics; distributed control of applications.
- **National Energy Research Scientific Computing (NERSC):** Unsurpassed high-end computing services to the energy research user community; access to seven state-of-the-art computers, including the Cray T3E-900 and J90s; collaboration and support for external users and computational scientists for modeling, software implementation, and system architecture, as well as science-of-scale projects; computation tools for the Human Genome Project; scientific data management.
- **Energy Sciences Network (ESnet):** Nationwide high-speed computer-data-communications network that underpins DOE's laboratory and university research.
- **Center for Computational Science and Engineering:** High-resolution numerical methods for partial differential equations; adaptive methodologies; computational fluid dynamics; algorithms for parallel architectures; scientific visualizations.

Energy Sciences

- **Advanced Light Source (ALS):** Provides a growing scientific user community with high-brightness ultraviolet, soft x-ray and intermediate energy x-rays for scientific advancement in many fields; supporting scientists from universities, government, and industry in areas such as protein crystallography, condensed matter physics, reaction dynamics, surface science, and molecular environmental sciences and biology; user services and experimental systems support, operational systems, optical and beamline systems, synchrotron physics and engineering.
- **Chemical Sciences:** Chemical physics and the dynamics of chemical reactions; structure and reactivity of transient species; synthetic chemistry; homogeneous and heterogeneous catalysis; chemistry of the actinide elements; molecular and environmental chemistry; atomic physics.
- **Earth Sciences:** Structure, composition, and dynamics of Earth's subsurface; geophysical imaging methods; chemical and physical transport in geologic systems; isotopic geochemistry; physicochemical process investigations and environmental biotechnology.
- **Environmental Energy Technologies:** Energy-efficient building technologies; indoor air quality; batteries and fuel cells for electric vehicles; combustion, emissions, and air quality; industrial, transportation, and utility energy use; national and international energy policy studies; aspects of global climate change related to energy.
- **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.

Biosciences

- **Life Sciences:** Gene expression; molecular genetics; genome sequencing studies; cellular differentiation; carcinogenesis and aging; hematopoiesis; subcelluar structure; DNA repair;

diagnostic and functional imaging; innovative microscopies; radiation biology; animal models of disease; computational biology; environmental biology.

- **Physical Biosciences:** Development of physical science techniques to elucidate important biological problems including macromolecular and mesoscopic structure, function and dynamics; rapid automated methods for gene expression optimization; biochemical reaction networks; cellular machinery engineering; high throughput determination of protein structure and function; sensory and signaling systems; nanoscale manipulation of molecular architecture; genetics and mechanisms of photosynthesis; operation and development of the Macromolecular Crystallography Facility at the ALS.

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, semiconductor fabrication, and engineering and biomedical applications.
- **Nuclear Science:** Relativistic heavy-ion physics; low-energy nuclear physics; nuclear structure; nuclear theory; nuclear astrophysics; weak interactions; nuclear chemistry; studies of transuranium elements; nuclear data evaluation; advanced detector development; operation of the 88-Inch Cyclotron; pre-college education programs.
- **Physics:** Experimental and theoretical particle physics; advanced detector development; particle database for the high energy physics community; astrophysics; innovative programs for education and outreach.

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.
- **Environment, Health, and Safety:** Technical support for protecting the safety of Berkeley Lab employees, the public, and the environment; radiation safety associated with accelerator technology, hazards assessment and control of radionuclides; waste management.
- **Resource Departments:** Administrative, financial, human resources, technical services, and facilities support for research and Laboratory management.

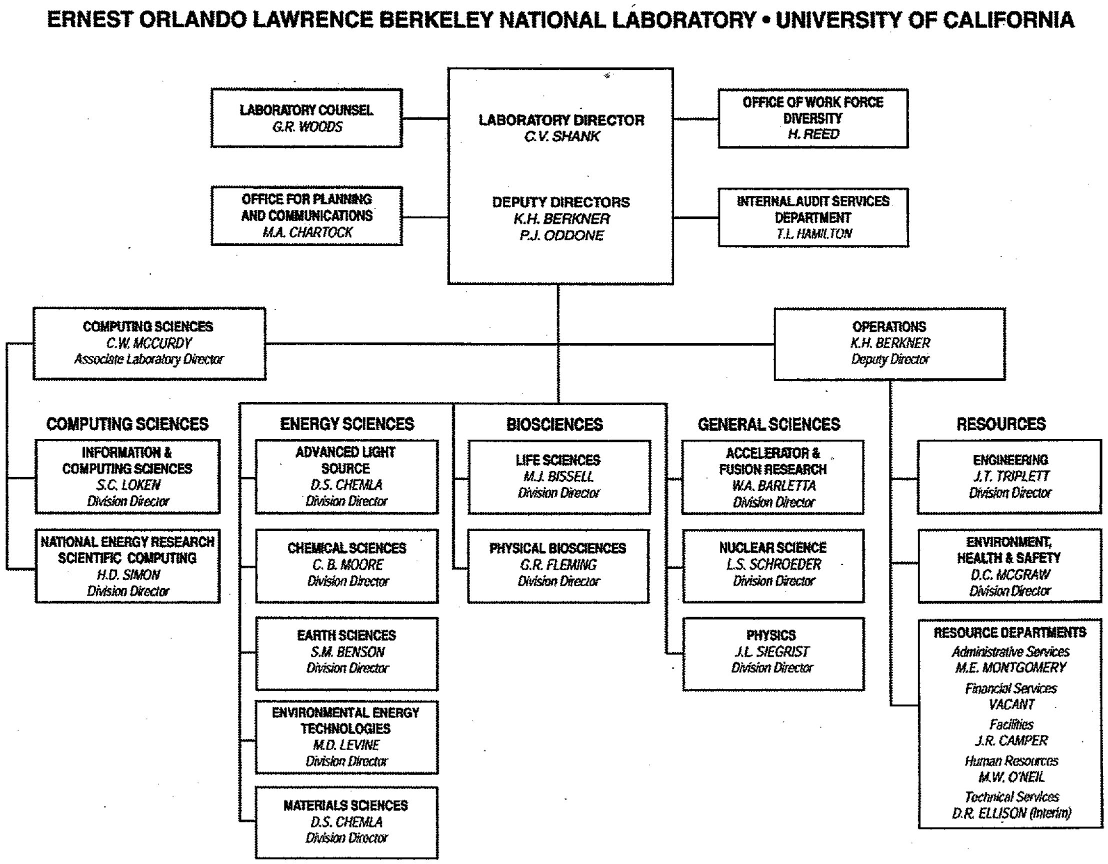

Figure II(1) Ernest Orlando Lawrence Berkeley National Laboratory Organization Chart

III. LABORATORY STRATEGIC PLAN

BERKELEY LAB'S VISION 2010

As a part of its ongoing strategic planning activities, Berkeley Lab has prepared a Vision 2010 that identified key scientific opportunities that support DOE scientific missions and Berkeley Lab's national role within the DOE system of laboratories. Five key areas provide the long-term outlook for Vision 2010 as the Laboratory enters the next millennium: understanding the universe, complex systems, quantitative biology, new energy sources and solutions, and integrating computing with our research.

- **Understanding the Universe.** In a historic sense, high energy and nuclear physics are at the heart of the Laboratory. The programs remain vital and productive, with exciting opportunities on the horizon that match our core capabilities. The Berkeley-led Supernova Cosmology Project shared *Science* magazine's citation as "Breakthrough of the Year for 1998." Calibration and data collection have begun at the Sudbury Neutrino Observatory. The STAR detector at Brookhaven's RHIC and the PEP II B Factory at SLAC are now being commissioned. In June, the discovery of superheavy elements 116 and 118 at the 88-Inch Cyclotron made headlines around the world. We are investigating optical accelerator technologies using laser-plasma acceleration as a key new direction for high energy accelerators of the future. Our results are encouraging, but a long way from being practical. A high priority at the Laboratory is to discover and accurately define the most fundamental properties of matter and energy in the universe through a supernova satellite, moving earth-bound observations to space. These observations would have sufficient precision to answer fundamental questions concerning the mass density, vacuum energy, and curvature of space.
- **Complex Systems.** With DOE, the Laboratory organized and co-hosted a workshop in Berkeley, chaired by the Associate Director for Basic Energy Sciences and the Director of Berkeley Lab. The purpose of the workshop was to help lay the groundwork for a national initiative on Complex Systems. It is clear that great scientific opportunity lies in understanding—at the molecular and higher levels of organization—how to design and control complex systems including their collective phenomena, functions, novel properties, self repair, evolution, and characterization. We are poised to develop nanoscience—through theory, instrumentation and experiments—to probe and exploit this world of complexity. The Advanced Light Source plays a leading role both in our exploration of complexity and in contributing to the national structural biology effort (more than 230 users of the crystallography beamline alone).
- **Quantitative Biology.** Recent advances in genomics, structural biology, simulation and other techniques are providing a basis for creating a new level of understanding of biological systems from the molecular level to the complete organism. Biology, mostly an observational science in the last century, is on its way to becoming a predictive quantitative science in the next century. The Laboratory created a new Physical Biosciences Division to exploit the tools of physics, chemistry, engineering, mathematics, and computing to solve problems in biology. We have launched a new partnership for a more quantitative biology with the Berkeley campus, and are building our programs in computational biology to address this growing scientific opportunity. Progress in the Human Genome Project has been so dramatic that the challenge is now to look beyond the finished sequence. The community now plans a "working draft" by the spring of 2000. The Joint Genome Institute offers the prospect of a central resource for the Department's structural genomics and proteomics program. The JGI is providing broad infrastructure support for biological discoveries, and the Berkeley, Livermore and Los Alamos Laboratories are committed to its continuing success.
- **New Energy Sources and Solutions.** Three pivotal issues are appropriate subjects for Berkeley Lab research for Vision 2010: How can we guarantee a reliable supply of energy going into the distant future? What are the long-term global consequences of energy use and how do we mitigate them? And how might technology be applied to reduce public energy consumption? Berkeley Lab has

been a player of long standing in the areas of energy and the environment. Consumer products that had their genesis in research here and energy-efficiency tools developed here for consumer use have saved billions of dollars in annual energy costs. For two decades we have pursued the concept of heavy-ion fusion, increasingly viewed as a practical possibility in the effort to harness fusion energy. We now stand ready to develop a design for an Integrated Research Experiment to further advance the scientific understanding of beams and plasmas, and the engineering issues of heavy-ion inertial fusion. In the coming years, we also plan to advance the nation's understanding of carbon sequestration to mitigate the potential effects of global greenhouse gases.

- **Integrating Computing into Our Research.** Our vision of Berkeley NERSC is to integrate high performance computing into all of our scientific efforts. A great deal of progress has taken place in our ability to exploit high performance computing. Two recent prizes for achievements in computation studies (Gordon Bell Prize and the Fernbach Award) have highlighted our successes. Our commitment to the scientific community is reflected in the recent acquisition of an IBM SP3/RS 6000, which will provide NERSC with 4-teraflop capability by the end of the year 2000. For the next decade, the challenge is to fully exploit this computational power in studying the universe, in exploring complexity, in pushing biology toward its place as a predictive science, and in seeking solutions for environmental and energy problems.

These five themes describe our scientific vision, and we are maintaining our focus on the tools and resources that are delivering high levels of scientific productivity now and for the future. As indicated below, Berkeley Lab's Vision 2010 and its current research efforts support the Office of Science Strategic Plan and Research Portfolio, and the program goals of our sponsoring offices.

SITUATION ANALYSIS: KEY CUSTOMERS

Berkeley is situated within the national science scene as a multiprogram energy research laboratory whose primary role is fundamental science with important further contributions in energy resource and environmental research. While specific changes occur in project and program activity, the Laboratory has consistently supported a number of DOE programs and the needs of other Federal sponsors. The following discussion presents a synopsis of the major Laboratory research sponsors, our direct customers who are central to DOE's missions. Berkeley Lab's efforts for all of our customers is unclassified.

Office of Science

The Office of Science is the primary customer for Berkeley Lab's fundamental science mission. The Laboratory has participated in the recent planning workshops to develop the Strategic Plan of the Office of Science and the Science Portfolio, and to help define research on complex systems. These efforts chart important goals, objectives and strategies in which Berkeley Lab has an important role in planning and implementation. Berkeley Lab activities involve all five of the Office of Science Strategic Goals:

- Fuel the Future—Science for clean and affordable energy
- Protect our Living Planet—Energy impacts on people and the environment
- Explore Matter and Energy—Building blocks from atoms to life
- Provide Extraordinary Tools for Extraordinary Science—National assets for multidisciplinary research
- Manage as Stewards of the Public Trust—Scientific and operational excellence

These goals are implemented by Laboratory and University professionals through the programs of the Office of Science. Berkeley Lab's research and facilities support, in particular, the following research offices: Basic Energy Sciences, Advanced Scientific and Computing Research, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics.

Office of Basic Energy Sciences

Basic Energy Sciences programs in materials sciences will focus on the science roadmap for the Advanced Light Source and the forefront research projects for advanced materials, chemistry, and geoscience research. The Advanced Light Source, which provides the world's brightest beams of ultraviolet and soft x-ray radiation and is a powerful source of harder x-rays for structural studies, has doubled the delivery of beamline-hours and its science user base over the past year. The National Center for Electron Microscopy and Center for Advanced Materials are also essential aspects of our Basic Energy Sciences program, and complement our programs in solid-state physics, surface sciences, catalysis, polymers, biomolecular materials, metallurgy, electrochemical materials, electronic materials (including super- and semiconductors), ceramics, and materials chemistry. The Laboratory is committed to the multi-lab partnership for building the front end of the Spallation Neutron Source.

Berkeley Lab supports DOE's Chemical Sciences Program in chemical physics, dynamics and mechanisms of chemical reactions and combustion processes, catalysis, electron spectroscopy, atomic physics, laser-material interactions, photochemistry, theoretical chemistry, chemistry of the actinide elements and their relationship to environmental issues, and electrochemistry of advanced batteries for consumer products and electric vehicle applications.

DOE's Geosciences Program at Berkeley Lab is strengthening its multidisciplinary effort to establish the scientific basis of many technologies related to energy and the environment. This effort includes fundamental studies related to the development of hydrocarbon resources, remediation of toxic waste sites, safe disposal of radioactive and toxic chemical wastes, and mitigation and sequestration of carbon dioxide emissions. Earth sciences researchers at Berkeley Lab are among the leading experts in the areas of subsurface imaging of the structure and dynamics of 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.

For Energy Biosciences, Berkeley Lab's program continues to improve understanding of the unique features of photosynthetic organisms for collecting light and storing it as chemical energy.

Office of Advanced Scientific Computing Research

Berkeley Lab brings the power of advanced computing to serve as an important tool for scientific discovery for Office of Science research programs. Key elements of the Berkeley Lab organization are:

- **National Energy Research Scientific Computing Center (NERSC):** an extremely powerful computing environment incorporating high performance computing capability, capacity and storage resources. Also in NERSC is the Center for Computational Science and Engineering which addresses high-resolution numerical methods for advanced modeling and problem solving in areas such as computational fluid dynamics.
- **Information and Computing Sciences Division (ICSD):** applies and develops the Berkeley Lab infrastructure including advanced software engineering, information management, and network development.
- **Energy Sciences Network (ESnet):** the backbone of DOE's research network. ESnet provides access to NERSC computing environment—and to other research, experimental and computational facilities—for scientists across the nation and by international collaboration.
- **Applied Mathematics:** research into computationally intensive techniques for solving complex mathematical problems.

The Office of Advanced Scientific Computing Research also sponsors eight Grand Challenge projects in which Berkeley Lab is a partner. Grand Challenge applications address fundamental problems in science and engineering by applying high performance computing and communications technologies.

Other Computing Sciences focus areas include networking research, security and authentication, collaborative technologies, distributed computing, future high-performance computing technologies, and scientific data management.

The Office of Advanced Scientific Computing Research also manages the Advanced Energy Projects and Technology Research programs, to which Berkeley Lab makes important contributions.

Office of Biological and Environmental Research

Research at DOE's Joint Genome Institute focuses on the national goal of a rough draft of the human genome sequence in the year 2000 through advanced techniques for efficient sequencing of human DNA. Analysis of the biologically relevant signals culled from sequence information is under way. The biological function of the human DNA sequences will be determined using genetically engineered mice developed by researchers at Berkeley Lab. Related programs include studies in gene expression within mammary-gland and blood-forming systems, and hematopoietic research.

The thrust of Berkeley Lab's physical biosciences program is to use the techniques and concepts of the physical sciences to determine the structure and function of biologically important molecules and complexes. The program spearheads a multidisciplinary approach to science, integrating structural biology, biological dynamics, computational and theoretical biology, advanced microscopies, chemical biology, and molecular design. An important new direction in crystallography is delivering x-ray crystallographic data at high efficiency and with extremely small crystal sizes. Electron crystallography and nuclear magnetic resonance spectroscopy also focus on protein and nucleic acid structures.

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 has led to new concepts in detection. In parallel with an emerging national trend in molecular nuclear medicine, Berkeley Lab has initiated studies in four critical areas for DOE and the National Institutes of Health: using transgenic animal models to study the relationship between genomic variations and the occurrence of atherosclerosis; studying relationships among neuroreceptor concentrations, brain metabolism, mental disorders, and the genome; developing labeled DNA probes for understanding inflammatory diseases, autoimmune conditions, atherosclerosis, and cancer; and monitoring gene therapy.

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; hormones and extracellular matrix; hematopoiesis; mammary biology; biology of aging; oncogenes and tumor suppressor genes; radiation and chemical carcinogenesis; and DNA repair.

In response to DOE solicitations of research proposals for the Low Levels of Radiation Exposure Program, the Radiation Biology Department of the Life Sciences Division has initiated a new direction that will specifically address how to improve the scientific basis for reducing uncertainties in current risk estimation. The radiation biology program presents an integrated approach designed to identify and characterize genes and gene products involved in cellular response to DNA damage induced by low levels of ionizing radiation and to elucidate their role in determining susceptibility. The approaches include genetic, molecular, and biochemical analyses of repair pathways in human cells. Theoretical studies incorporating the experimental results will develop meaningful models for extrapolation to low doses.

The Earth Sciences Division of Berkeley Lab is the Natural and Accelerated Bioremediation (NABIR) Program Office for the Office of Science. This long-term research program, which Berkeley Lab was instrumental in starting, focuses on basic research concerning the natural and engineered remediation of metals and radionuclides using biological methods; e.g. immobilization in situ.

BER is supporting research on boron neutron capture therapy as a potential treatment for glioblastoma multi-formae cancer. In partnership with UC San Francisco and other institutions, we have demonstrated that accelerator-based epithermal neutrons can be produced with a spectrum that is clinically superior to reactor-based neutrons, and the accelerator-based treatments can be delivered more economically. We are now embarking on the construction of such a treatment facility.

Office of Fusion Energy Sciences

Fusion energy research at Berkeley Lab focuses on accelerator systems that support the nation's inertial-confinement energy science programs. Berkeley Lab's heavy-ion fusion accelerator research focuses on the physics of induction acceleration as the means for producing high-current, heavy-ion beams as drivers for inertial-confinement fusion systems. Current efforts have resulted in successful completion of a multiple-beam experiment to examine the initial accelerator components for space-charge-dominated beams undergoing current amplification. Specific areas of study will address beam quality (focusability) and cost—two primary accelerator issues to be addressed by the design and construction of a multi-kilojoule accelerator. Such an accelerator will provide the scientific and technical data for building a full-scale fusion driver through conducting a wide range of experiments in beam physics, beam-target interaction physics, fusion target physics, and physics of the reactor chamber. Expertise in induction linacs is instrumental to Berkeley Lab's ability to deliver an advanced induction electron linac for the Dual Axis Radiographic Hydrodynamic Test Facility at Los Alamos National Laboratory, an effort sponsored by Defense Programs, which takes advantage of developments originating in the fusion science program.

Office of High Energy and Nuclear Physics

In high energy physics, Berkeley Lab continues its strong program of experimental and theoretical research, including the development and operation of innovative detectors and research on advanced accelerator components and concepts. Berkeley Lab's experimental programs in high energy physics focus on the properties of quarks and leptons and are closely aligned with national priorities set by the High Energy Physics Advisory Panel (HEPAP) subpanel on long-range planning. Efforts to study these particles emphasize the development of sophisticated detectors and their operation at colliding-beam facilities.

The Large Hadron Collider at CERN will search for the mechanism of electroweak symmetry breaking and substantially extend the search for new particles beyond those described by the standard model of particle physics. Berkeley Lab is responsible for aspects of the Large Hadron Collider accelerator design and some components, as well as components for ATLAS, one of the two large experiments at the Large Hadron Collider. Berkeley Lab will play important roles in computing and the silicon tracker and pixel detector arrays. For the B Factory at Stanford Linear Accelerator Center, Berkeley Lab has completed commissioning for the Low-Energy Ring. Berkeley Lab has also completed a major part in the B Factory detector, including design and construction of the silicon vertex tracker, and electronics and computing.

The Collider Detector Facility at Fermilab has been greatly enhanced by the Silicon Vertex Detector, for which Berkeley Lab was the lead institution. This detector played a crucial role in the Collider Detector Facility's 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. The D-Zero detector at Fermilab has made important measurements of tri-gauge couplings and analysis of W and Z events. Berkeley Lab has helped complete the design and fabrication of the SVX-2 chip for D-Zero that was developed jointly with Fermilab.

Nuclear science research at Berkeley Lab will continue to focus on the experimental and theoretical investigation of the structure and properties of nuclei at the limits of temperature, isospin, angular momentum, and energy density in nuclear matter. Berkeley Lab research programs are closely coupled with national priorities in nuclear science as defined in the Nuclear Science Advisory Committee Long-Range Plan for Nuclear Science. In addition, ongoing technology development efforts contribute to significant advances in nuclear instrumentation and nuclear data evaluation and dissemination. Large-scale computing capability is being developed at Berkeley Lab for both high energy and nuclear physics experiments in order to provide new concepts for data analysis, data management tools, and event simulation and distribution over networks.

The main focus of the high-energy heavy-ion research program at Berkeley Lab is at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, which is scheduled to run its first experiment in

FY 2000. Berkeley Lab is the lead laboratory for the first approved Relativistic Heavy Ion Collider (RHIC) experiment, the Solenoidal Tracker (STAR) detector to identify and study the phase transition between normal nuclear matter and quark matter. The STAR Time Projection Chamber, constructed by Berkeley Lab scientists and engineers, has been integrated into the complete STAR system. The STAR detector has been commissioned in the Wide Angle Hall at RHIC.

The 88-Inch Cyclotron, a national user facility, is the center of a broad and versatile nuclear structure and reactions research program. This cyclotron is equipped with two state-of-the-art electron cyclotron resonance ion sources (with a third-generation electron cyclotron resonance source under construction) capable of producing high-charge-state ions of most elements. New low-energy research opportunities have been opened up in nuclear structure and the study of exotic nuclei and transuranic elements by a new high-efficiency mass separator (Berkeley Gas-filled Separator - BGS) which discovered elements 118 and 116 on the island of stability, the 8π gamma-ray array (on loan from Canada), Berkeley Experiments with Accelerated Radioactive Species (BEARS), and the ^{14}O beam test stand. Forefront reaction studies and laser trapping of radioactive atoms to explore fundamental symmetries also present new physics opportunities. Gammasphere will return to the 88-Inch Cyclotron in FY 2000 to continue its world-class nuclear structure program. In order to pursue the physics of nuclei at high spin and angular momentum in even more detail, the nuclear structure group is 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 (see Section IV, Initiatives). Berkeley Lab researchers are also participating in plans for an advanced radioactive beam ISOL facility. Areas of interest include the physics program, instrumentation, and research and development. To complement this effort, Berkeley Lab is also working to make the 88-Inch Cyclotron the premier stable beam facility.

The Sudbury Neutrino Observatory, an experiment to detect neutrinos from the sun and from supernovae, is now completely installed in the Sudbury Neutrino Observatory laboratory, 6800 feet underground. Berkeley Lab scientists have played a major role in the installation and are now looking forward to the first physics results later this year. Research and development continues on a next-generation neutrino detector called the Km^3 Detector and is complemented by work on a new neutrino oscillation experiment in Japan, KamLAND (see Section IV, Initiatives). Berkeley Lab continues its leadership in astrophysics and cosmology, having found that the universe is continuing to expand at an accelerating rate, evidence for a positive value for Einstein's cosmological constant.

Science Education for DOE

The Berkeley Lab develops and implements programs that utilize DOE scientific resources to improve the content of mathematics, science, and technology education in the region and throughout the country. These efforts for improved technical and scientific education are essential for the fulfillment of the Department of Energy missions. On an annual basis, The Laboratory's Center for Science and Engineering Education's activities reach thousands of students and faculty. The Center conducts national programs sponsored by DOE, including the Energy Research Laboratory Fellowship Program, as well as programs cosponsored by other agencies, including the National Science Foundation, National Institutes of Health, and the State of California. In a partnership with Oakland schools and the University of California, Berkeley Lab is working to expand internet-mediated science content to nationwide audiences through the World Wide Web. .

The Laboratory has been leading the development of models of education and outreach to the California student population to ensure a diverse science and engineering work force. New partnerships with California Community Colleges are underway to bring the power of the computing, biotechnology and environmental resources of DOE to underserved college populations. Berkeley Lab enables the professional development of teachers through programs at the Advanced Light Source and other program areas, and supports a School-to-Work educational program at high schools and junior colleges to diversify the work force.

Office of Energy Efficiency and Renewable Energy

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 carbon emissions, urban and regional air pollution, and cost to consumers, as well as to enhance energy security. These have been separated into building, power, industry, and transportation technologies. Berkeley Lab's leadership in the inter-laboratory study on *Scenarios of U.S. Carbon Reductions* has been instrumental for the nation's program on carbon management. Berkeley Lab also has a leadership role in the follow-on study *Clean Energy Future* which will include a detailed assessment of potential policies and their impacts.

Building Technologies at 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.

Research continues on advanced window systems, including the development of electrochromic coatings for the active control of the transmission of light and infrared radiation. Advanced lighting fixtures are being developed to facilitate the increased use of energy-efficient lamps such as compact fluorescents. Ongoing research is aimed at a next generation of building energy simulation and design tools, including ones that will encourage increased use by practitioners (e.g., architects) and provide advanced computational methods for the research community. Work continues on infiltration, ventilation, airflow, and thermal distribution in the interests of having energy-efficient buildings while maintaining desired indoor air quality levels. Technical assistance activities are carried out in support of DOE new construction and retrofit programs such as Rebuild America. Technical and economic analyses continue to support DOE's setting of energy standards for appliances and equipment. Work extends beyond individual buildings to the regional issue of urban heat islands and measures such as light surfaces that could mitigate the effect.

The work in Power Technologies includes a geothermal energy resources program that consists of delineation and evaluation of geothermal systems, definition of reservoir processes, modeling of reservoir dynamics and exploitation effects, and analysis of field-management practices. Fluid production and injection technologies are also being studied to optimize reservoir management. In addition, Berkeley Lab undertakes a variety of analysis activities on issues and opportunities that may impact renewable energy, including the restructuring of the electric utility industry, energy demand and energy technologies in developing countries, specific renewable technologies for the U.S., and renewable energy use by Native Americans.

Industry Technologies focuses on advanced industrial concepts, including energy-efficient chemical separations and other industrial applications. Catalysts for industry are studied—through chemistry, immunology, and modeling—for the rational design of stable, active enzymes. Berkeley Lab is participating in the Industries of the Future program, which includes the development of sensors and control systems for improved energy efficiency and productivity in the pulp and paper industry. Berkeley Lab also provides support for government-industry programs such as for the more energy-efficient use of electric motors.

In Transportation Technologies, Berkeley Lab manages the Exploratory Technology Research Program, which seeks to advance the development of high-performance rechargeable batteries and fuel cells for use in electric and hybrid vehicles. Performance goals for the Exploratory Technology Research Program have been established by the U.S. Advanced Battery Consortium. Berkeley Lab is also working in conjunction with the other DOE multi-program laboratories to assist DOE in its role in the federal/industry Partnership for a New Generation of Vehicles by applying its expertise to combustion and emissions, lightweight materials, and improved manufacturing techniques.

Based primarily on Berkeley Lab's extensive work on building technologies and analysis capabilities, we provide technical support to the Federal Energy Management Program (FEMP) in its efforts to help agencies use energy more efficiently. Other activities for the Office of Energy Efficiency and Renewable Energy include studies of energy use in China, and field tests of energy-efficient drinking water disinfectant methods for developing countries.

Office of 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.

Office of Fossil Energy

Berkeley Lab conducts basic research for the Office of Fossil Energy. Research projects are directed toward making coal more usable, and include studies on conversion to gaseous and liquid fuels and reduction of emissions. Studies are done of oil and gas that characterize heterogeneous and fractured reservoirs to gain an improved model of reservoir performance and enhance our ability to manage reservoir production. Berkeley Lab uses the computational capabilities at NERSC and other laboratories through the Computational Technologies program, for studies in subsalt imaging, drill-site analysis of rock properties, visualization and virtual reality techniques for the reservoir engineer, control of production-related ground subsidence, and optimization of fluid injection. Research is also conducted into understanding selenium's presence in San Francisco Bay. Studies are also underway to assess both the regional air quality issues associated with fossil fuel use and the health effects of petroleum products. In addition, Berkeley Lab is developing new techniques for bioprocessing of heavy crude oil.

Environmental Management

Berkeley Lab is implementing site projects for restoration and waste management consistent with DOE's National Environmental Management Program. In collaboration with other labs, Berkeley Lab will help address major technology gaps in environmental restoration. Components are improved characterization of subsurface environments; development of methods for assured containment and control of contamination; development of advanced remediation technologies; and improved risk assessment and prioritization systems. The methodologies 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. One example is a current collaboration with the Office of Biological and Environmental Research for development of an optical probe system that uses near-infrared spectroscopy to characterize mixed waste.

Office of Environment, Safety, and Health

Berkeley Lab is continuing its 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 to analyze 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.

Defense Programs

Berkeley Lab's unique capabilities in accelerators are being utilized in an unclassified project to design and fabricate the induction electron accelerator for the second axis of the Dual Axis Radiographic Hydrodynamic Test Facility at Los Alamos.

Office of Nonproliferation and National Security

DOE has a growing role in chemical and biological nonproliferation. The purpose of the DOE effort in this area is to develop the capacity to predict and represent the concentration and containment levels resulting from chemical and biological agent releases in outdoor urban environments, buildings and subways, over time and space. As part of a multi-laboratory effort, Berkeley Lab will use its building science expertise to develop a modeling capability to estimate airborne concentrations of particles and vapors in multi-zone buildings, including loss processes by deposition in duct systems and on indoor surfaces. A major application for this modeling is the development of guidance for "first responders" (fire and police departments) in the event of a release of a chemical or biological agent in or near a building. All of this Berkeley Lab work is unclassified.

Work for Other Agencies

National Institutes of Health

DOE biosciences and environmental programs at Berkeley Lab are complementary to the National Institutes of Health (NIH) which supports research closely coupled to DOE programs. Several critical technologies—specifically genome sequencing, molecular medicine, biotechnology, and structural biology—build on the unique facilities and expertise available at Berkeley Lab. The NIH applies the Laboratory's unique resources to investigations of the human genome and of carcinogenesis and mutagenesis. Berkeley Lab is central to the *Drosophila* genome project. Other major focus areas are repair and recombination in yeast, the genetic effect of carcinogens, and the culturing of human mammary epithelial cells to study breast cancer. The NIH also support programs on radionuclides, nuclear magnetic resonance imaging, diagnostic image reconstruction, and radio-pharmaceuticals related to advanced instrumentation and disease treatment. Other programs involve lipoproteins and their relationship to cardiovascular disease; biological structure analysis by electron crystallography to characterize cell-membrane proteins and the cytoskeleton; 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.

Department of Defense

The Center for X-Ray Optics has received funding from the Defense Advanced Research Projects Agency (DARPA) for construction of two beamlines at the Advanced Light Source (one for extreme ultraviolet interferometry and one for extreme ultraviolet metrology), construction of the Nanowriter (an advanced electron-beam writer) and supporting research activities. An analogous effort in the Accelerator and Fusion Research Division is research on maskless ion-beam lithography and on advanced focused ion beam writing techniques. DARPA also funds testbeds that combine high-speed, wide-area-network technology, distributed image-storage systems, and high-speed graphics with aerial and satellite images to create a virtual reality simulation of terrain travel. In addition, DARPA is funding work to advance the modeling of chemical and particle dispersion in multi-zone buildings. While the Agency's concern is chemical or biological agent releases, the methodology will be applicable to indoor pollutants generally. This effort is complementary to, but will result in a considerably more sophisticated model than, the work described in the section on Nonproliferation and National Security (see above).

Berkeley Lab also conducts research on cellular circuitry and sensing and on engineering new functions from nature. Furthermore, the Department of Defense supports a breast cancer research program. Berkeley Lab also conducts a program of Bioremediation Education Science and Technology for the United States Army Corps of Engineers in partnership with Jackson State University and the Ana G. Méndez University System in Puerto Rico. The DOD research conducted at Berkeley Lab is not classified.

National Aeronautics and Space Administration

The space radiation environment and what it means to continual human presence in space is one of the most unique challenges confronting NASA. Berkeley Lab investigators are conducting multidisciplinary research at the molecular, cellular, and tissue levels for understanding the biological impact of solar and galactic cosmic radiation exposure on astronaut health and that of future colonizers. The Berkeley Lab Astrophysics Group has been instrumental in the understanding of 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. NASA also supports analysis of Hubble telescope data in the Supernova Cosmology Project, which has recently discovered that the universe is expanding at an accelerating rate. Berkeley Lab also undertakes research in aerogel-based materials, combustion under micro-gravity conditions, and remote sensing of land-use changes.

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, and studying effects of tropical deforestation. Berkeley Lab, along with other national laboratories, is also working to develop new ways to advance national environmental goals, including the more efficient use of energy to reduce greenhouse gas emissions. Berkeley Lab is also undertaking research on understanding the transport, transformation, and human exposure to environmental pollutants.

Department of the Interior

Laboratory scientists are investigating the geochemistry of selenium and other trace elements at Kesterson Reservoir, 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, with related research at Stillwater Marsh, Nevada.

Agency for International Development

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

Other Agencies/State and Private

Berkeley Lab conducts research for the Electric Power Research Institute on the reduction of oxidation and scale formation; oxygen depletion in compressed-air storage; and surface modification with metal plasma techniques. The Gas Research Institute supports databases on the influence of clays on seismicwave attenuation in reservoir rocks. The California Air Resources Board is sponsoring an analysis of polycyclic aromatic hydrocarbons in indoor air. A Memorandum of Understanding between the California Energy Commission and DOE supports a larger role for Berkeley Lab in the Public Interest Energy Research program. Certain energy efficient buildings and other research projects formerly supported by the California Institute for Energy Efficiency (CIEE) are now part of this program, and several new buildings-related projects are underway. Utility funding for some projects, such as research on natural gas burners with low nitrogen oxide emissions, continues through CIEE. The California Breast Cancer Research Program was established after passage of the Breast Cancer Act by the California legislature in 1993. The program supports research in the life sciences to reduce the human and economic costs of breast cancer in California. Under the University of California Tobacco Related Disease Research Program, the Laboratory investigates various aspects of secondary tobacco smoke. The U.S. Postal Service supports work on energy efficient lighting for post office buildings.

ADVANCING STRATEGIC GOALS

Berkeley Lab participates in the development and implementation of the goals, objectives and strategies of the Strategic Plan of the Office of Science. As indicated in the Laboratory Profiles of the Strategic Laboratory Missions Plan, Berkeley Lab plays a principal role in fundamental sciences and a major contributing role in DOE energy resource research, and adds its specialized and distinctive capabilities to DOE's environmental quality mission. As a multi-program laboratory, Berkeley Lab has key strategies that support Office of Science strategic goals:

Provide Extraordinary Tools for Extraordinary Science—National Assets for Multidisciplinary Research

- **With the Office of Advanced Scientific Computing and in partnership with the system of DOE national laboratories, the Scientific Simulation Initiative is being developed as a powerful new tool for scientific discovery.** Computational sciences, mathematics, and computing capability are at the core of our scientific capabilities and impact all programs for the Office of Science. Advances in simulation are integral to progress on accelerated climate prediction, combustion simulation and modeling, subsurface transport, genomics, materials and fusion energy sciences, and high energy and nuclear physics. In addition, ESnet provides nationwide and international connectivity enabling the entire DOE community to take advantage of the developing computational power brought about through this initiative.
- **With the Office of Basic Energy Sciences and an international user community, Berkeley Lab is delivering on the scientific productivity of the Advanced Light Source (ALS) for scientific advances in many fields.** The scientific community has charted the directions of the ALS, redefining the scientific areas and beamline developments, and doubling the number of users at the ALS. A greatly expanded program in macromolecular crystallography is underway, and new research is being developed on highly correlated materials.
- **In support of DOE's electron beam microcharacterization facilities, Berkeley Lab is working to return the United States to the forefront of atomic resolution electron beam analysis of materials with unique new instrumentation and a research effort focused on the mechanisms and dynamics at internal interfaces in materials.** A Dynamic Atomic Resolution Microscope will provide unprecedented capabilities for imaging the inner structure of materials at atomic resolution and in real-time. Development and operation of the facility would involve an external steering committee representing industry, universities, and government laboratories. 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.

- **In support of DOE's low-energy nuclear science research program, Berkeley Lab is working to make the 88-Inch Cyclotron the premier stable beam facility.** Berkeley Lab will maintain a leadership role in low-energy nuclear physics while an Isotope Separate On-Line (ISOL) facility for radioactive beams will be sited elsewhere. Key nuclear physics directions identified by the scientific community are in nuclear astrophysics, nuclear structure, exotic nuclei, and heavy elements. These will require both stable and radioactive beams. Therefore, we envision the need for a premier stable beam facility to complement the planned ISOL facility, and we are working to ensure that the facility of choice will be the 88-Inch Cyclotron.

Protect our Living Planet—Energy Impacts on People and the Biosphere

- **With the Office of Biological and Environmental Research, Berkeley Lab is advancing a program of fundamental biology that will enable scientists to understand how the three-dimensional architecture of cells is developed from the inherently one-dimensional code of DNA bases and amino acid sequence.** The normal and disease functions of cells are derived from the interaction of these codes and their environment and are essential to our understanding of the health and environmental effects of energy systems. Imaging technologies have been developed to determine the effect of low-dose insults.
- **Berkeley Lab provides 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 Natural and Accelerated Bioremediation Research Program is strongly supported by development efforts at Berkeley Lab.

Fuel the Future—Science for Clean and Affordable Energy

- **For Fusion Energy Sciences, Berkeley Lab applies its accelerator physics and engineering and plasma science capabilities to address the key questions for Inertial Confinement Fusion.** Berkeley Lab applies its research expertise and experience to assess and develop heavy-ion accelerators or drivers for an inertial confinement energy source. The results of successful single-beam transport and multiple-beam experiments provide encouragement and justification to conduct an integrated program of larger, more complex experiments on the road to such a driver.
- **Berkeley Lab is developing energy-supply and energy-efficient technologies and minimizing the environmental impacts of energy use.** Berkeley Lab continues to play a pioneering role in the development of electromagnetic and seismic methods for imaging subsurface resources; in development of advanced energy-efficient building technologies; in studies of indoor air quality; and in research on combustion, emissions, and urban/regional air quality. Berkeley Lab also has a leading role in characterizing global energy use and the related greenhouse gas emissions that may lead to global climate change.

Explore Matter and Energy—Building Blocks from Atoms to Life

- **Berkeley Lab provides world leadership in astrophysics with discoveries in the accelerated expansion of the universe and the anisotropy of cosmic microwave background radiation.** A key strategy is to accurately define the fundamental properties of matter and energy in the universe through a supernova satellite, revealing the mass density, vacuum energy, and curvature of space.
- **In support of DOE's Functional Genomics efforts, Berkeley Lab is working with the Joint Genome Institute to define and develop programs to understand the significance of gene coding and non-coding regions, the expression of these regions as proteins, and for non-coding**

regions in their possible role in control of gene expression. This work would involve the comparative evolutionary analysis of these sequences, their expressed systems, and their regulatory elements. To complement the extraction of sequence information from the human genome and various model systems, Berkeley Lab is bringing powerful computational, x-ray and electron diffraction tools to understand protein structure and function. These include advanced characterization systems for structural determination from single molecule diffraction with computational reconstruction that can revolutionize structural biology.

- **In conjunction with the Office of Basic Energy Sciences and the Office of Biological and Environmental Research Berkeley Lab is addressing the challenge to understand complex systems.** This effort will, integrate capabilities in structural biology, materials science, genomics, and computation in order to understand and develop advanced materials through a range of methods. These approaches offer the prospect of developing arrays of materials with tailor-made properties, providing new understanding of complex materials, and improving capabilities for design and synthesis.

Manage as Stewards of the Public Trust—Scientific and Operational Excellence

- **Peer Review and Performance-Based Management.** DOE, Berkeley Lab, and the University of California Office of the President (UCOP) have implemented performance-based management systems that advance the science and technology and operational performance of the Laboratory. The performance measurement system and the criteria and measures are incorporated in the contract between the University of California Regents and the Department of Energy (Contract 98). These performance measures are the components of the performance-based management system that UCOP and DOE utilize for Berkeley Lab oversight; and this system is one mechanism for the implementation of the Government Performance and Results Act of 1993. Outside peer review committees assess Berkeley Lab'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. Berkeley Lab will continue to work collaboratively with DOE and UCOP to optimize the performance evaluation process, eliminate redundancies, and develop a system that provides positive feedback for improved performance in support of DOE missions and Office of Science Strategic Goals.
- **Operating the National Laboratories as a System.** Berkeley Lab is part of the system of DOE national laboratories and is applying its capabilities as part of coordinated inter-laboratory efforts. Key examples are the Joint Genome Institute, Spallation Neutron Source, Dual Axis Radiographic Hydrodynamic Test Facility, High Energy and Nuclear Physics collaborations and inter-laboratory global change studies. Partnerships support the increasingly productive arrangements with national user facilities such as the Advanced Light Source and NERSC. Current thrusts of these partnerships center on the full utilization of the Advanced Light Source, simulation and computational science of scale, and the advancement of the physical biosciences to fulfill the promise of the physical sciences for modern biology.
- **Integrated Safety Management.** Berkeley Lab policy is to integrate its performance in the areas of environment, safety, and health into the planning and implementation of all of its operations, in order to protect the health of employees, the public, and the environment. Laboratory plans integrate environment, safety, and health requirements in a prioritized manner to assure that Berkeley Lab can meet DOE's Critical Success Factors for these areas in the conduct of research. All Conceptual Design Reports and other supporting materials indicate environment, safety, and health requirements for program planning.
- **Effective Community Relationships.** Berkeley Lab has developed a Communications Plan that seeks constructive relationships with the community and engages in proactive corporate

citizenship activities. These activities include mechanisms to incorporate community concerns into decision-making and the establishment of effective lines of communications and trust. Examples of Berkeley Lab's current activities include establishment and participation in the community Tritium Monitoring Task Force. An outgrowth of this effort has been the development of a monitoring plan, now submitted to the Environmental Protection Agency. Berkeley Lab also worked with the City of Berkeley on the development and implementation of its community-based vegetation management plan, serves in a leadership position in the Berkeley Hills Emergency Forum, and has renewed a partnership with the City for first response by the Laboratory's Fire Department. A survey research firm has performed a community baseline survey on perceptions of the Laboratory, identifying community views, public knowledge, environmental concerns and further beneficial directions. Berkeley Lab's education, Work Force Diversity and Human Resources programs include components that reach out to the community. These include computer training for Head Start parents; exhibits and demonstrations on health and the environment and environmental protection with local community groups; a School-to-Work program for enhancing local training and employment opportunities; and teacher and student education program with Berkeley and Oakland school districts.

- **Cost-Effectiveness and Administrative Performance.** Berkeley Lab has established performance improvements, in concert with DOE, to address streamlined, efficient, and cost-effective management systems. Savings have been accomplished through integration of management, new business information systems, cross-organizational work assignments, and management of employee job performance. We are promoting a culture in which we measure and analyze performance results and encourage greater communication to assure the development of quality and customer-focused programs. We continue to work in partnership with a Laboratory-DOE Oakland Operations and Site Office Executive Streamlining Group to advance efficiencies. Laboratory investments in new information management systems offer the prospect of improved service and data access, while reducing the need for routine and repetitive data entry and cumbersome report generation tasks.
- **Research Infrastructure and Facilities.** Berkeley Lab will continue to give priority to modernizing and constructing facilities to sustain national programs while maintaining high standards of performance in safety and the environment. Critical elements of Berkeley Lab modernization and infrastructure improvements are implement through Multiprogram Energy Laboratory Facilities Support and General Plant Projects. The General Purpose Facilities program has been vital for replacing aging infrastructure components, such as electric power distribution and sewers. General Plant Projects are essential for modifications and small building replacement or additions; for compliance with environmental, health, and safety standards; and for upgrades of obsolete and deteriorated infrastructure. Both programs require expanded support to address facilities needs at Berkeley Lab. The Laboratory closely coordinates its facilities, institutional planning, safety and environmental planning so that a safe working environment will be provided. Berkeley Lab uses the National Environmental Policy Act and California Environmental Quality Act processes to aid in environmentally sound facilities planning and decision making.
- **Diverse Work Force and Career Development.** Berkeley Lab values diversity in the workplace, and establishes 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. A new School-to-Work program with the Peralta Community College System is part of this effort. 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 Administrative Services Department enables more consistent skill levels and expectations and provides improved opportunities for staff development, planning, and placement. Our goal is the career growth of all Berkeley Lab employees, facilitated by a responsive management.

ADDRESSING MANAGEMENT ISSUES

Berkeley Lab planning and operational efforts are coordinated through meetings and discussions with DOE management at the Berkeley Site Office, Oakland Operations Office, and DOE Headquarters within DOE's realigned Office of Science management framework. Issues being addressed include:

- **Adequate space and infrastructure resources.** The Laboratory continues to work with DOE to secure the necessary infrastructure investments to meet its scientific mission requirements. With the Oakland Operations Office and the Berkeley Site Office, the Laboratory is addressing issues of adequate on-site facilities and augmented off-site leased property to meet critical needs in research, computing and office space.
- **Behavior-based worker safety and environmental protection.** The Laboratory is working to instill continuous improvement in worker safety behavior, with a current focus on ergonomics and up-to-date radiation safety training. The Laboratory is also focusing on environmental control programs that will assure the lowest possible environmental releases.
- **Determination of the appropriate level of site and cyber-security for Berkeley Lab's unclassified site.** The Laboratory works to assure that its personnel and visitors are safe and that its assets—intellectual, property, computational and other resources—are properly protected for its scientific mission and operational requirements.
- **Work force diversity recruitment activities.** The Laboratory is working to improve minority recruitment in key areas through targeted outreach efforts and a long term School-to-Work program.
- **Building openness and trust with the community.** The Laboratory is working with the community and coordinating its efforts with DOE and other stakeholders to address community environmental information needs, including tritium environmental monitoring.
- **Program support needs.** The Laboratory is working with DOE Headquarters and Oakland Operations Office to address sufficient support for key research programs to meet their national demands and obligations, including support for the Advanced Light Source, inertial fusion energy, structural biology and computational sciences programs, as examples.

The planning efforts on the administrative and operational issues are addressed in Section V, "Operations and Infrastructure Strategic Planning," and the context, programmatic opportunities, and challenges related to programmatic support are discussed in Section IV, "Initiatives."

IV. INITIATIVES

INTRODUCTION

Berkeley Lab's role in the national laboratory system—charted by Laboratory management working in concert with DOE—is based on scientific leadership, core competencies, and research facilities. Berkeley Lab advances initiatives that hold promise for maintaining national leadership in science and technology in areas that support DOE's mission, with a focus on the thematic science goals: Provide Extraordinary Tools for Extraordinary Science, Explore Matter and Energy, Fuel the Future, and Protect Our Living Planet. Berkeley Lab's initiatives represent priority scientific thrusts that meet criteria of timely and forefront science, scope, and national scale and that mobilize institutional resources. Initiatives are provided for consideration by the Department of Energy, and in several cases, in conjunction with other sponsors as well. Inclusion in this plan does not imply DOE's funding approval or intent to implement an initiative.

Provide Extraordinary Tools for Extraordinary Science

- Scientific Simulation Initiative
  (Advanced Scientific Computing)
- Advanced Light Source Science Roadmap
  (Basic Energy Sciences)
- Macromolecular Crystallography Facility Upgrades
  (Biological and Environmental Research and National Institutes of Health)
- Dynamic Atomic Resolution Microscopy at NCEM
  (Basic Energy Sciences)
- Center for Advanced Computation in High Energy and Nuclear Physics
  (High Energy and Nuclear Physics)
- Large-Scale Neutrino Detector
  (High Energy and Nuclear Physics, Work for Others)
- Next Linear Collider
  (High Energy and Nuclear Physics)
- Isospin Laboratory
  (High Energy and Nuclear Physics)
- GRETA (Gamma-Ray Energy Tracking Array)
  (High Energy and Nuclear Physics)

Explore Matter and Energy

- Supernova Astrophysics: SNAP
  (National Aeronautics and Space Administration)
- Neutrino Physics at KamLAND
  (High Energy and Nuclear Physics)
- Complex Systems and Nanoscience
  (Basic Energy Sciences)

- Microscopies of Molecular Machines
  (Biological and Environmental Research)
- Functional Genomics with the Joint Genome Institute
  (Biological and Environmental Research)

Fuel the Future

- Heavy-Ion Fusion Integrated Research Experiments
  (Fusion Energy)
- Electric Reliability Performance Systems
  (Energy Efficiency and Renewables)
- Understanding and Engineering Photosynthesis
  (Basic Energy Sciences)
- Advanced Energy-Efficient Building Technologies
  (Energy Efficiency and Renewables)

Protect Our Living Planet

- Carbon Science to Address Global Climate Change
  (Basic Energy Sciences and Biological and Environmental Research)
- Carbon Sequestration
  (Biological and Environmental Research and Fossil Energy)
- Linear Information to Three-Dimensional Structure
  (Biological and Environmental Research)
- Molecular Environmental Science
  (Biological and Environmental Research)
- Computational and Theoretical Biology
  (Biological and Environmental Research)
- Advanced Characterization of Multi-Protein Complexes
  (Biological and Environmental Research)
- Center for Aging Research and Education
  (National Institutes of Health and Biological and Environmental Research)

PROVIDE EXTRAORDINARY TOOLS FOR EXTRAORDINARY SCIENCE INITIATIVES

Scientific Simulation Initiative

As part of their FY 2000 budget, the Administration is proposing a significant increase in the government's investment in information technology research. This initiative, known as the IT^2 (Information Technology for the Twenty-First Century) will support three kinds of activities:

- *Long-term information technology research* that will lead to fundamental breakthroughs in computing and communications, in the same way that government investment beginning in the 1960's led to today's Internet.
- *Advanced applications* and the supercomputers, software, and networks needed to support these applications—such as reducing the time required to develop life-saving drugs; designing cleaner, more efficient engines; and more accurately predicting tornadoes.
- *Research on the economic and social implications of the Information Revolution,* and efforts to help train additional Information Technology workers at our universities.

The Department of Energy is a full partner in this initiative. As a science-based, mission agency the Department's role brings a unique set of research capabilities, mission goals, and high-performance computing and advanced applications expertise, which are critical to three primary goals of the President's Information Technology initiative to:

- Design, develop, and deploy computational simulation capabilities to solve scientific and engineering problems of extraordinary complexity
- Discover, develop, and deploy crosscutting computer science, applied mathematics, and other enabling technologies
- Establish a national tera-scale distributed scientific simulation infrastructure

DOE's Office of Science national user facility at the National Energy Research Scientific Computing Center (NERSC) and the Defense Program's Accelerated Strategic Computing Initiative tera-scale computer systems, with associated massively parallel software applications and tools, will enable the solution of many of the basic scientific problems addressed by the Scientific Simulation Initiative. In fulfillment of its objectives, the Scientific Simulation Initiative includes three broad components:

- **Global Climate Modeling.** Over the past three centuries, humans have altered the atmosphere's chemical composition with little understanding of the consequences. Integrating knowledge about the workings of the climate systems is crucial to formulating the scientific basis for predicting climate change and characterizing its effects. One fundamental computational challenge to be addressed is significantly improved spatial resolution in climate models.
- **Combustion.** The long-term economic and environmental health of our nation requires more fuel-efficient and reduced-emissions direct-injection engines and less polluting entrained-flow boilers found in the electric power generation industry. Advanced computational tools and models would revolutionize high-fidelity predictive simulation of complex, practical combustion systems and facilitate rapid and improved design of such combustion devices. A central computational challenge is to address the time and length scales (18 and 12 orders of magnitude for time and space, respectively) of combustion regimes.
- **Basic Science.** In most scientific areas, the simulation and modeling tools associated with the rapid advances in high-end computing technology have been limited in their application by the broader scientific community. In numerous areas (e.g., materials sciences, fusion energy science, accelerator design and modeling, high energy and nuclear physics, data management and analysis, structural

genomics, subsurface transport), enhanced computational resources and capabilities can dynamically transform research by, for example, insights into the functioning and the integration or coupling of physical, chemical, and biological systems that would otherwise be unattainable. An important challenge is to significantly improve delivery of the benefits of rapidly advancing and new computational technologies to the scientists, both as code developers and code users.

The Scientific Simulation Initiative also addresses the underlying technological requirements and issues necessary for advances in these fields:

- Programmability for large-scale parallel systems to achieve high efficiency;
- Storage and data management to deal with the problems of data access, staging, coordination, and transfer of massive data sets;
- Algorithm improvements, particularly in scalability to thousands of processors;
- Visualization, virtual environments, and other data presentation techniques to glean insight from both computational and experimental data; and
- Networking to allow complex scientific and engineering problem solving by distributed computation across collections of network-connected parallel systems.

In support of these ambitious objectives and components, the Scientific Simulation Initiative calls for significant investments. In particular, DOE's Office of Science has developed an implementation plan, the Computer Science and Enabling Technologies (CSET) effort, to apply and expand the capabilities of the DOE laboratory system. The Office of Science also envisions major facility improvements, specifically the addition of two sites adding up to ten teraflops in FY 2000 and forty to sixty teraflops in FY 2003. Berkeley Lab considers itself an ideal location for one of the proposed sites and has prepared a plan to optimize use of the Office of Science investments, as well as the Laboratory's unique research capabilities.

Scientific Simulation Initiative Resource Requirements ($M)*

Category	2000	2001	2002	2003	Total
Operating	6.0	6.0	6.0	10.0	28.0
Construction	20.0	10.0	20.0	20.0	70.0

*Preliminary estimate of total DOE Budget Authority (B&R Code KJ)

Advanced Light Source Science Roadmap

The soft x-ray and vacuum-ultraviolet (VUV) range of the spectrum offers tremendous promise for scientific advancement, as vividly portrayed at the workshop on Scientific Directions of the Advanced Light Source (ALS), held at Berkeley Lab in 1998. Sponsored by Basic Energy Sciences and Berkeley Lab, the workshop attracted more than 300 scientists, who addressed the scientific promise of the ALS in the following areas:

- **Strongly Correlated Materials.** Complex materials, such as the transition-metal oxides, are characterized by strong coupling between the electronic, spin, and structural degrees of freedom. The strong coupling is at the heart of the richness of the novel behavior of these materials (e.g., high-temperature superconductivity and colossal magnetoresistance) as well as the resulting technologically important applications. Tunability of properties is a significant attraction of complex materials that derives directly from their complexity, which thus becomes an asset rather than an obstacle. Owing to the strong coupling between degrees of freedom, there is as yet limited fundamental understanding of complex materials (a new paradigm of solid-state physics may be required) to guide attempts at engineering them.
- **Magnetism and Magnetic Quantum Structures.** The importance of magnetism and magnetic materials is enormous, with applications ranging from transducers and media in information-

storage technology to the most basic transformers and motors used in the generation and application of electric power. The focus of research will be on magnetic nanostructures characterized by ultrathin magnetic layers and laterally patterned structures, magnetoelectronics, the role of structure in magnetic order (as in the structural origin or magnetic anisotropy and frustration), and new materials such as bio and molecular magnets.

- **Semiconductor Nanostructures.** Nanostructures are low-dimensionality material systems whose size is intermediate between that of atoms or molecules and that of bulk solids (i.e., any structure with at least one dimension on the order of one nanometer). These novel materials have electronic, optical, structural, chemical, or even biological properties that are different from those of the bulk parent compounds and also from those of the constituent atoms and molecules. The properties are strongly dependent on size and shape. Areas of opportunity include: manipulating quantum wavefunctions for tailored properties; synthesis and fabrication; nanostructures embedded in solids; and wide-bandgap semiconductors.
- **Surface and Interface Science.** Surface and interface science is a pervasive component of contemporary materials science, physics, and chemistry, with crucial implications for most technologies and for the environmental and life sciences. The continuing trend to nanometer-scale, and even atomic-scale, elements in technological applications is increasing the importance of surfaces and interfaces. One challenge is to develop a thorough understanding of the relationships between atomic/molecular-scale surface properties and potential applications and devices. These studies will require working at higher pressures, shorter time scales, and higher spatial resolutions, as well as studying more complex systems (e.g., with lateral and vertical heterogeneity and lacking long-range atomic order).
- **Atomic and Small Systems.** The scientific motivations in atomic, molecular, and optical physics fall into two major categories: first, the fundamental quest to understand the interactions of photons with atomic, molecular, and cluster systems in their own right; and second, atomic, molecular, and optical phenomena that impinge on other areas. Photoexcitation and photoionization of the underlying atomic and molecular systems control many key processes in fields such as biology, atmospheric physics, astrochemistry, radiation physics, materials science, and environmental science. Specific areas of opportunity include photon-ion interactions, inner-shell spectroscopy of atoms and molecules, strongly correlated systems, control of photodissociation and photoionization, and free clusters.
- **Biosciences.** Protein array technology makes it possible to find the important regulatory proteins. Protein crystallography, soft x-ray microscopy, and biological and chemical x-ray spectroscopy combine to offer advances in forefront areas of biological structure at molecular, subcellular, cellular, and tissue levels. Between the size of proteins and whole cells, subcellular structure is critical to cell function. Soft x-ray microscopy provides structural information at high resolution from whole, hydrated cells. Recent advances in protein-localization techniques make it possible to probe cellular functions, such as differentiation, growth, aging, and carcinogenesis. Metals in enzymes play both beneficial and negative roles in human health and are important environmental agents. X-ray spectroscopy can answer questions about the molecular, electronic, and magnetic structure of enzymes' active sites, spatial dependence of concentration and chemical speciation in an organism, and time dependence of speciation.
- **Environmental Sciences.** The emergence of the multidisciplinary field now referred to as molecular environmental science is a direct offshoot of research on environmental science problems at DOE synchrotron light sources over the past decade. There are numerous requirements for molecular environmental science research in the soft x-ray/vacuum ultraviolet spectral range: speciation, spatial distribution, and phase association of chemical contaminants at spatial scales ranging from nanometers to millimeters; characterization of chemical processes at solid/aqueous-solution interfaces; actinide environmental chemistry, including fundamental electronic and magnetic structure; microorganisms, organic contaminants, and plant-metal interactions; and fate and transport of contaminants.

- **Polymers, Biomaterials, and Soft Matter.** The applications of polymers and soft condensed matter range from the nanoscopic (e.g., biomolecular material and copolymeric mesophases) to the microscopic (microelectronics) to the macroscopic (high-performance structural composites). Synthetic polymers have now begun to mimic the biological world of macromolecules, such as DNA and proteins, as well as viruses and cells. They represent ideal model systems for investigating the fundamental chemical and physical principles related to supramolecular formation, folding, and phase transitions. Other areas of opportunity include miniaturized advanced materials, such as biomolecular materials and nanoscopic structures, polymer thin films, pattern recognition in copolymer synthesis, polymer surface relaxation, engineering polymers, and organic Earth materials.
- **Chemical Dynamics.** This area encompasses the study of elementary chemical reactions and thus underlies virtually all macroscopic chemical systems. Radical chemistry and dynamics are keys to our understanding of combustion chemistry, which in turn will underlie improvements in efficiency and reduction in pollution. Atmospheric chemistry provides great opportunities for understanding and ultimately controlling some of the most important processes affecting society today. Clusters and interfacial chemistry are especially important in bridging the gap between chemical physics and materials science. Astrochemistry, plasma chemistry, ultrafast kinetics, and photoionization dynamics of complex molecules are other areas of opportunity.

To ensure development of this science and full utilization of the ALS, the research community and the Laboratory have begun to design a roadmap based on the recommendations from the workshop. The forthcoming ALS Science Roadmap will address emerging needs of users from industry, academia, and government laboratories. The roadmap 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 a substantial number of front ends for high-performance, yet cost-effective, application-specific, bend-magnet beamlines to be developed by the user community. The roadmap will include the development of intermediate x-ray energies to accommodate the rapidly growing demand from the crystallography and other communities. The roadmap will also provide for beamline and associate beamline scientists to provide support for users. The intent is to arrive at a complete facility dedicated to user service over a broad scientific range.

Although the roadmap is not complete, some portions are reflected in recent proposals for experimental facilities that address high-priority scientific areas, including the installation of superconducting bend magnets (superbends) that enable the ALS to produce high brightness intermediate x-rays in the 10 to 20keV range:

- **Molecular Environmental Science.** (This is part of a separate initiative described more fully below.) A new interdisciplinary field, molecular environmental science, has emerged in the last few years in response to the need for basic research that underpins long-term solutions to environmental problems. This proposal is to establish adjacent undulator and bend-magnet beamlines equipped with experimental stations for microscopy and spectroscopy at the ALS that would provide powerful tools for the study of molecular processes occurring at environmental interfaces.
- **Protein Crystallography.** The substitution of the central bend magnets in the ALS storage ring with high-field superconducting dipole magnets (superbends) would generate higher fluxes of high-brightness x rays in the intermediate photon-energy range than existing conventional bend magnets without degrading the performance of other beamlines. The proposal is to establish a suite of high-performance stations for protein crystallography around one superbend port, thereby relieving the pressure from the rapidly growing number of users who are requesting beam time at the existing world-class Macromolecular Crystallography Facility.
- **Microbeams for Materials and Earth Sciences.** The ALS has demonstrated the ability to provide sub-micron focused beams of intermediate-energy x rays from bend magnets for spatially resolved x-ray diffraction and absorption. The proposal is to extend this capability by establishing superbend facilities for microbeam x-ray diffraction for materials sciences, microbeam extended x-

ray absorption fine structure (EXAFS) spectroscopy for Earth sciences, and microbeam powder diffraction.

- **Magnetic Microscopy.** The study of magnetism in thin films and at surfaces at length scales as short as 20 nm is now possible using a newly developed photo-emission electron microscope (PEEM2) in combination with the spectroscopic technique of x-ray magnetic circular dichroism (XMCD). While this instrument can address many important problems in magnetism, such as the origin of exchange biasing of ferromagnetic layers by anti-ferromagnetic substrates, there is a clear need for even higher spatial resolution to address problems in which, for example, quantum size effects become important. A new proposal will establish a state of the art, nanometer spatial resolution spectroscopic and magnetic imaging facility at the ALS, using an elliptically polarized undulator (EPU), a new beamline optimized for this work, and an aberration corrected PEEM.
- **Femtosecond X-rays.** An important new area of research in chemistry, physics, and biology is the application of x-ray techniques to investigate structural dynamics associated with ultrafast chemical reactions, phase transitions, vibrational energy transfer, and surface dynamics. The fundamental time scale for these processes is a single vibrational period (~100 fs). This proposal establishes an in-vacuum undulator beamline at the ALS optimized for the generation of high-brightness femtosecond x-rays for time-resolved structural studies of solution reactions, surface processes, and protein dynamics.

The five-year budget plan below does not support those elements of the roadmap that are based on user proposals (whether from within the Laboratory or outside). The budget plan does assume one new associate beamline scientist, and mechanical technician in each of FY 2002, FY 2003, and FY 2004 to cover one new bend-magnet and insertion-device beamline in each of those years.

Advanced Light Source Science Roadmap Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	28.0	28.6	34.4	36.2	38.0	39.9	205.1
Equipment	1.6	1.7	3.7	3.8	3.9	4.0	18.7
ARIM/AIP	1.7	1.7	3.7	3.8	3.9	4.0	18.8

*Preliminary estimate of total DOE Budget Authority (B&R code KC). There is also an estimated small amount of Work for Others resources.

Macromolecular Crystallography Facility Upgrades: World-Class Protein Crystallography

Funded principally by the DOE Office of Biological and Environmental Research, the Macromolecular Crystallography Facility at the Advanced Light Source (MCF/ALS) is a national facility for the study and advancement of protein crystallography. Since the MCF began operation in November 1997, over 220 users from universities, government and industry have collected data. The quality of this data has been universally impressive: more than 100 structures have been solved, some in a matter of hours; numerous papers are currently in press or have been published in *Science, Nature, Cell* and other journals.

The expansion of the MCF is a major priority for biosciences at Berkeley Lab. Synchrotron radiation plays an increasingly critical role in determining biological structures, a key component in understanding human disease and designing more effective pharmaceuticals. As technical advances increase the speed of x-ray structure determination, greater demands are being placed on synchrotron x-ray beamlines, already oversubscribed more than two-fold worldwide. User applications to the MCF alone exceed the facility's capacity over a factor of three. Plans are therefore underway to develop both the capabilities and the capacity of the MCF. Recent installation of permanent mirrors has already enhanced the performance of the current beamline, which will be completed over the next year. To expedite user access, Berkeley Lab plans to partner with Stanford's Synchrotron Radiation Laboratory in a beamline-sharing arrangement.

Automated crystallography is one of the most exciting technologies being pioneered at the MCF/ALS. Working with researchers from academia and industry, Berkeley Lab scientists and engineers are designing and building robots to do the laborious and difficult work of protein purification, screening, crystallization and data collection. The resulting optimization of time, effort, and accuracy afforded by automation could revolutionize the field of protein crystallography. This potential was recognized by two major 1998 reports on structural biology by DOE and NIH that listed protein crystallography automation as a high-priority item. When completed later this year, the technological innovation generated by this project will move the Advanced Light Source to the forefront of beamline design.

Another technological advance is represented in the MCF/ALS superbend project. The incorporation of superconducting bend-magnet sources ("superbends") into the design of synchrotron beamlines is a bold move to address the problem of capacity, while offering high performance at a reasonable cost. Superbends can also accommodate multiple beamlines with specialized capabilities on one source; another design innovation. The MCF is currently seeking funding for this project.

Only nineteen months into its operation, the performance of the MCF/ALS stands with the best. Fully realized, the facility will serve as a research resource with capabilities for structural biology studies that match or exceed other synchrotrons in the United States.

Macromolecular Crytallography Facility Upgrades
Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
DOE Operating	0.3	0.3	0.3	0.3	0.3	1.5
Work for Others (Operating)	5.2	5.9	4.6	3.5	3.9	23.1
Work for Others (Equipment)	3.6	5.0	0.6	0.8	0.8	10.8

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP). Work for Others includes the National Institutes of Health.

Dynamic Atomic Resolution Microscopy at NCEM

The National Center for Electron Microscopy (NCEM)'s instrumentation provides unique and indispensable research tools to the scientific community, complementing the photon and neutron beam characterization tools at DOE's major facilities. For the U.S. to maintain its leadership position in electron-beam microcharacterization, it is necessary to upgrade the array of electron-optical instrumentation at NCEM.

NCEM plans to extend the limits of electron beam microcharacterization with a new generation of user instruments featuring unprecedented capabilities for atomic resolution imaging and for dynamic in-situ microscopy. This initiative will integrate recent breakthroughs in electron optics with advances in computing and the preparation/manipulation of thin foil samples to develop new tools for quantitative characterization of nanostructure. These exceptional tools will provide opportunities for groundbreaking research, aid in the development of advanced materials, and facilitate the discovery of new nanoscale phenomena.

By combining electron-optical instrumentation with a forefront effort in computing it will be possible to develop unique new capabilities for quantitative atomic scale imaging and spectroscopy. These new capabilities will include:

- Atomic structure refinement from nanocrystals and defects;
- Real-time in-situ observation of atomic-level mechanisms and dynamics; and
- Three-dimensional reconstruction at atomic resolution.

In a joint effort with Oak Ridge and Argonne National Labs and the University of Illinois at Urbana, NCEM plans to initiate a project to develop a new generation of aberration-corrected electron beam instruments with unparalleled capabilities. Within this cooperative effort, NCEM will focus on the development of tools for quantitative imaging at sub-Angstrom resolution. As a major advance over current capabilities, these tools will make it possible to obtain atomic-column resolution in real time, in different orientations as necessary for 3-d reconstruction, and for a range of important new materials with short bond lengths. Two major approaches toward quantitative sub-Angstrom imaging will be pursued in parallel:

- In the high-voltage approach to atomic resolution, a next-generation Dynamic Atomic Resolution Microscope will replace the two existing high voltage instruments at NCEM. Based on proven technology, this instrument will support a diverse national user base by providing access to quantitative real-time imaging at one Angstrom resolution. The instrument will offer the unique advantages of increased penetration depth in high resolution and diffraction contrast imaging, decreased ionization damage, and the ability to perform in-situ dynamic experiments. As the only modern high-voltage microscope in the U.S., this machine will serve as a unique resource for the scientific community.
- In the aberration-corrected approach to atomic resolution, a new field emission instrument will be developed, optimized to approach 0.7Å resolution in real-time, using both, phase- and Z-contrast. The objective lens geometry will maintain sufficient space in the sample area to allow high-angle tilting for nanocrystal structure refinement, 3-d reconstruction, and for in-situ manipulation during atomic-resolution observation. This instrument will also include the ability to perform energy-filtered imaging, holography and highly localized spectroscopy with high spectral resolution. *Similar instruments optimized for different performance criteria will be installed at the three sister facilities.*

At instrument resolution levels around one Angstrom, the sample itself becomes the limiting factor. Quantitative imaging and spectroscopy at this level of resolution require methods for preparation of uniformly thin, artifact-free samples, often in geometries designed for specific experiments. These methods must be reliable and applicable to the vast variety of heterogeneous and composite materials typical for advanced technologies. NCEM will enhance its competency in this area with specialized instrumentation, such as microlithography, a focused ion beam, dedicated personnel and laboratory space. This facility will be made broadly available to the user community and is expected to contribute greatly toward the goal of fully quantitative electron beam microcharacterization.

Exciting new research opportunities emerge from the ability to observe the dynamic mechanisms that underlie the mechanical, magnetic or thermodynamic behavior of materials. NCEM plans development of its research focus on in-situ microcharacterization with the design of novel techniques, specialized stages, and a unique UHV instrument capable of observing the behavior of nanocrystals on clean surfaces. Uncommon in-situ capabilities will be developed by applying advanced technologies such as microlithography, focused ion beams, and piezo-electric manipulators to build novel geometries for key experiments. The resulting array of cutting-edge scientific tools will provide opportunities for groundbreaking research such as in-situ synthesis of fullerenes, property measurement of single nanotubes, in-situ measurement of stress relaxation in thin films, and direct observation of the initiation of melting or solidification.

In preparation for new ways of conducting research, NCEM will further develop its link to the other DOE microcharacterization facilities in an electronic "collaboratory," a laboratory in cyberspace that serves as a gateway to the combined instrumentation and expertise available at all participating member institutions. Researchers will be able to collaborate via internet link with NCEM or any of the other facilities, using their combined expertise and instrumentation in a new platform-independent setting.

Dynamic Atomic Resolution Microscopy Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	1.0	1.5	1.5	1.5	1.5	7.0
Equipment	18.0	5.0	3.0	1.0	1.0	28.0
Construction	0.0	2.0	0.0	0.0	0.0	2.0

*Preliminary estimate of Budget Authority (B&R Code KCO3)

Center for Advanced Computation in High Energy and Nuclear Physics

The challenges of experimental and computational high energy and nuclear physics call for a new approach to computing problems and to advanced software development. To address these needs, we propose to create a virtual center that will bring together physicists, accelerator engineers, computer scientists, and computational scientists. The virtual center will focus on three key areas of high energy and nuclear physics computing: large-scale data management, accelerator physics, and cosmology.

Data management in high energy and nuclear physics (HENP) is unique in its combination of scale and complexity. Each HENP experiment requires the intellect and labor of hundreds to thousands of physicists at universities and laboratories all over the world. Current data analysis capability greatly limits the number of collisions that can be studied. Today's limit for the complex and granular HENP data is around one petabyte. At this limit, it can take many months for a student to try a simple new analysis idea.

We plan to undertake a multi-laboratory effort to design and develop a revolutionary advance in the science of distributed data management and analysis in high energy and nuclear physics. The goal is to give data-management intelligence to networked computers and storage, such that queries that may have taken months or years could be completed in minutes or hours.

Particle accelerators are fundamental tools in all four of DOE's mission areas. A major DOE role in basic science is the building and operating of large accelerator facilities for the nation's science community in universities, national laboratories, and industry. The expected increase in computational capability offers the opportunity to revolutionize our approach to accelerator design by allowing simulations that approach the level of a complete accelerator system. This promises performance and efficiency gains in current and future accelerators, as well as significant cost reduction in future accelerator designs. It will also promote the opening of new applications in material science, biology, and medicine.

The work in cosmology will focus on the creation of a set of linked models that trace the history of the universe from the Big Bang to the present day. These models will provide a computational testbed for the exploration of theoretical models for each phase in the evolution of the universe. The computational challenge of this work is enormous and will exceed the capacity of all computing systems available for many years to come. For this reason, a multidisciplinary approach bringing algorithm designers and computer scientists together with cosmologists, will be critical to its success.

Center for Advanced Computation for High Energy Physics
Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	2.0	4.0	5.0	5.0	5.0	21.0

*Preliminary estimate of Budget Authority (B&R Codes KA and KB)

Large-Scale Neutrino Detector

Detection of high-energy neutrinos offers unique opportunities for high energy physics and for astrophysical investigations. There are mechanisms in the cosmos that are able to accelerate charged particles to energies many orders of magnitude beyond what will ever be attainable with Earth-based accelerators. Since neutrinos are not deflected by magnetic fields and interact only weakly with matter, they can be used to find and study these sources of acceleration beyond our galaxy and other objects for which all 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/ANTARES, deep ocean water) point the way toward a large detector system—on the scale of a square or cubic kilometer—necessary to observe the low fluxes of high-energy neutrinos from distant and energetic cosmic objects such as active galactic nuclei. Other scientific goals will be to make sensitive searches for Weakly Interacting Massive Particles (a possible form of dark matter), understand neutrino oscillations (by observations of tau neutrinos), and detect supernovae and currently unexplained phenomena such as gamma-ray bursters, which may be accompanied by a detectable neutrino signal.

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, certain technical and logistical challenges are connected with scaling up the number of detector 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 electrically over large distances to a base station. Berkeley Lab has been doing leading-edge development work on custom integrated circuits for recording the full signal waveform and has developed a complete digital system applicable to the kilometer scale. Prototypes of these circuits have been tested at a depth of over a kilometer in South Polar ice and have revealed never-before-measured complex waveforms. Berkeley Lab is also involved in developing simulation codes leading to understanding the detector system geometry, triggering modes, data acquisition, fault analysis, and physics performance. These will be tested at the NERSC facility on data obtained by the AMANDA collaboration. The next stage is a more intensive approach to the development of the microcircuit technology and larger-scale simulations of the detector performance. A full "string" of 42 advanced digital optical modules will be installed in Antarctic ice during the 1999/2000 Austral summer in collaboration with the AMANDA group. The application of this technology in the deep ocean will continue to be explored with NESTOR.

A proposal for construction of a km-scale array to be installed in South Polar ice will be submitted to the National Science Foundation in FY 2000 by the AMANDA collaboration. Berkeley Lab scientists will join with their AMANDA colleagues in the design and the preparation of the scientific case for the km-scale detector. Berkeley Lab is prepared to provide project management in support of the participating universities and international institutions. Construction may be expected to begin in FY 2002 and extend over five to eight years.

Large-Scale Neutrino Detector Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	1.0	1.4	1.4	1.6	1.6	1.6	8.6
Construction	0.0	0.0	0.0	15.0	18.0	18.0	51.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KA)

Next Linear Collider

Berkeley Lab is collaborating with other institutions to develop an experimental program and accelerator design approaches for the next-generation electron-positron linear collider, which we refer to as the Next Linear Collider (NLC). The effort supports the mission of DOE's Office of Science and the nation's high energy physics community; the National Research Council's Committee on Elementary Particle Physics, and the DOE High Energy Physics Advisory Panel's Subpanel on Planning for the Future of U.S. High Energy Physics, have recommended beginning such an R&D program.

In the past two decades, electron-positron colliders have provided a powerful complement tool to hadron colliders in discovering and elucidating new phenomena in particle physics. It is anticipated that new phenomena will appear at the Large Hadron Collider—in particular, interactions that are responsible for creating the masses of the elementary particles. The NLC will be capable of thoroughly exploring and elucidating whatever new forces and particles are found on this yet-unopened frontier. Among the most exciting possibilities is the appearance of supersymmetry, a proposed extension of space-time relativity, which would be signaled by many totally new elementary particles.

Preliminary NLC design approaches are being developed in collaboration with Stanford Linear Accelerator Center and Lawrence Livermore National Laboratory, and internationally with the Japanese Center for High Energy Physics (KEK). The goal is a successor to the Stanford Linear Collider in high energy physics, colliding positrons and electrons at a 500 GeV to 1.5 TeV center of mass collision energy. This energy, driven by physics goals, implies a large machine—a few tens of kilometers from end to end. Berkeley Lab is actively working on the accelerator physics associated with this system of accelerators, with particular attention to the damping storage rings necessary to achieve high luminosity and small emittance. Our work on the damping rings includes the radio-frequency power (rf) systems and components, collective effects, feedback, lattice structures, damping wiggler magnet design, and vacuum chamber design.

While this is underway, Berkeley Lab will also be involved, as part of a multi-laboratory collaboration, in detector development. Design studies have begun, aimed at understanding the detector performance needed for precision measurements in the presence of intense machine backgrounds, as well as at elucidating the detector R&D effort needed to support the conceptual and engineering design of a prototype detector.

The work by SLAC, Livermore and Berkeley Labs is currently being assessed by the Office of High Energy and Nuclear Physics for its readiness to proceed with a full conceptual design of an NLC. (Annual resource requirements are not defined at this stage.)

Isospin Laboratory

DOE Nuclear Physics is moving forward with planning for an advanced radioactive beam facility, as recommended in the DOE/NSF 1996 Long Range Plan (LRP) for Nuclear Science. The nuclear physics identified in the 1996 LRP, and in subsequent Isotope on-line Separation (ISOL) white papers, covers a broad range of science topics, including nuclear structure, nuclear astrophysics, exotic nuclei and heavy elements, requiring both stable and radioactive beams. The concept for such a facility is presently being evaluated and is evolving from a pure ISOL facility to one driven by an energetic heavy ion (up to uranium) accelerator, in combination with projectile fragmentation/selection of the radioactive species of interest, followed by slowing down and capture in a gas/ion source system, before eventual re-acceleration of the selected radioactive species for experiments of interest. The fragmentation/selection technique was pioneered at the Berkeley Lab Bevalac in the 1970's. Existing expertise, from advanced nuclear instrumentation to accelerator hardware and operations experience with heavy ion beams, may be essential to the success of this new national facility. Depending on design parameters, which are still in the conceptual stage, eventual siting at the Berkeley Lab or in the nearby Bay Area, is not precluded. Berkeley Lab researchers are actively participating in developing the concepts for the next-generation world-class ISOL facility. For example, last July (1998) we hosted an advanced instrumentation workshop for ISOL. R&D on the next generation gamma-ray detector, GRETA (Gamma-Ray Energy Track Array) for nuclear structure studies, is being carried out and we are working toward a prototype of this device which could be used in early studies with radioactive beams presently available at Berkeley and elsewhere. A full-scale GRETA would be one of the major pieces of instrumentation to address ISOL physics.

Several activities are underway at the 88-Inch Cyclotron which can provide valuable information and R&D infrastructure for ISOL, including: (1) IRIS (intense radioactive ion source)—an exotic ion test stand presently developing beams of radioactive ^{14}O for fundamental nuclear physics measurements, (2) the BEARS (Berkeley Experiments with Accelerated Radioactive Species) experiments and infrastructure and (3) the third-generation Electron Cyclotron Resonance (ECR) ion source. We expect to play a strong role in both the science and the technology of an eventual ISOL, wherever it is sited. Resource requirements for an ISOL facility are currently under discussion by DOE and members of the national laboratory system.

GRETA (Gamma-Ray Energy Tracking Array)

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 ratios. 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, currently the most powerful array of its type in the world. From April 1993 to September 1997, this national facility was in use at the 88-Inch Cyclotron, and over 200 experiments were carried out with about 300 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. Communities in both the United States and Europe 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 approximately 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. The gamma-ray energy is obtained by summing only these interactions.

To realize such a detector array, research and development efforts are being pursued in three areas:

- Manufacture of segmented detectors that can give high energy resolution and three-dimensional position information.
- Improvement of electronics based on pulse-shape digitization and digital processing of signals to give the energy and coordinates of the interaction points.
- Development of an algorithm to identify interaction points belonging to a particular gamma ray.

A 12-segment prototype detector has been purchased and has been fully studied, together with the electronics, data processing method, and tracking algorithm. A second prototype with 36 segments has been delivered. Improved designs have made of miniature preamplifiers with faster rise times and have since been fabricated and installed at Berkeley Lab. If successful, the next stage would involve a 7 to 9 element array (each consisting of 36 segments) for further studies under actual experimental conditions. This mini-GRETA would be available for cutting-edge nuclear science experiments at the 88-Inch Cyclotron and elsewhere, and represents a phased approach to a full-scale GRETA in the ISOL-era. Costs for a mini-GRETA are estimated to be ~$2.5 -3.0M over two years. Extensive tests of this prototype are planned for 1999. By 2000, we should be ready to order a "cluster" of seven such segmented detectors which can be used for more realistic tests and to perform experiments. Full operation, with multiple clusters, could be achieved by 2004.

GRETA Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	0.0	0.0	0.2	0.4	0.5	1.1
Construction	0.0	1.0	2.0	7.0	7.0	17.0

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

EXPLORE MATTER AND ENERGY INITIATIVES

Supernova Astrophysics: SNAP

Recent studies of Type Ia supernovas, including measurements by the Supernova Cosmology Group at Berkeley Lab, produced significant evidence that, over cosmological distances, they appear dimmer than would be expected if the universe's rate of expansion was constant or slowing down. This was the first direct experimental evidence for an accelerating universe potentially driven by a positive Cosmological Constant. However, only about 80 supernovas accumulated over several years have been studied and other explanations have not been completely ruled out.

A space mission is now being considered that would increase the discovery rate for such supernovas to about 2,000 per year. Discovery of so many more supernova would help eliminate possible alternative explanations, give experimental measurements of several other cosmological parameters, and put strong constraints on possible cosmological models. The satellite called SNAP (Supernova/Acceleration Probe Satellite) would be a space based 1.8m telescope with a one square degree field-of-view with 1 billion pixels. Such a satellite would also complement the results of proposed experiments to improve measurements of the cosmic microwave background.

In addition to the supernova discovery program itself, Berkeley Lab's Supernova Cosmology Group has unique expertise in large charge-coupled device (CCD) detectors. While smaller CCD's are now common, the Laboratory has developed techniques to construct the large mosaics required for SNAP by stitching together several hundred of the largest ones. The group has also devised a way to manufacture the detectors at significantly reduced cost. Technically, the CCD's have high resistivity with excellent quantum efficiency at 1 micron, which is the same as the emission from distant Type Ia supernova and where conventional CCD's have very low sensitivity.

The project schedule would take approximately four years to construct and launch SNAP, and another three years of mission observations. SNAP would be in the range of NASA's Mid-size Explorers (MIDEX) Satellites program, with a detailed budget and schedule to be developed in coordination with NASA and DOE's Office of Science/High Energy and Nuclear Physics program.

Supernova Astrophysics: SNAP Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total***
DOE	**	15.0	23.0	25.0	13.0	76.0
NASA/Other	0.0	24.0	33.0	35.0	39.0	131.0

*Preliminary estimate of Berkeley Lab Budget Authority KA and Work for Others/NASA. Post-launch operational funding for FY05 to 07 approximately $5M/year for DOE and $3M/year for NASA. Full scope of science partners is under development.
**Possible preliminary funding being discussed with DOE/SC.
***Contingency budgets not included in spending profiles.

Neutrino Physics at KamLAND

The persistence of deficits in solar neutrino experiments and the impressive results from Super Kamiokande on atmospheric neutrinos are the impetus for new, higher sensitivity measurements of neutrino oscillations. The KamLAND experiment will exploit the old Kamiokande underground site and the presence of large nuclear power reactors to obtain two orders of magnitude more sensitivity than previous reactor experiments. The substantial investment ($20M) already made by the Japanese government provides a firm basis for the development of this experiment. The U.S. KamLAND Collaboration proposes several initiatives designed to make this experiment robust against potentially crippling backgrounds and to increase its sensitivity still further, enabling it measure directly solar neutrinos from ^{7}Be.

The KamLAND detector will employ one kiloton of liquid scintillator. This very large mass will result in approximately 750 neutrino events per year from the reactors, though they are 140 to 200 km away. These events are detected in the traditional way, using the delayed coincidence between positron emission and the gamma from neutron capture. The very large ratio of this distance to the neutrino energy will make the experiment sensitive to $\Delta m^2 \approx 7 \times 10^{-6}$ eV^2 at large mixing. This would cover one of the two MSW solutions to the solar neutrino problem.

KamLAND can attack the solar neutrino problem directly, as well. The observation of elastic scattering of solar neutrinos by electrons will produce large numbers of events, albeit with rather low energies. This will place stringent demands on backgrounds, which can be met by minimizing radioactive contaminants in the construction of the detector itself, by keeping radon away from the active scintillator, and by designing electronics capable of providing extra discrimination. In all these areas, the U.S. Collaboration will make leading contributions. In fact, the reactor neutrino experiment will be enormously enhanced by the measures required for the solar neutrino experiment. Reduced backgrounds and increased discrimination against surviving backgrounds will provide the kind of robustness so essential to producing a convincing result for a neutrino experiment.

To work effectively with the Japanese beam, the U.S. Collaboration will be coordinated through Berkeley Lab, which has significant technical resources, infrastructure, and pertinent experience from experiments like SNO. This organization will enable the other contributing U.S. institutions to be more effective partners with the Japanese team. The timetable is for the experiment to function early in 2001. The various U.S. contributions will have to be scheduled with this in mind, with the earliest efforts directed towards components that must be ready at turn-on.

KamLAND will exploit two special opportunities: the existence of the old Kamiokande underground site and the presence of powerful nuclear power reactors. These provide an outstanding opportunity for neutrino physics. The strong support of the Japanese government for the project has made it possible to construct a very substantial detector with one kiloton of liquid scintillator. The result will be hundreds to thousands of useful events per year.

The large distance from the reactor's to the KamLAND detector is a great advantage over previous reactor experiments like CHOOZ and Palo Verde. KamLAND's large fiducial volume, six times that of Borexino, will be especially important for the solar neutrino experiment. KamLAND is thus in an excellent position to obtain decisive results in both areas.

Neutrino Physics at KamLAND Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	1.2	1.2	1.3	1.3	1.4	1.4	7.8
Construction	1.6	4.9	1.3	0.0	0.0	0.0	7.8

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KA)

Complex Systems and Nanoscience

In support of the Office of Science Strategic Plan and its objective to support research that will lead to our understanding and control of nanostructures and complex systems of matter and energy, the Office of Basic Energy Sciences and Berkeley Lab organized a workshop in March 1999 to help define the scientific opportunities for the next millennium in this field. The primary thrust of this effort is to understand how simple structures, especially at atomic scale, interact to create new phenomena and assemble themselves into highly functional and well-adapted devices. The elements of this area of science have been defined in the workshop report, "Complex Systems," which was presented to the Basic Energy Sciences Advisory Council. The workshop participants identified several emerging themes:

- **Nanoscience and Nanotechnology.** Can we exploit the new properties, phenomena, processes and functionalities that matter exhibits at sizes between 1nm and 100 nm?
- **Collective Phenomena.** Can an understanding of collective phenomena be developed to create materials with novel, useful properties—properties that emerge from the interactions of the components of the material and whose behavior differs significantly from the individual components, such as a large response from a small stimulus?
- **Materials by Design.** Can the design of materials with specific predictable and desired characteristics and unusual properties be tailor made directly from the understanding of atomic structure; can nanostructured "dimensionless" materials be assembled with specific electronic, structural, and optical properties?
- **Functional Systems.** Can multicomponent molecular machines and devices be created through self-organized structures that function as pumps, sensors, and even factories?
- **Natures Mastery.** Can biological complexity provide the basis for materials and physical systems that respond to the environment, capture energy, repair themselves, and even evolve?
- **New Tools.** Can characterization instruments and theory probe and exploit the world of complexity?

The Berkeley Lab proposes to focus a number of scientific resources on these themes, with a major thrust in nanoscience. The Laboratory's scientific and engineering staff and its powerful tools, including the Advanced Light Source, National Energy Research Scientific Computing Center, and the National Center for Electron Microscopy will be utilized to make fundamental advancements in the design, and nanofabrication of new materials and devices. Indeed, the Laboratory proposes to further advance these tools for dramatic new insights, including understanding the dynamic processes at atomic dimensions and femtosecond time scales. Three key areas will be addressed:

- **Nanodesign.** Berkeley Lab proposes to advance research in compositional control, multicomponent assembly, and theoretical understanding to develop materials with highly specific actions, including catalytic and energy absorbing and transforming states. Several of the initiatives already discussed have specific approaches to this effort, including work on biological molecular machines and molecular engineering of photosynthetic systems. However the approaches for this initiative will focus on the assembly of materials and chemical systems in non-organismal systems, taking advantage of the tools of biology but apply these efforts to largely physical systems. Key targets are sensors, catalytic, magnetic, optical and superconducting nanosystems.

- **Nanofabrication.** Berkeley Lab has unique expertise in parallel chemical fabrication; quantum dot and nanotube fabrication; and the fabrication of unusual molecules, including dendrimers and molecules that have multiple coupled properties. The Laboratory proposes to apply these needs to the Department's major challenges in energetics, energy storage, energy transmission, sensors and other areas of direct importance to DOE's missions.
- **Nanocharacterization.** Berkeley Lab has powerful tools in the ALS and NCEM that are ideal for understanding and testing the properties of complex nanosystems, including understanding molecular component functions and structures under a range of experimental conditions. New tools are under development, including high brightness femtosecond x-ray lasers and the dynamic atomic resolution microscope (see related initiative). The focus of this effort is to experimentally evaluate and develop new techniques in materials science applications, including single molecule characterization, ultrafast (femtosecond) characterization, and the development of experimental apparatus for extreme conditions, including high pressures, to better understand performance at the atomic scale.

This integrated nanoscience effort for design, fabrication, and new methods for characterization of complex systems is central to materials science for the next decade and to the benefits that materials science can derive from biology, computing and advanced instrumentation. This scientific direction—posed by the DOE Complex Systems Workshop and in the administration's efforts to assure long-term U.S. technology leadership—is an important element of Berkeley Lab's Vision 2010.

Complex Systems and Nanoscience Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	2.0	4.0	4.0	4.0	4.0	18.0
Construction and equipment	0.5	1.0	1.0	1.0	1.0	4.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KC)

Microscopies of Molecular Machines: New Tools for Watching Proteins and Cells at Work

DOE has long been a national leader in developing technology that will address tomorrow's scientific challenges. Over the next few years, one of its great projects will be completed: the sequencing of the human genome. Meanwhile, the pace at which protein, DNA, and RNA structures are being solved, many at DOE synchrotrons, is rapidly accelerating, bringing with it the prospect of complete catalogues of gene sequences and structures. This data explosion, however, does not guarantee a proportional increase in our understanding of how cells work. Gaining biological insight from this emerging information requires a new approach which recognizes that cells are complex, highly integrated, biological factories with many discrete and compartmentalized production lines, each of which is comprised of molecular machines. These machines are large assemblies of proteins with highly specialized functions. The challenge for the next generation of investigators will be to develop and employ new methods to observe, manipulate and characterize these large, localized protein assemblies.

While some of these studies can be done with conventional techniques, standard structural, molecular, and cellular methods fail to deal with the large scale and dynamism of molecular complexes. Under the aegis of the Physical Biosciences Division, researchers from several Berkeley Lab divisions and the University of California are developing novel combinations of established and new forms of microscopy to forge a powerful toolkit for macromolecular analysis. By incorporating such diverse technologies as cryo-electron microscopy; atomic force microscopy and laser tweezers; multiphoton microscopy; and single-molecule confocal and total internal reflection fluorescence microscopy and spectroscopy, it will be possible to obtain structures that are large-scale and high-resolution, study molecular dynamics with high spatial and kinetic resolution and apply these methods to purified preparations, living cells, and living tissue. This initiative, nicknamed M^3, the Microscopies of Molecular Machines, will initially study three fundamental cellular processes: DNA Replication and Repair, DNA Transcription, and Synaptic Transmission and Plasticity.

DNA replication, repair and transcription are the essential processes through which the cell preserves and utilizes its genetic information. DNA replication insures the passage of information contained in the DNA from one generation to the next. Transcription governs the regulation of gene expression and functional identity. When regulation goes awry or DNA is damaged, the consequences to human health can be catastrophic. Unfortunately, DNA is extremely susceptible to environmental effects: ionizing radiation, mutagens and cytotoxic chemicals, and ultraviolet radiation can all damage DNA. Even the thermal energy present in warm-blood organisms can split some bases from the DNA backbone; a process that happens 10,000 times a day in a human cell. In somatic cells these errors can lead to cancer or accelerate cell aging. The study of the complex structural dynamics underlying gene expression and DNA replication and repair by these new microscopies promises to advance DOE's study of the effects of radiation and chemical damage to biological systems and human health.

The Synaptic machinery lies at the heart of one of nature's most mysterious biological processes: the communication network of the nervous system. Containing over a thousand neurons making many thousands of connections with each other, this intricate network receives and reacts to stimuli, processes and stores information, and controls complex behavior. The synapse is the site through which these connections are made. The molecular machinery of the synapse contains protein complexes that are ultimately responsible for the conditions that underlie memory and learning. Until now, there have been no methods for studying these proteins in their native environments, nor for measuring their interactions within the synapses. The tools being developed for M^3 will generate novel techniques for understanding how neuro-active substances act on the brain, and in some cases produce addiction. These technologies will also add an important new high-resolution method for extremely precise imaging in biomedical applications.

M^3 is an outgrowth of the Molecular Design Institute II, a multidisciplinary initiative to devise new strategies and methods to meet the challenges created by our growing need for new molecular structures with novel physical, chemical, or biological properties in many fields of science including the biomedical sciences, chemistry, solid state physics, and the materials sciences.

Taken together, the tools under development by M^3 will open up central biological problems to a level of inquiry that was previously unattainable. To the extent that high-resolution structures have already been obtained for components of molecular machines under investigation, they will help inform the design of many of the experiments. Even more exciting—these methods can be designed and applied fruitfully before individual crystal structures have been solved. The Microscopies of Molecular Machines will put in place and in action the tools for asking the next generation of problems long before the present generation of single component crystal structure and the preceding generation of genome projects are complete.

Microscopies of Molecular Machines Resource Requirements ($M)*						
Category	2000	2001	2002	2003	2004	Total
DOE Operating	1.9	1.9	1.9	1.9	1.9	9.5
DOE Equipment	0.2	0.2	0.2	0.2	0.2	1.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP)

Functional Genomics with the Joint Genome Institute

With the progress on the national goals for human genome sequencing, and on the genomes of other organisms, the nation is faced with the opportunity and the challenge to understand the proteins coded and their functions, as well as the role of the non-coding elements. Comparative genomic analysis of homologous sequences from multiple species offers an effective means to identify conserved non-coding sequences that are likely to have biological function. Human and mouse genomes are particularly attractive for such analyses as they are separated by an evolutionary distance that facilitates such sequence comparisons, i.e. close enough that biological regulatory elements will have been maintained but distant enough that non-functional sequences will have diverged. This type of comparative genomic analysis, and the analysis of genes and their derivative structures, must be coupled to the efforts of the Joint Genome Institute to derive the highest levels of understanding from the overall U.S. genome effort.

To date, labor intensive biological experiments have identified a limited set of non-coding sequences of biological importance. Few algorithms are available for recognizing such elements in sequence; and the only computational methods that allow cross-species sequence comparisons are laborious. Based on the proven importance of non-coding regulatory elements in gene expression and the paucity of information available about such elements, the goal of this program is to develop a combined experimental and computational program in non-coding functional genomics. The program's four central objectives are to:

- Establish a publicly available database that will serve as a repository of "annotated" non-coding regulatory sequences which have been identified through cross species sequence comparisons and biological investigations;
- Use this database to develop computational approaches for identifying non-coding elements in genomic sequence;
- Establish a cross-species resequencing program to verify the existence of such sequences in several vertebrates; and
- Develop and exploit in vivo and in vitro approaches for testing the function of sequences identified from sequence comparisons and/or computational analysis.

The program, utilizing unique capabilities of the Berkeley Lab, will work best as a highly interactive program coordinated between the Life Sciences, Physical Biosciences and National Energy Research Scientific Computing Center Divisions. It would support the Joint Genome Institute's goal to add value to the Institute's human sequence data and meet the research community's need for in-depth studies of how the genome is expressed. The effort would complement other functional genomics research that addresses areas such as mapping gene functions, developing large-scale functional annotation of sequence, coding DNA with protein domains, understanding the patterns of structures of protein families, and prediction of dynamic cellular functions.

Functional Genomics with the Joint Genome Institute Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	1.0	3.0	3.0	3.0	3.0	13.0
Equipment	0.3	0.5	0.5	0.5	0.5	2.3

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP)

FUEL THE FUTURE INITIATIVES

Heavy-Ion Fusion Integrated Research Experiments

The U.S. Inertial Confinement Fusion Energy Program is applying and enhancing its capabilities 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 on the road to a "driver" accelerator at power-plant scale.

In support of these objectives, the Berkeley Lab program has joined forces with Lawrence Livermore National Laboratory in a novel concept called the "Virtual National Laboratory" or VNL. The Heavy Ion Fusion VNL, headquartered at Berkeley Lab, promotes rapid progress in the development of heavy-ion inertial fusion drivers through the technical management integration of the scientific staff, equipment, and experimental facilities of the two laboratories, as well as other laboratory and university partners that might join.

The Berkeley Lab program has largely completed a series of small experiments addressing all components of a heavy-ion fusion power plant (except conventional components such as turbines, generators, etc.; and the targets and reaction chambers). We are now poised to move forward on two frontiers:

- **End-to-end numerical simulation.** Accelerator science (largely the science of nonneutral plasmas) is synergistic with the Laboratory-wide effort in numerical science inspired by the capabilities of the National Energy Research Supercomputing Center. We plan end-to-end numerical simulations of existing and proposed accelerator systems as an integral part of our long- and short-range design work.
- **A new accelerator facility—the Integrated Research Experiment (IRE).** Together with results from the National Ignition Facility at LLNL, the IRE will provide all the data necessary to determine the feasibility of inertial fusion energy production. We plan to submit a Conceptual Design Report for the IRE in early FY 2002.

Three broad areas of hardware and experimental prerequisites for the IRE will require great effort during the next three years. These are:

- **Development of a 10 to 100 ampere injector.** We have built an injector with a single 1-A (driver-scale) beam. However, scaling this technology to multiple 1-A beams for a total current of 10 to 100 amperes, as required for the IRE, involves a number of uncertainties that must be resolved.
- **Completion of a high-current transport experiment.** Our previous experiments validated high intensity beam theory, but they were scaled experiments. The beam currents were of the order of 10 mA rather than the 1 A required for a driver or the IRE. We plan to do a transport experiment at full scale to look for unexpected phenomena that may not have been observable in the scaled experiments. These experiments will also provide information of fill factors and beam precision limits—information that will enable us to build a more cost-effective IRE.

- **Technology development.** To build a cost-effective IRE, we have begun and must continue a vigorous program in improved technologies. The important areas of research are:

  —Development of techniques to anneal and insulate inexpensive varieties of amorphous magnetic materials to make them suitable for pulse applications.

  —Development of low-cost fabrication techniques for insulators.

  —Design and fabrication of several types of quadrupole arrays. Progress in superconducting arrays has been particularly gratifying.

  —Development of low-cost switches and energy storage devices for pulsers.

We are making progress in all these areas; in general, the major focus of our program has become preparation for the IRE.

Heavy-Ion Fusion Integrated Research Experiments Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	4.8	7.9	10.9	17.0	10.0	10.0	60.6
Construction	0.0	0.0	0.0	5.0	10.0	50.0	65.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code AT) in FY 1995 dollars. Costs include designs and research and development operations and beginning period of machine construction.

Electric Reliability Performance Systems

Regulation, technology, and market forces are fundamentally changing the electric utility industry. The new market involves many players, increased transactions, use of the grid in different ways than originally designed, and the substitution of market forces for central control and regulatory oversight. There is a critical need to develop the necessary tools, technologies, and systems to support this competitive market structure.

With the creation of new structures for the electricity utility industry, utilities are no longer in a position to oversee the reliability of the entire interconnected grid. The disaggregation of electric industry functions has led to a diffusion of responsibility for reliability research and technology development. The competitive market requires a portfolio of technologies, models, database systems, and tools that would provide the necessary monitoring, control, communications, dispatch, and reliability management capabilities consistent with the new market structure. The old tools developed for the vertically integrated structure in which utilities operated are not applicable to a competitive market structure. The new competitive market requires technologies that can provide reliability management services such as voltage control, congestion management, grid security and stability independent of competitive energy production.

No one institution has sufficient expertise to perform the needed research and development to create these tools (as well as apply them and get them to market). The problems can best be addressed through the establishment of a consortium of leading institutions. The objective of this initiative will be to create a consortium of research institutions that will carry out a variety of research and development activities to increase the performance of the electricity grid, with particular attention to the reliability of the electricity system, the efficiency of electricity transmission, and economic performance. The consortium will have two specific goals:

- Development of the next-generation electricity grid computer model.
- Technology to improve the performance of the grid.

Berkeley Lab will be the lead institution and will have responsibility for coordinating and integrating the research and technology development. We anticipate that other partners will include a private firm that is a leading electricity reliability research and development performer (Edison Technology Solutions), Sandia National Laboratories (which is heavily involved in electricity reliability technology), and a consortium of leading universities involved in power systems engineering.

Electric Reliability Performance Systems Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	10.0	15.0	20.0	25.0	25.0	95.0

*Preliminary estimate of Budget Authority (B&R Source EE and WFO). Berkeley Lab will manage overall project and perform key aspects of research, but much of funding will be passed through to other members of the research consortium.

Understanding and Engineering Photosynthesis

Science in the next century will embrace fundamentally complex issues that will require skills and concepts from a broad range of today's disciplines. Developed by Physical Biosciences Division researchers, this initiative in photosynthesis cuts across specialties to address two major scientific issues: the delineation and application of nature's design rules to create a new function in photosynthesis; and the obstacles toward progress in the harnessing of sunlight and its conversion to alternative fuels.

The first project will explore and test tools and concepts that lie at the heart of complex and collective phenomena. In particular, synthesis of complex materials, self-assembly and response of natural systems to their environment will be combined with dynamical and structural studies of both natural and synthetic nanoscale photochemical devices. The second investigation addresses DOE's commitment to carbon management and renewable energy sources. The conversion of sunlight to chemical energy in the form of a transportable fuel constitutes a potential alternative to petroleum, natural gas, or coal combustion as a means of power generation. Replacement of these fossil energy sources by synthetic fuels, such as methanol or hydrogen would have the single largest impact on the reduction of anthropogenic carbon dioxide. Progress toward the goal of solar energy to fuel conversion requires the creation of synthetic reaction centers capable of converting carbon dioxide and water to fuels, linked to efficient and robust light-harvesting systems with built-in capability for protection and self-regulation.

Understanding and Engineering Photosynthesis has a tightly focused research program that integrates expertise in synthesis, genetics, and dynamics to elucidate mechanisms and design principles from natural antenna systems, and applies this knowledge to the creation of engineered synthetic assemblies, such as combined dendritic antenna and reaction center core systems, photosynthesis based on metal clusters and photochemistry in transition metal molecular sieves. Emphasis is on mechanistic understanding using ultrafast spectroscopies and *ab initio* electronic structure methods, and on structural insight gained from x-ray crystallography and advanced microscopies.

Understanding and Engineering Photosynthesis Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
DOE Operating	1.0	1.0	1.0	1.0	1.0	5.0
DOE Equipment	0.2	0.0	0.0	0.2	0.0	0.4

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KC).

Advanced Energy-Efficient Building Technologies

The more efficient use of energy played a major role in holding energy use in the United States to approximately the same level for a 20-year period beginning in the early 1970s. The accelerated market penetration of more efficient energy technologies is widely viewed as key to reducing greenhouse gas emissions in a cost-effective way if the United States is to meet emission targets of the Framework Convention on Climate Change. Energy efficiency can similarly be a cost-effective approach to addressing other national needs, including reducing the emissions that lead to urban and regional air pollution and reducing oil imports.

Berkeley Lab has been a leader in taking energy-efficient building technologies from the lab to the marketplace. Past successes include low-emissivity windows, high frequency ballasts for fluorescent lamps, the building energy simulation computer code DOE-2, and technical and economic analyses that are the basis for federal appliance standards. More recent developments that are entering the marketplace include fixtures that facilitate the use of compact fluorescents and other light sources, and methods for reducing energy losses in duct systems. Similarly, ongoing work is expected to lead to the introduction of new products in the marketplace.

This Advanced Energy Efficient Building Technologies Initiative builds on these past successes and ongoing efforts by taking advantage of advances in other fields, including high-performance computing, computational science, visualization systems, and materials and chemical sciences.

In the commercial buildings sector, there is a major opportunity to apply advanced information systems to improve the entire process from design through construction, start-up, operation, maintenance, and renovation. Virtual reality systems driven by high-performance computers will permit real-time visualization of design and design changes, including lighting, thermal flows, and air quality. Advanced computation models (e.g., Computational Fluid Dynamics) will provide the details of heat transfer, air flow, and pollutant transport. "Life-cycle" information systems will feed design intent into construction, and construction implementation into start-up, etc. Cheaper and more abundant sensors to monitor lighting, indoor air quality, occupancy, and temperature, etc. will couple to control systems that use real-time data and the "life cycle" information to optimize building performance. Anticipated benefits include heating, ventilation, and air-conditioning equipment that is sized more appropriately; improved human health, comfort, and productivity; and a 30% reduction in energy use.

In the residential sector, there is an emerging opportunity for a "direct replacement" for the energy-inefficient incandescent light bulb. A miniature high-intensity discharge lamp fabricated using semiconductor manufacturing techniques would be packaged such that its physical appearance, light distribution properties, and purchase price would be similar to the incandescent light source it is replacing, but would be two to four times as efficient and have a much longer lifetime. These properties should overcome the barriers that prevented the compact fluorescent lamp from significantly penetrating the residential market.

**Advanced Energy-Efficient Building Technologies
Resource Requirements ($M)***

Category	2000	2001	2002	2003	2004	Total
Operating	1.0	3.0	5.0	5.0	5.0	19.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source EE)

PROTECT OUR LIVING PLANET INITIATIVES

Carbon Science to Address Global Climate Change

Berkeley Lab scientists are investigating promising technologies and science-based strategies to reduce greenhouse gas concentrations in the atmosphere. Through carbon research programs in the basic energy, environmental, and computational sciences, they are working to enable the nation to make significant advancements in understanding the science of climate change and in assessing and developing technologies that sequester carbon and promote low-carbon energy sources. This work can help provide the scientific basis for reducing the world-wide contribution of carbon to the atmosphere, especially the increasing contribution from anthropogenic sources of carbon to the modification of Earth's climate.

Science of Climate Change. Berkeley Lab researchers have shown that organic aerosols are as abundant as sulfate aerosols, and that both must be considered to properly understand climate change. They have also created a San Francisco Bay paleoclimatic record over the past 1,000 years based on salinity changes deduced from radiocarbon dating. Through partnership with UC Berkeley and the Space Sciences Laboratory, these capabilities will be broadened to include regional climate modeling, climate prediction, and carbon cycling in oceans and the terrestrial biosphere as part of a new center for atmospheric sciences.

A major focus of the new center will be high-resolution climate and impact modeling that will enable enhanced prediction of precipitation changes and consequent impacts. Current Global Climate Models use coarse grids, on the order of 250 km, that neglect the geographic variability of California and encompass many microclimates that respond differently to climate change. Improved computational capability and enhanced modeling approaches will enable a grid size that is better matched to California's microclimates. Improved meso-scale models of California's Russian River have already shown good correlation between predicted and observed precipitation and streamflow.

Low-Carbon Energy Sources. New sustainable energy sources will be needed for a more carbon-free energy economy. Berkeley Lab research will primarily address methane hydrates as a low-carbon energy resource. On-shore and off-shore gas hydrates represent a potentially enormous untapped resource—more than twice the recoverable fossil fuels oil, coal, and natural gas. But first, fundamental issues must be resolved, including sea-floor stability, resource assessment, development of prediction techniques, and understanding impacts on climate change of unintentional releases of methane. Berkeley Lab's seismic techniques can contribute to enhanced understanding of the amount of hydrates present, while the Laboratory's modeling capabilities can be applied to develop reservoir simulators to enhance production.

Other Berkeley Lab programs could contribute to new science for fuel cells, hydrogen production, chemical light pumps (photochemistry), bioengineering photosynthetic systems, reactive membranes, reverse genetic engineering of novel biosystems, new catalytic processes, photovoltaics, and other energy conversion systems.

Carbon Science to Address Global Climate Change
Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	1.0	2.0	5.0	10.0	10.0	10.0	38.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KC). Resource projections do not include Accelerated Climate Change Modeling (see Scientific Simulation Initiative).

Carbon Sequestration

Carbon sequestration, the long-term capture and storage of carbon, is one part of an overall strategy to reduce the buildup of CO_2, a greenhouse gas, in the atmosphere. Other strategies include using energy more efficiently and using energy sources that burn less carbon.

Soils and the surface oceans are the largest carbon reservoirs in rapid exchange with the atmosphere. It has been suggested that the amount of carbon dioxide naturally absorbed by the oceans could be enhanced through direct injection of CO_2 into the deep ocean, or through fertilization of marine organisms living near the ocean surface. Purposeful manipulation of ocean sequestration has never been attempted on a large scale and is one of many strategies that demands study.

The new DOE Center for Research on Ocean Carbon Sequestration (DOCS), a joint Berkeley Lab/Livermore Lab project, will pursue fundamental research on ocean sequestration issues ranging from environmental policy to the assessment of the effectiveness and consequences of ocean fertilization and CO_2 injection. The Center will conduct, focus, and advance the research necessary to evaluate and improve the feasibility, effectiveness and environmental acceptability of ocean carbon sequestration. The Center will develop this information, in collaboration with other researchers, through a combination of in-situ experimentation and observations in key oceanic regimes and through numerical simulation of the ocean carbon system.

Berkeley Lab has special expertise in addressing the scientific questions related to terrestrial and geologic sequestration of CO_2. Berkeley Lab's program will focus on gaining a fundamental understanding of the carbon cycle, and management to enhance carbon removal storage in plant matter and agricultural soils. One of the main thrusts of the Laboratory's terrestrial carbon sequestration will be to use advanced isotopic and experimental techniques to determine the capacity for long-term storage of organic carbon in soils, and how storage capacity may be affected—increased or decreased—by agricultural and forestry practices, land use, and climate change.

For the study of geological sequestration, the Laboratory's earth science expertise will be important to address issues, such as storage capacity, chemical reactions, and monitoring related to the storage of CO_2, possibly as a super-critical fluid, in deep rock formations and in underground cavities.

Carbon Sequestration Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	1.0	2.0	4.0	6.0	6.0	19.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP, KC, and Fossil Energy)

Linear Information to Three-Dimensional Structure

The unifying hypothesis examined in this initiative is that the unit of function in higher organisms is neither the genome nor the cell alone, but complex, three-dimensional tissues. We propose that this is due to bidirectional connections between the components of the cellular microenvironment (growth factors, hormones, and extracellular matrix) via their receptors and the cytoskeleton, to the nucleus via the nuclear matrix and chromatin for selective gene expression. Thus, cells need to be studied "in context" (i.e., within a proper tissue structure) if one is to understand the bidirectional crosstalk. This initiative has several components: designer microenvironments, crystallography, microscopy, and new technology development.

We will use well-characterized existing human and mice mammary cell lines, which can be maintained in "designer microenvironments" either as two-dimensional monolayers or as three-dimensional structures. Use of mouse and human cell lines and the mouse itself will allow us to test directly the relevance of culture studies to the *in-vivo* setting. We will use stable or conditional loss or gain of function manipulations; transgenic and knockout mice; state-of-the-art molecular biology technologies including serial analysis of gene expression (SAGE); differential display; fluorescence in-situ hybridization (FISH); two-dimensional protein gels; advanced imaging and microscopy methods; electron crystallography; theoretical and computational biology; and automation of three-dimensional culture technologies.

Electron crystallography is an emerging technique in the field of structural biology. State-of-the-art electron microscopes, cryo-techniques, and complex image analysis are used to gain high-resolution information (~ 3.5 Å) from two-dimensional crystalline arrays of proteins. The technique is especially suited for membrane proteins—which are difficult to crystallize in three-dimensions for x-ray diffraction studies but have a natural tendency to order in lipid bilayers—and for soluble proteins that are obtained in such small amount that three-dimensional crystallization becomes impractical.

A special case is that of tubulin, a protein that polymerizes and creates the microtubules essential for the life of every cell, and that has resisted x-ray crystallographers for more than two decades. Here at Berkeley Lab, we have exploited electron crystallography to study two-dimensional polymers of tubulin induced in the presence of zinc ions, and have obtained an atomic model of this protein. The model contains information not only about the structure of tubulin, but also about the contacts responsible for polymerization between tubulin subunits and the binding of the anticancer agent taxol. Having solved the structure of tubulin, we are now addressing other important structural and informational molecules such as integrins which are receptors for extracellular matrix proteins. We are also continuing our studies with tubulin to find more effective anti-cancer drugs.

New technology development is a critical component of the advancement of electron microscopy. In collaboration with the Advanced Light Source, new electron decelerating systems are being designed that will allow significant improvements of the performance of CCD detectors used with high-voltage electron microscopes. For example, Field Emission Guns result in more than a hundredfold increase in the coherence of the electrons. In addition, the Field Emission Gun is the perfect complement for electron microscopes that use high voltages, which have high temporal coherence and minimize the number of double scattering events. Advancing these new electron microscopy activities will entail the acquisition of a new $2 million, 300keV electron microscope equipped with the Field Emission Gun.

Linear Information to Three-Dimensional Structure
Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	1.3	2.5	2.5	3.0	3.0	3.0	15.3

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP)

Molecular Environmental Science

A new interdisciplinary field, molecular environmental science, has emerged in the last few years in response to the need for basic research that underpins long-term solutions to environmental problems. The objectives of molecular environmental science research are to provide information on the chemical and physical forms (speciation), spatial distribution, and reactivity of contaminants in natural materials and man-made waste forms, and to develop a fundamental understanding of chemical and biological molecular-scale environmental processes that affect the stability, transformations, mobility, and toxicity of contaminant species.

Important applications of synchrotron radiation spectroscopy and microscopy to molecular environmental science have been made over the past five years at several light sources, including the Stanford Synchrotron Radiation Lab, National Synchrotron Light Source, and most recently at the ALS.

Based on the successes of these efforts and the unique information on environmental processes provided by synchrotron techniques, the molecular environmental science community has identified the need for new synchrotron facilities with unique capabilities at the ALS. In addition to the scientific opportunities provided by these proposed facilities, there is also a pressing need to accommodate many new synchrotron users in the molecular environmental science area. For example, molecular environmental science research in the vacuum ultraviolet/soft x-ray region has approximately doubled within the last two years at the Stanford Synchrotron Radiation Lab and National Synchrotron Light Source, and it has tripled at the ALS.

In March 1998, national workshops that addressed molecular environmental science in the soft x-ray region were convened at the Berkeley Lab to critically examine specific issues with respect to the scientific case, capabilities, opportunities, needs, and future prospects for molecular environmental science-synchrotron radiation research in this spectral regime. The workshops identified several areas of particular need for molecular environmental science research that could be addressed by vacuum ultraviolet/soft x-ray techniques. Specifically, because chemical reactions at the surface of natural solids play dominant roles in many environmental processes, molecular-level studies of contaminant reactions at interfaces (solid-liquid, solid-gas, liquid-gas) are an important focus of molecular environmental science research. The vacuum ultraviolet/soft x-ray synchrotron radiation region has traditionally been one of the domains of surface science research. Experimental molecular environmental science studies in this spectral region are complicated, however, by the need for *in-situ* studies with aqueous solutions, spatial and spectral resolution, and the ability to characterize the speciation of contaminants at very low concentrations. The combination of new technologies provided by third-generation, high-brightness synchrotron radiation sources, improved vacuum techniques, and improved detectors provides the opportunity for new applications of traditional surface science methods to molecular environmental science issues. This proposal is to establish molecular environmental science beamlines at the ALS to provide powerful tools for this study of molecular processes occurring at environmental interfaces, to translate this fundamental information into useful models, and to correlate these models with studies on natural samples.

Molecular Environmental Science Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	0.0	0.0	1.0	1.0	1.1	1.1	4.2
Construction	0.5	3.6	3.6	3.1	2.7	2.7	16.2

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC03)

Computational and Theoretical Biology: Understanding Complex Biological Processes

The exponential growth of biological data poses a challenge to provide new theoretical frameworks and computational approaches to managing, interpreting, and integrating this deluge of information into coherent models of life processes. This challenge defines the interdisciplinary field of Computational and Theoretical Biology, which draws tools and concepts from biology, chemistry, physics, mathematics, statistics, and computer science. Three interrelated thrusts can be defined: bioinformatics and computational genomics, structural biology and biophysics, and cellular and systems modeling.

Working with scientists representing all of these disciplines, Berkeley Lab's Physical Biosciences Division researchers are meeting DOE's challenge to advance scientific computation and applications software with two new initiatives.

The proposed Center for Integrated Physiome Analysis (CIPhA) will bring together a national scientific consortium to design, test, document, and archive quantitative information and integrative models of the functional behavior of biological entities from biomolecules to tissues to organisms. Specifically, CIPhA has three aims: (1) to create a suite of analytical tools for deriving the properties of biochemical cell components and elucidating their dynamic functions in parts as well as whole systems; (2) to provide a database backbone for organizing and systematizing biological data from diverse sources; and (3) to provide a central resource through which biologists can easily access these analytical tools and be trained to use them to pursue complex questions that rely on this type of informational array. CIPhA will benefit greatly from Berkeley Lab's unique constellation of facilities serving the fly and human genome projects and the structural biology projects at the Advanced Light Source. Also, tools requiring the use of supercomputers are well supported by Berkeley Lab's National Energy Research Supercomputing Center.

The sequencing of the complete genomes of a variety of microbes, such as the soon to be completed *Drosophila* and human genome projects, are a driving force for understanding biological systems at a new level of complexity. The goal of the computational structural and functional genomics initiative of the future is to link these sequencing efforts to a high-throughput program of annotation and modeling of both molecular structures and functional networks. The first steps in this type of strategic initiative are now underway. This effort will build Berkeley Lab's program in computational and theoretical biology by linking research in DNA modeling; protein fold recognition, comparative modeling, and *ab initio* prediction of individual gene products; molecular recognition of protein-protein and protein-nucleic acid complexes; and modeling biochemical and regulatory pathways, using *Deinococcus radiodurans* and *Bacillus subtilis* as its testbeds.

Computational and Theoretical Biology Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
DOE Operating	0.3	0.3	0.3	0.4	0.5	1.8
Work for Others Operating	1.0	1.0	1.0	1.0	1.0	5.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP). Work for Others includes the National Institutes of Health.

Advanced Characterization of Multi-Protein Complexes

An emerging challenge in biology concerns the structural biochemistry of large multi-protein complexes that coordinate complex inter-related processes not understandable through the biophysical chemistry of single proteins. This initiative proposes techniques and facilities to bridge the size and resolution gap between electron microscopy of biological assemblies and x-ray diffraction structures of separate proteins in order to advance the interpretative framework for molecular and cellular biology. It builds upon major strengths of Berkeley Lab in Life Sciences, Physical Biosciences, the National Energy Research Scientific Computing and the Advanced Light Source Divisions and links them with collaborative efforts by Berkeley Lab academic collaborators.

The first of the two main foci of this initiative is to exploit the high-speed computational capabilities at NERSC to define efficient mathematical approaches (and algorithms) which produce a three-dimensional reconstruction from high resolution, cryo-electron microscopy images of single protein molecules. These tools must make it possible to automatically identify between 10^5 and 10^6 single particles and automatically merge these images to produce the three-dimensional reconstruction. In order for this to be practical, identification and merging should be accomplished with less than $\sim10^{17}$ floating point operations ($\sim10^5$teraflop). The long-term goal is to be able to carry out structural studies of large, multi-subunit protein complexes at high resolution, using electron microscope images of fields that contain ~100 particles each. Merging data from single particles is equivalent to crystallization in silicon. By eliminating the need for biochemical crystallization, and by reducing data collection and three-dimensional reconstruction to about one day each, single-particle electron crystallography will achieve a level of high throughput that is similar to the speed of x-ray crystallography.

The second focus is to combine the proposed above improvements in cryo-electron microscopy with the development of novel resources at the Advanced Light Source to help characterize multi-protein complexes essential for two processes key to maintenance of genomic stability: (1) transcription-coupled repair of oxidative damage to DNA, and (2) DNA double-strand break repair. Such structural information on critical DNA repair complexes is essential to understand variations in individual susceptibility to environmental genotoxic agents by assessing the functional significance of polymorphisms in genes encoding these proteins.

Ultimately, a major goal of this strategic initiative is to design and fund a novel beamline for the structural cell biology of these and other multi-protein complexes. Such a beamline will utilize the unique properties of a 5 Tesla superconducting bending magnet beamline at the ALS to provide both high and low resolution single-crystal x-ray diffraction, and small angle x-ray scattering (SAXS). As a result of Berkeley Lab's investment in this strategic initiative, it is expected that the ALS together with Life Sciences and Physical Biosciences Divisions will have developed a unique capability in structural biology of large multi-protein complexes that does not presently exist at any facility world-wide.

Advanced Characterization of Multi-Protein Complexes
Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	Total
Operating	2.0	2.5	3.0	1.5	1.5	10.5
Construction	1.3	2.5	1.3	0.0	0.0	5.2

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP).

Center for Aging Research and Education

For the most common forms of human cancer, increasing age brings an exponential rise in both morbidity and mortality. Age may predispose a person to cancer through at least two mechanisms:

- Malignant tumors frequently develop from only one or a few cells and almost inevitably harbor multiple genomic mutations. Thus, the rise in cancer with age may reflect the time required to accumulate successive mutations.
- The cellular microenvironment can suppress the expression of potentially oncogenic mutations, and aging causes striking changes in tissue integrity and function. Thus, age-dependent changes in the tissue environment may synergize with mutation accumulation.

Aging is the result of (1) genetic and epigenetic changes in individual cells and (2) intrinsic and environmental influences on extracellular structures, cells, tissues, and organ systems. The Center for Aging Research and Education (CARE) will integrate the efforts of geneticists, physiologists, and cell and molecular, structural, and computational biologists to understand the changes that accompany aging. The problem of aging is ripe for attack by tools of biology that are now available and currently being developed.

A central focus of the proposed Center will be to determine how cell growth and differentiation are regulated by genomic and extracellular processes. The following tools will be critical to this effort: genomics (including sequencing); functional analysis of protooncogenes, cell cycle activator genes, and tumor suppressor genes; and the identification of single nucleotide polymorphisms (SNPs) in candidate aging genes. Individual genetic variation should have a high predictive value, not only in terms of disease susceptibility but also as a source of information on such variables as drug response and various aspects of disease progression. The Center will provide answers about the causal relation between somatic mutation load cancer risk and aging and identify new targets for cancer prevention and therapeutic intervention.

CARE is designed to create a research training and education environment that will increase the number of advanced degrees in the area of aging research. Already, significant steps have been taken toward the development of the Center. Last year, the National Institute on Aging funded a five-year postdoctoral training program in basic aging. The program will offer research training in the laboratories of both Berkeley Lab and UC Berkeley investigators. Trainees will be exposed to diverse topics in aging and related areas, ranging from genomics and structural biology to physiology. They will be prepared for productive careers in cancer and aging research by laboratory experience, multidisciplinary team research, and critical reviews of their work. In addition, a unique arrangement between Berkeley Lab, the University of California, Berkeley, and a small, local biotechnology company, Biotime, Inc. was signed recently establishing an endowment to support aging research and training at the Center.

Center for Aging Research and Education Resource Requirements ($M)*

Category	1999	2000	2001	2002	2003	2004	Total
Operating	1.2	1.7	2.0	3.5	4.5	6.0	18.9
Equipment	0.0	0.0	5.0	5.0	5.0	5.0	20.0

*Preliminary estimate of Berkeley Lab Budget Authority (NIH and B&R Source KP).
TEC of construction project is $23.5M through FY 2005.

V. OPERATIONS AND INFRASTRUCTURE STRATEGIC PLANNING

Berkeley Lab's strategic planning focuses on aligning Berkeley Lab's management and operational systems to support DOE national research programs and achieve Vision 2010 (see Vision and Strategic Plan, Section III). A number of organizational systems have been identified as critical factors for measuring Berkeley Lab's performance. These systems directly support DOE's Strategic Plans and operating objectives, including core values and corporate management goals, and the DOE's Quality Leadership Group Plan ("The Quality Transformation: A Catalyst for Achieving Energy's Strategic Vision"). The material in this section describes the management and operational systems plans that support Berkeley Lab's programs and are key to successful infrastructure management and institutional planning. The plans and activities are developed and reviewed with DOE Oakland and Headquarters offices to address and resolve management issues.

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 Environment, Safety, and Health programs correspond to and cooperate with the DOE goals in support of this vision. Environment, safety, and health priorities are set and followed in accordance with DOE's Environment, Safety, and Health and Infrastructure Management Plan. Strategic Planning for environment, safety, and health is defined in several planning and report documents, and a summary is given here.

Berkeley Lab is committed to perform all work safely and in a manner that strives for the highest degree of protection for employees, participating guests, visitors, subcontractors, the public, and the environment. In addition, Berkeley Lab seeks continuous improvement and sustained excellence in the quality of all safety (environment, health and safety) efforts.

The primary objective of the Environment, Health and Safety (EH&S) Division is to protect workers, the public, and our environment by providing professional and technical expertise, follow-on services, and integrated ES&H policy to the Laboratory's research and support programs. The ES&H programs are guided by the following goals:

- Serve with line management to ensure that protection of workers, the public, and the environment is integrated into the primary research and support functions of each division or unit.
- Support and provide expertise directly to each Laboratory worker who seeks ES&H advice and help, or who voices a concern.
- Provide employees with a safe workplace.
- Design and operate facilities and research activities to minimize adverse impact on public health and the environment.
- Produce and use only materials that can be disposed of safely and will minimize waste.
- Promptly communicate to affected persons the known hazards of activities and the related methods necessary for safety and health protection.

- Use available technology, engineered safeguards, and responsible science to mitigate all significant risks arising from research and related activities.
- Train and develop staff to meet the commitments to a safe workplace and minimal adverse impact on public health and the environment.

The objectives of the Environment, Safety, and Health program in conducting research activities are to ensure the integrity of human health and safety and the environment in which we operate; manage resources with a value-added perspective; maintain a capability that is not currently supported by other Berkeley Lab programs; provide opportunities for staff development; build new competencies that could prove useful to future Berkeley Lab and DOE Environment, Safety, and Health programs; and support Berkeley Lab's technology transfer mission. Berkeley Lab accepts responsibility for protecting the health of its workers and the public and commits itself to achieve this goal by adopting the following principles, reflected in the Laboratory's Integrated Safety Management Plan:

- Line Management Responsibility for EH&S
- Clear Roles and Responsibilities
- Competence Commensurate with Responsibilities
- Balanced Priorities
- Identification of EH&S Standards and Requirements
- Hazard Controls Tailored to Work Being Performed
- Operations Authorization

These guiding principles, which must become part of every aspect of work at Berkeley Lab, are implemented through the Core EH&S Functions: Work Planning, Hazard and Risk Analysis, Establishment of Controls, Work Performance, and Feedback and Improvement.

Berkeley Lab's Environment, Safety, and Health Performance Measures are utilized to improve performance and institute a more quantitative framework for Berkeley Lab's environment, safety, and health trends and activities. For employee health and safety, representative measures include those that document occupational radiation doses and accident frequency and severity rates (expressed as cases or days lost per 200,000 hours worked). Environmental Performance Measures include measuring and controlling public radiation doses from Berkeley Lab operations, continuing waste minimization activities, and reducing environmental releases. 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 percentage of Berkeley Lab office waste recycled and the total number of waste streams recycled. In addition, Berkeley Lab has established procedures to ensure that there will be no discharge of materials into the environment above established standards.

SECURITY

Berkeley Lab works to assure that its personnel and visitors are safe and that its assets— intellectual, property, computational, and other resources—are properly protected to sustain its scientific mission and operational requirements. Berkeley Lab maintains and updates its Site Safeguards and Security Plan, which addresses potential threats and targets and describes the protection systems and strategies that are in place. These systems include protection strategies and physical protection systems; protective forces; material control and accountability programs; provisions for personnel, information, and property protection; and records and risk assessment activities.

As indicated in Section II of the Institutional Plan, Berkeley Lab's role is in fundamental research and development—the research subject areas are generally available in the public domain with civilian science purposes and aligned to university disciplines. Since it does not have classified research or information files or facilities, the Laboratory has been classified as an exempt laboratory for DOE's unclassified

Foreign Visitors and Assignments Order (except for hosts with clearances—see below). Nevertheless, Berkeley Lab participates in the operational framework of the national laboratory system and with security considerations similar to other non-classified facilities such as SLAC and Fermilab. The Laboratory is fully committed to the protection of sensitive information, including export sensitive information, personnel sensitive information, computer operations, and site protections for property and personnel, and related needs.

The Laboratory implements physical security programs appropriate for the protection of its employees and Lab property. Intellectual property, including data obtained through industrial contracts such as Cooperative Research and Development Agreements and Work for Others is reviewed for export control sensitivity and for patent disclosure considerations. Berkeley Lab has an Export Control Officer responsible for the Export Control Program. Export control activities include review of intellectual property and of instruments and technology that may be shipped off-site. Procedures are addressed and reviewed through the relevant DOE orders and guides. The approved business practices and procedures will be formalized and disseminated through the Berkeley Lab Regulations and Procedures Manual.

As manager of the unclassified National Energy Research Scientific Computing Center (NERSC) and Energy Sciences Network (ESnet), the Computing Sciences Directorate of Berkeley Lab has an important responsibility in maintaining the security of these national user resources. Best business practices, consistent with DOE orders and oversight procedures, are maintained, reviewed, and updated to prevent unauthorized access to its computer systems. Computing Sciences operational practices are aligned with Department of Commerce regulations for export control, including supercomputer access by foreign nationals.

The Laboratory has a designated counterintelligence officer, and has worked with this officer to prepare a Counterintelligence Program Plan, whose focus is on requirements for the approximately 66 staff that possess security clearances (these are held by other facilities, for work at other institutions). Security-cleared personnel attended the Laboratory's Safeguards and Security Stand-down that addressed the new DOE security organization and program, the Laboratory's Security Plan, cyber security, export controls, and the application of the Foreign Visitors and Assignments Order for cleared staff. A security awareness immersion program is being prepared for all employees.

COMMUNICATIONS

Information Management

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 Berkeley Lab. To achieve this goal, the following objectives have been developed:

- **Corporate information.** To provide comprehensive, integrated information systems for the administration and operation of Berkeley Lab. To employ modern relational database technology that provides electronic access to consistent, timely administrative information, making full use of Berkeley Lab's computing and network infrastructure. To provide appropriate distribution, protection, and disposition of administrative data.
- **Dissemination of scientific and technical information.** To increase the use of generally accessible electronic media such as the World Wide Web. To encourage the development of a paperless exchange of scientific and technical results, reports, and journal articles.
- **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 are rapidly rendering this insufficient.)

- **Staff.** To provide state-of-the-art and seamless 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, seamless access to computing resources, upgraded central computing and mass storage facilities, and proper control of access to sensitive files. Berkeley Lab is also developing and expanding the use of collaborative technologies.

These goals support 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 Berkeley Lab, 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.

Berkeley Lab's cyber security program addresses the needs of all computer and networking systems and is fully appropriate to systems that contain no classified information. The program is coordinated by the Computer Protection Program Manager and includes centralized resources of personnel and monitoring equipment and a division-based network of systems managers. A program for lab-wide awareness of security issues addresses all Berkeley Lab employees and guests. The Laboratory's cyber security software is a powerful system for detecting network intruders and has served as a model for other laboratories.

Stakeholder Involvement

Strengthening communications and involvement at all levels, internal and external, in order to build trust with the public and Berkeley Lab employees is a key element of the Berkeley Lab Strategic Plan. This emphasis parallels the DOE's goal to maintain a culture of openness, communication, and trust. A Laboratory-wide Communications Plan was instituted in 1995, and a Community Relations Plan in 1999. Berkeley Lab has taken many steps to enhance community interaction and understanding, including establishing a community-based Tritium Issues Work Group, successfully negotiating a fire services agreement, and implementing a community-developed vegetation management plan. An ongoing speakers bureau and tour program provides continued outreach to the breadth of community stakeholders. Berkeley Lab also participates in community-sponsored activities like science education and energy reduction programs, offering the Laboratory's expertise and in-kind support.

Communications with local government, agencies, citizens' groups, schools, the news media, and other stakeholders require regular interactions between Berkeley Lab and community members. The purpose of these measures is to respond to the information requirements and interests of specific groups, including elected officials, city staff, site neighbors, and employees. Activities have included briefings for elected officials, attendance at local community meetings, and sponsorship of meetings with the public, as well as Berkeley Lab tours. In addition, through the National Environmental Policy Act and California Environmental Quality Act processes, Berkeley Lab works with these stakeholders to disseminate information and solicit public input on all undertakings requiring preparation of major NEPA and CEQA environmental documents such as Initial Studies. Berkeley Lab values its relations with local communities and is committed to an expanding outreach effort.

Berkeley Lab will continue to promote two-way interactions between management and the work force through training for Berkeley Lab leadership, increased opportunities for employee development and feedback, and improved communication mechanisms and programs. Integration of electronic communications systems and networks, essential for effective linkage of Berkeley Lab personnel and programs, and development of World Wide Web-based technologies to share information are being implemented.

HUMAN RESOURCES

Effective human resources activities are critical to the success of Berkeley Lab's programmatic initiatives. The Human Resources Department is an integral part of Berkeley Lab Operations, providing the infrastructure to support Berkeley Lab's programs and research efforts. The Department works cooperatively with DOE and the University of California to ensure that human resource activities at Berkeley Lab are fully responsive to current and future needs. The Human Resources Department strives to build and maintain quality and cost-effective programs and services that effectively support the research mission of Berkeley Lab, keep the Laboratory in compliance with applicable employment regulations, promote work force diversity, and encourage positive, proactive employee and labor relations. See Tables V(1), and V(2).

Human resources activities at Berkeley Lab are guided by five overarching performance objectives, developed jointly by Berkeley Lab, DOE, and the University of California. Berkeley Lab's objectives are:

- **Cost Effectiveness.** Strive to achieve cost-effective human resources systems and practices.
- **Work Force Excellence.** Develop and motivate Berkeley Lab's work force to excel in meeting its programmatic needs as well as those of its customers.
- **Equal Opportunity.** Work to strengthen Berkeley Lab's commitment to and accountability for equal opportunity, affirmative action, and work force diversity.
- **Customer Needs.** Human Resources has a system for identifying and evaluating customer needs and for building and maintaining positive customer relationships.
- **Human Resources Leadership in Deploying Mission/Business Strategy.** The intent of this objective is to align the Laboratory's Human Resources plan with its strategic or institutional plan and to support the principle of the DOE Contractor Human Resources Strategic Plan.

Table V(1) Laboratory Staff Composition (FY 1998)

LABORATORY STAFF COMPOSITION										
Full & Part Time Employees	Total		PhD		MS/MA		BS/BA		Other	
Scientists	832	(23%)	719	(87%)	45	(5%)	56	(7%)	12	(1%)
Engineers	138	(4%)	37	(27%)	46	(33%)	40	(29%)	15	(11%)
Management & Administrative	561	(15%)	30	(5%)	82	(15%)	193	(34%)	256	(46%)
Technicians	1304	(36%)	63	(5%)	207	(16%)	380	(29%)	654	(50%)
All Other	785	(22%)	266	(34%)	84	(11%)	241	(31%)	194	(24%)
Grand Total	3620	(100%)	1115	(31%)	464	(13%)	910	(25%)	1131	(31%)

The Human Resources Department supports institutional efforts to provide cost-effective programs and services that support Berkeley Lab's mission. Regular meetings occur with division customers regarding the development of work force planning strategies and evaluation of the effectiveness of recruitment efforts. Several groups of human resources, division, and administrative staff meet regularly to discuss and evaluate human resources systems and processes and to recommend improvements and implementation of new programs. Significant efforts are underway to locate human resources staff in closer proximity to division customers and to streamline and improve human resources processes, as well as improve the interface between central and division-based human resources staff. Human Resources supports Berkeley Lab's efforts to provide a cost-effective compensation program that recognizes and rewards employees for work performance and accomplishments based on merit, and to establish salary ranges and pay rates competitive with external market levels.

The Human Resources Department supports institutional efforts for employee career growth and training by coordinating educational opportunities and job-related training to assist in addressing professional development of Berkeley Lab employees. Human Resources staff offer a number of workshops including "Effective Performance Management," "Effective Management in a Unionized Environment," "Conflict Resolution," "Pre-Retirement Planning," and "Substance Abuse Prevention."

The Human Resources Department, working in tandem with the Work Force Diversity Office, supports and develops Berkeley Lab programs to expand efforts to create a climate where diversity in the work force is valued. The Work Force Diversity Office has been co-located with Human Resources to cooperatively work to improve organizational recruitment and outreach efforts, and support institutional efforts and commitments to equal employment opportunity and affirmative action. A Human Resources staff member has been assigned the task of improving diversity outreach recruitment responsibilities in tandem with staffing professionals and hiring managers. This staff member is also linked to the University of California system-wide outreach recruitment consortia. The Employee/Labor Relations Office actively investigates complaints of discrimination and harassment and works with line management to ensure that employment actions are consistent with Laboratory policies

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 this has created for Berkeley Lab is two fold: how to attract qualified diverse candidates, particularly those who have been historically under-represented; and how to sustain a vibrant diverse culture and an equal employment environment for all.

In more recent years, "work force diversity" has been recognized at Berkeley Lab to mean that there is a broader set of issues than the traditional focus on affirmative action compliance. In effect, these issues are a new emphasis on harnessing diversity to the cause of scientific excellence. Five key principles form the basis of Berkeley Lab's broader definition of diversity:

- Differences in ethnicity, culture, gender, age and lifestyle are valued for the variety of perspectives they bring to the workplace. All perspectives are equally important and differences are not only welcomed, but actively sought.
- Management takes these differences into account in setting policies and motivating people to higher productivity.
- The sense of being valued and developed for opportunities motivates all employees to put forth their best efforts and therefore leads to higher productivity.
- The spirit of mutual regard, cooperation and investment through development of our staff leads to synergism—the state in which working together yields results greater than the sum of individual efforts.
- The Laboratory takes responsibility to create and actively participate in professional and local community opportunities that will attract and develop, when necessary, top candidates for the Laboratory, particularly women, people of color, and individuals from other targeted populations who have the potential to achieve excellence at Berkeley Lab.

To achieve these key principles, Berkeley Lab's Work Force Diversity Office, in partnership with senior management and the Human Resources Department, will undertake, over the next few years, the following initiatives:

- Proactively create and sustain an internal climate of equal opportunity for all through work force development initiatives such as job growth opportunities through mentoring, job shadowing and training, tuition reimbursement, employee recognition, and improved communication on relevant issues and activities.

- Provide specific resources to help managers and supervisors implement the Laboratory's affirmative action program to ensure a working atmosphere that is supportive and gives a sense of belonging to employees from all cultures.
- Develop new opportunities for Berkeley Lab and each division to review performance with regard to affirmative action.
- Strengthen Berkeley Lab's outreach in the recruitment marketplace to help develop viable and sustainable pools of qualified candidates, particularly women and people of color, through initiatives such as an active advertising campaign; more targeted representation at job fairs; a widely distributed job listing; special employment, education and internship programs; and more proactive development of qualified candidates from professional associations, universities, colleges, and technical and K-12 schools.

These initiatives represent Berkeley Lab's framework for an equal employment environment for all and an affirmative approach that serves to increase the representation of people of color and women in segments of our work force in which they have historically been under-represented.

Table V(2) Equal Employment Opportunity (FY 1998)

					Minority									
Federal Occupational Category	Total		Caucasian		Total Minority		Black		Hispanic		Asian/Pac.Isl.		Nat. Am.	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
OFFICIALS & MANAGERS	98	38	82	30	16	8	4	2	4	2	8	4	0	0
	72.06%	27.94%	60.29%	22.06%	11.76%	5.88%	2.94%	1.47%	2.94%	1.47%	5.88%	2.94%	0.00%	0.00%
Total Male and Female	136		112		24		6		6		12		0	
	100%		82.35%		17.65%		4.41%		4.41%		8.82%		0.00%	
PROFESSIONALS														
Scientists & Engineers	493	86	397	67	96	19	6	2	5	1	85	16	0	0
	85.15%	14.85%	68.57%	11.57%	16.58%	3.28%	1.04%	0.35%	0.86%	0.17%	14.68%	2.76%	0.00%	0.00%
Total Male and Female	579		464		115		8		6		101		0	
	100%		80.14%		19.86%		1.38%		1.04%		17.44%		0.00%	
Management/Administrative	439	317	333	233	106	84	12	17	10	10	83	53	1	4
	58.07%	41.93%	44.05%	30.82%	14.02%	11.11%	1.59%	2.25%	1.32%	1.32%	10.98%	7.01%	0.13%	0.53%
Total Male and Female	756		566		190		29		20		136		5	
	100%		74.87%		25.13%		3.84%		2.65%		17.99%		0.66%	
TECHNICIANS	330	70	258	44	72	26	16	5	20	5	35	15	1	1
	82.50%	17.50%	64.50%	11.00%	18.00%	6.50%	4.00%	1.25%	5.00%	1.25%	8.75%	3.75%	0.25%	0.25%
Total Male and Female	400		302		98		21		25		50		2	
	100%		75.50%		24.50%		5.25%		6.25%		12.50%		0.50%	
CLERICAL	38	241	25	132	13	109	5	61	5	20	2	28	1	0
	13.62%	86.38%	8.96%	47.31%	4.66%	39.07%	1.79%	21.86%	1.79%	7.17%	0.72%	10.04%	0.36%	0.00%
Total Male and Female	279		157		122		66		25		30		1	
	100%		56.27%		43.73%		23.66%		8.96%		10.75%		0.36%	
CRAFTSMEN/LABORERS	138	4	97	4	41	0	14	0	18	0	7	0	2	0
	97.18%	2.82%	68.31%	2.82%	28.87%	0.00%	9.86%	0.00%	12.68%	0.00%	4.93%	0.00%	1.41%	0.00%
Total Male and Female	142		101		41		14		18		7		2	
	100%		71.13%		28.87%		9.86%		12.68%		4.93%		1.41%	
SERVICE WORKERS/APPRENTICES	46	18	19	5	27	13	13	8	10	3	4	2	0	0
	71.88%	28.13%	29.69%	7.81%	42.19%	20.31%	20.31%	12.50%	15.63%	4.69%	6.25%	3.13%	0.00%	0.00%
Total Male and Female	64		24		40		21		13		6		0	
	100%		37.50%		62.50%		32.81%		20.31%		9.38%		0.00%	
Total All Categories	**2356**		**1726**		**630**		**165**		**113**		**342**		**10**	
	100%		**73.26%**		**26.74%**		**7.00%**		**4.80%**		**14.52%**		**0.42%**	

Source: 07/26/99 download from Peoplesoft Database. Figures are FTE based on end of fiscal year 1998. (10/01/97 - 09/30/98)

SITE AND FACILITY MANAGEMENT

Site and Facilities Context

Berkeley Lab's 82-hectare (200-acre) site is immediately adjacent to the University of California, Berkeley. As Berkeley Lab is actively committed to supporting researchers and is continually vigilant about creating conditions that protect our staff, the public, and the environment, it has prioritized buildings and spaces for modernization, adaptive reuse, and replacement. Berkeley Lab has one of the highest space utilization rates of all multi-program laboratories. Some buildings still in use were constructed as early as 1940. See Figure V(1). A key issue for the Laboratory is the need for office space and how to most effectively relocate appropriate administrative and programmatic resources to off-site leased space.

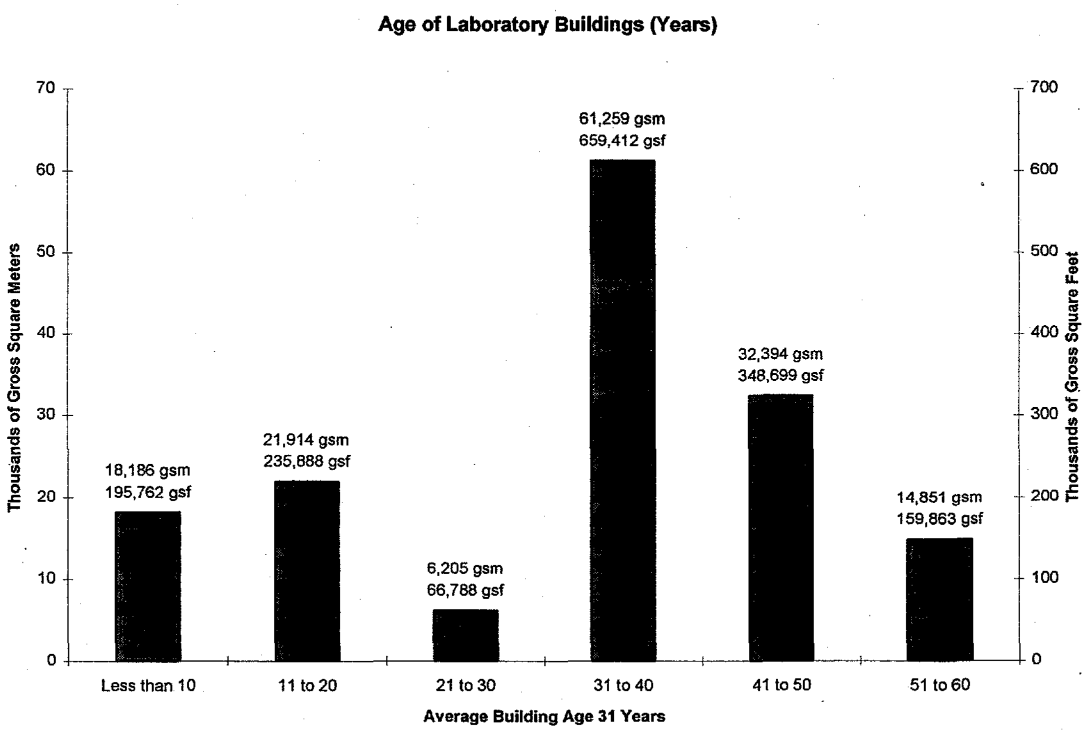

Figure V (1) Age of Laboratory Buildings, Modulars, and Trailers

Eighty-seven percent of Berkeley Lab's buildings and space are located at the Berkeley Hill site. See Table V(3). In 1999, there were 80 buildings of conventional construction and 107 trailers and temporary structures at the main site. Approximately 3% of Berkeley Lab's space is located on the UC Berkeley campus as provided under the UC-DOE Contract. In addition, some administrative support and laboratory research space is leased in commercial buildings located in the adjacent communities (approximately 10% of Berkeley Lab's space). This conventional lease space is used to meet program needs that cannot otherwise be accommodated on the main site.

Table V(3) Laboratory Space Distribution (FY 1998)

LABORATORY SPACE DISTRIBUTION			
Location	Area (Ksm)	Area (Mgsf)	% of Total
Main Site	162	1.74	87
UC Berkeley Campus	6	.07	3
Leased Off Site	18	.19	10
TOTAL	186	2.00	100

The 1999 replacement plant value of Berkeley Lab facilities is estimated to be $806 million. See Table V(4). This includes all on- and off-site buildings occupied by Berkeley Lab. The replacement plant value of the Berkeley Hill site infrastructure includes all site improvements, utilities, communication systems, and accelerators.

Table V(4) Facilities Replacement Plant Value (FY 1999)

FACILITIES REPLACEMENT PLANT VALUE		
Facility Type	Value ($Million)	% of Total
Buildings*	806[1]	75
Utilities and Accelerators†	269	25
TOTAL	1075	100

Includes all facilities, all sites
* Baseline FY 98
† Baseline FY 95
1 Building RPV includes property tracked in FIMS database (incl. buildings and trailers) as well as property not tracked in FIMS (e.g. small bldgs, leased bldgs, and campus bldgs,

Approximately 333,000 square feet of Berkeley Lab's space (at the main site) is substandard and in need of replacement. See Figures V(2) and V(3). This space is needed by existing research missions, and much of it remains in use pending replacement. If maintained well and updated where required, the vast majority, some 81%, of the Laboratory's main site space can continue to serve the research mission. For example, 80% of computer space, 98% of Wet Lab space, and 82% of Dry Lab space are rated as adequate or functional in 1999. Still, Berkeley Lab must continue to upgrade facilities that are rated as "Minor or Major Rehab Needed" rather than "adequate" to ensure that they continue to meet researcher needs and all applicable and new health, safety, environmental, and performance standards. Moreover, space is at a premium, and capabilities must be increased in order to reduce overcrowding. Evaluation of building condition and usability is based on categories utilized in the DOE Facilities Information Management System (FIMS).

Guidelines for placing a facility into a particular category are as follows:

- **Adequate< 10% of RPV**
- **Minor Rehab Needed 10% - < 25% of RPV**
- **Major Rehab Needed 25% - <60% of RPV**
- **Replacement Required >=60% of RPV**

Percentages are based on the total repair cost to a facility as a percentage of Replacement Plant Value (RPV). Total repair cost does not include normal operating/maintenance cost.

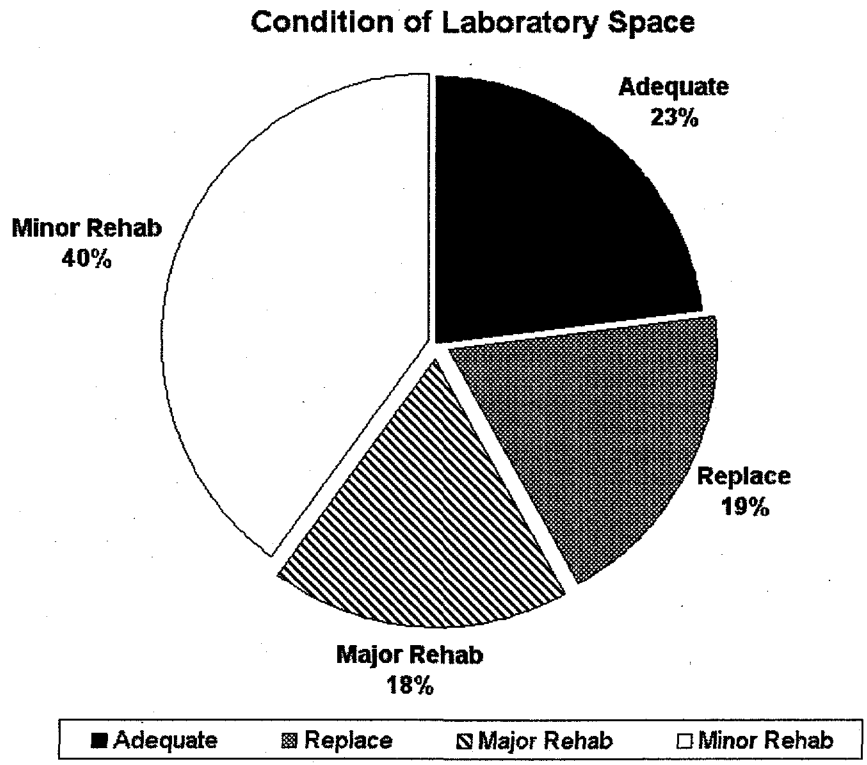

Figure V(2) Condition of Laboratory Space (All Structures)

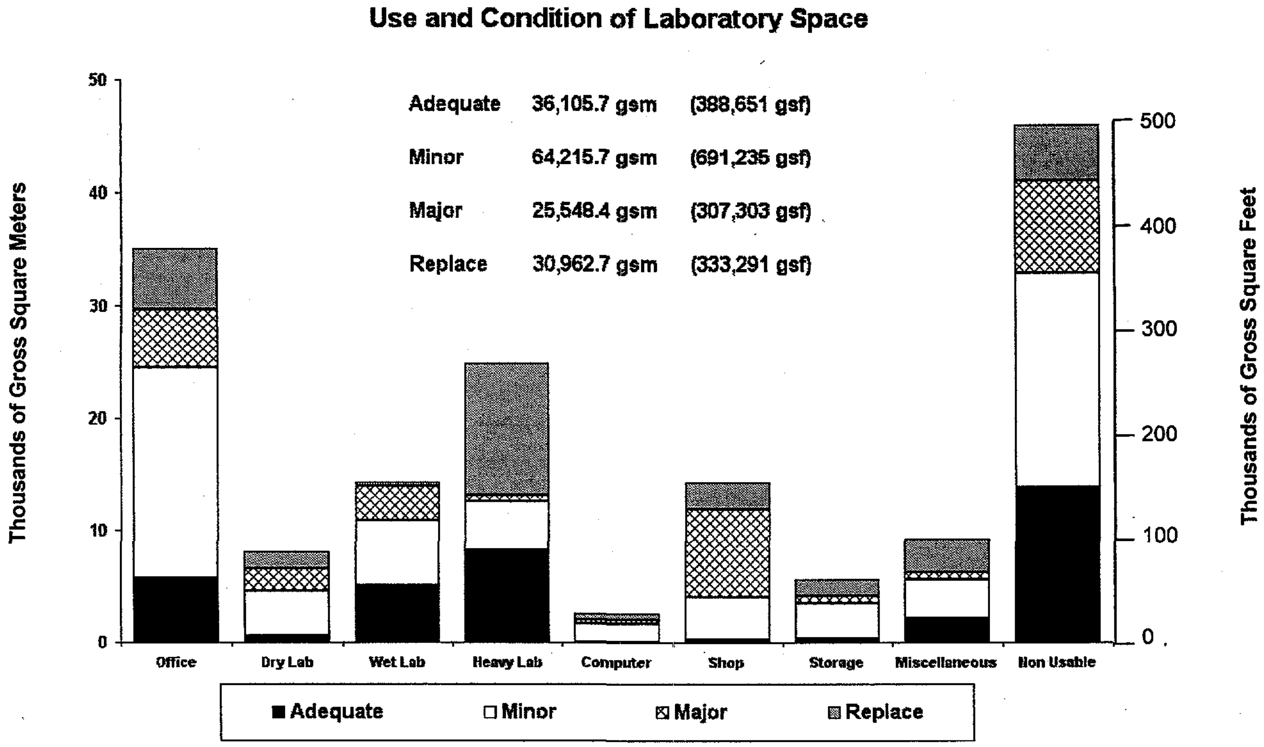

Figure V(3) Use and Condition of Laboratory Space (Buildings, Modulars, and Trailers Only)

Facilities Plans and Options

Berkeley Lab's Long-Range Planning anticipates DOE's scientific missions in a manner that continues the Laboratory's position of scientific leadership. The Laboratory currently operates within 186,000 gsm (2.0 Mgsf) of research and support space and can accommodate an increase of 37,000 gsm (.4 Mgsf) of research and support space. Additional development and re-use opportunities that could support further significant scientific program opportunities have also been identified. The Laboratory actively works to cost-effectively manage use of its current assets both in terms of space utilization and timely renovation. These efforts ensure that science continues to be efficiently and safely conducted.

Berkeley Lab has an integrated approach to facilities planning, which is closely coupled to Institutional and Program Plans. Candidate facilities projects are reviewed by a Multi-Divisional Project Coordination Committee. Review by this committee ensures that all infrastructure-related units are informed of upcoming projects and needs so that coordinated planning can occur. All project candidates, including non-capital alterations, are ranked using two rating systems:

- Each item is ranked by the submitting organization.
- Each item is scored using DOE's Risk-Based Prioritization Method.

The Project Coordination Committee's recommendations are reviewed by management within the Operations Division and submitted to the Director's Action Committee for final review for inclusion in plans and for advancement to DOE's Site Office Manager and DOE Program Manager.

Berkeley Lab has a maintenance plan designed to extend the useful life of all facilities to the maximum extent practical. Buildings that are in need of upgrade to ensure that they can continue to meet environment, safety, and health and performance standards have been identified, and projects to upgrade these facilities have been developed and prioritized. General Plant Projects and Line Item Projects funding limitations, however, restrict implementation of these plans. In addition, those buildings that cannot be economically upgraded and are therefore candidates for demolition and replacement have also been identified, and projects to replace this space have been developed. However, pressing needs for space during the interim will require that all spaces continue to be utilized prior to demolition and replacement. See Facilities Resources Requirements, below.

There are no Inactive Surplus facilities at Berkeley Lab, and no Inactive Surplus facilities are anticipated. The pressing need for space at Berkeley Lab necessitates adaptive reuse or reutilization of any space that is not fully utilized for an ongoing research mission. Structural rehabilitation and the identification of resources to complete timely reuse alterations are priorities at this site.

National Environmental Policy Act and California Environmental Quality Act

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

Berkeley Lab's general plan of action for projects includes preparation of NEPA/CEQA documentation for research, construction, and other actions undertaken at the Laboratory. When appropriate, NEPA recommendations are forwarded to DOE and CEQA recommendations are forwarded to the University of California for further action.

Facilities Resource Requirements

Berkeley Lab uses its facilities intensively, so space is at a premium. All space is used, and when space becomes available, it is reoccupied or adaptively reused for new purposes. Berkeley Lab now ranks among the top federal facilities in space utilization. Although the buildings have been maintained and continue to be used, some older buildings do not meet modern performance standards. Use of these spaces is inefficient, costly, and requires reliance on administrative controls to ensure that modern operational safety requirements continue to be attained.

The General Plant Facilities (GPF) is vital for infrastructure needs, with projects ranked using DOE's Capital Asset Management Process (CAMP) and Risk-Based Prioritization Method (RPM) ranking systems. The GPF funding budget has remained at $3.5M for years. There is a pressing need to increase the General Plant Projects allocation to $7M, to address the backlog of projects. Such a need has been recognized by DOE landlord offices.

Berkeley Lab has received funds for only three GPF Line Item Projects (over $5M) in the past five years. Of particular concern is the fact that not one of the building projects has been funded. This situation has challenged Berkeley Lab to operate in a manner that continues to maintain the performance standards of DOE, our employees, and the community. Space utilization is very high at Berkeley Lab and there is an essential need for new buildings, both for support and scientific functions.

There is also a pressing need to replace, renovate and modernize a number of Berkeley Lab buildings, particularly some of those constructed during the materials shortages of World War II (including converted barracks and storage facilities). Some of these World War II and early cold war-era buildings were constructed at a time that modern building and ES&H codes did not exist. These buildings cannot be economically upgraded and must be replaced. However, not all of the older buildings must be replaced, some can be safely and economically updated in order that they can continue to provide additional years of service.

The Five-Year Construction Plan presented in Table V(5) identifies the priority replacement buildings as well as other important infrastructure needs. DOE's support for the successful implementation of the Five-Year Plan as presented in this report is necessary to ensure the continued cost-effective operation of the Laboratory.

Table V(5) Major Construction Projects (FY 2000-2004)

MAJOR CONSTRUCTION PROJECTS							
$ in Millions (Budget Authority)	TEC	1999	2000	2001	2002	2003	2004
GPF Line Item Projects (KG)							
Rehab Structural Support & Operating Sys (B77)	8.0	0.8	6.1	1.1			
TOTAL FUNDED CONSTRUCTION	**8.0**	**0.8**	**6.1**	**1.1**			
Proposed Program-Related Projects							
National Co-Laboratories Roadmap	12.5		2.0	5.0	5.5		
TOTAL PROPOSED PROGRAM-RELATED PROJECTS	**12.5**		**2.0**	**5.0**	**5.5**		
Proposed GPF Projects							
Sitewide Water Distribution Upgrade, Phase 1	8.3			1.0	6.6	0.7	
Rehab Building Operating Systems (B 74)	8.3			1.0	7.1	0.2	
Upgrade Building Operating Systems (B 62)	8.3			1.0	7.1	0.2	
Replace Building 7	15.0				1.5	12.0	1.5
Sitewide Water Distribution Upgrade, Phase 2	8.0				0.8	6.4	0.8
New Operations Building	15.0				1.5	12.0	1.5
Replace Building 29	24.0					2.4	19.2
Roadway Safety and Stabilization	8.0					0.8	6.4
Replace Building 83	15.0						1.5
Rehab Building Operating System (B 70 Complex)	10.0						1.0
Rehab Building Operating System (B 50 Complex)	10.0						1.0
SUBTOTAL	**129.9**	**0.0**	**0.0**	**3.0**	**24.6**	**34.7**	**32.9**
TOTAL PROPOSED PROJECTS	**142.4**	**0**	**2**	**8**	**30.1**	**34.7**	**32.9**
TOTAL FUNDED, BUDGETED, AND PROPOSED GPF PROJECTS (excludes Program and Hazardous Waste Handling Facility-related projects)	**137.9**	**0.8**	**6.1**	**4.1**	**24.6**	**34.7**	**32.9**

INTELLECTUAL PROPERTY MANAGEMENT

Intellectual property is created in the course of research at Berkeley Lab, and is managed for the benefit of the DOE and Laboratory missions, and for the U.S. public under the applicable technology transfer statutes. Intellectual property includes patentable inventions, copyrightable works (e.g., software), and tangible research products and biological materials. Intellectual property disclosures are made to the Patent Department, and evaluated and transferred to the private sector by the Technology Transfer Department—typically under license, option, bailment or similar agreements. As with most other national labs and research universities, Berkeley Lab's technologies tend to be nascent and require substantial development by a private sector company before any commercial product is likely to emerge; therefore, protection and management of the intellectual property is a key factor to successful commercialization and the realization of the benefit to the consumer. In FY 1998, Berkeley Lab reported 86 inventions, filed 23 new U.S. patent applications and had 13 patents issued. A total of 40 new licenses and options were executed. These are generally typical rates for the last few years, although the number of disclosures increased somewhat due to the applied research under a large CRADA for the development of EUV Lithography, and numbers of licenses have increased partly due to a spike in nonexclusive software licenses.

Table V(6) Intellectual Property Management

Category	FY 1997	FY 1998	FY 1999 (est.)	FY 2000 (est.)	FY 2001 (est.)
Number of New Licenses [a]	63	40	46	50	50
License Income ($K)[b]	354	561	800	1,000	1,300
Invention Disclosures	70	86	80	80	80
U.S. Patent Applications [c]	27	23	28	28	28
U.S. Patents Issued	13	13	25	25	27

[a] Includes options
[b] Cash in only (i.e., not including fair market value of non-cash income)
[c] *Not including provisional patent applications or continuation applications*

Fiscal Year 1998 saw income from licensing ($561K) grow approximately 60% in comparison to the FY 1997 figures. We expect to see further growth as the program matures, based on the experience of comparable technology transfer offices throughout the U.S. The Laboratory allocates licensing income consistent with the DOE operating contract and University of California Regents policy, providing for the reimbursement of patent costs, then an allocation of a share to the inventor with the remaining going to the Laboratory for research purposes. The percentage share to the inventor is variable based on the policy in effect at the University of California at the time the invention was disclosed, but ranges from 35 to 42.5% of the net income.

Table V(7) Distribution of Net[a] Licensing Income

	FY 97 and Prior Disclosure	FY 98 and Subsequent Disclosure
Inventor Payments	42.5%	35%
Research and Development	42.5%	65%
Education	0%	0%
ORTA administration	15%	0%

[a] Gross income less cost of intellectual property protection such as patenting or copyright registration costs

One exciting result has been the licensing to a start up company of nanometer-sized (<10nm) crystals of semiconductors that light up like molecular scale LED (light emitting diodes) and can be used as fluorescent probes for the study of biological materials. Quantum Dot Corporation of Palo Alto plans to focus on biological assays, for which it received an exclusive license from Berkeley Lab. As partial consideration for the license, the company issued shares to the University.

VI. RESOURCE PROJECTIONS AND TABLES

Resource projections for the Institutional Plan provide a description of the budget authority to implement the research programs. The resource tables also indicate actual FY 1998 budget authority and FY 1999 projected budget authority for comparison. These tables include:

- Resources by Major Program:

  Laboratory Funding and Personnel Summaries, Tables VI(1)(a)–(b)
  Funding and Personnel by Secretarial Officer, Tables VI(2)(a)–(b)
  Office of Science Funding and Personnel, Table VI(3)(a)
  Energy Efficiency and Renewable Energy Funding and Personnel, Table VI(3)(b)
  Fossil Fuel and Other DOE Program Funding and Personnel, Table VI(3)(c)

- Subcontracting and Procurement:

  Work for Others Funding and Personnel, Table VI(4)
  Subcontracting and Procurement, Table VI(5)(a)
  Small and Disadvantaged Business Procurement, Table VI(5)(b)

- Experimenters at Designated User Facilities (FY 1997), Table VI(6)
- University and Science Education, Table VI(7)

The FY 1999 estimate is based on FY 1999 DOE budget guidance, the President's Request, and assessments by Berkeley Laboratory Divisions. For fiscal years 2000 and beyond, operating cost projections are in FY 1999 dollars, and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 2000 to FY 2003, the growth assumptions in program areas as tabulated range from 3% to 1.5% per year. These growth assumptions are based on the general direction indicated by DOE program personnel. Specific trend levels have been established within each program activity.

The resource projections that follow include all funded and budgeted construction projects, the projected General Purpose Facilities program, and the approved Environmental Restoration and Waste Management program funding. Resource projections for new initiatives are presented in Section IV and are not included in this section unless incorporated in budget submissions. Construction project cost details are provided in Section V.

Table VI(1)(a) Laboratory Funding Summary

LABORATORY FUNDING SUMMARY							
($ in Millions-BA)	FY98	FY99	FY2000	FY2001	FY2002	FY2003	FY2004
DOE Effort	236.7	260.7	285.7	298.8	310.7	320.8	328.7
Work for Others	69.6	79.4	93.5	95.1	93.7	93.1	93.7
TOTAL OPERATING	**306.3**	**340.1**	**379.2**	**393.9**	**404.4**	**413.9**	**422.4**
Capital Equipment	23.7	33.5	44.0	42.5	42.8	45.9	43.9
Program Construction	8.2	25.7	22.9	11.0	9.0	6.6	5.4
General Purpose Facilities	2.4	4.9	6.1	4.1	24.6	34.7	32.9
General Plant Projects	3.5	3.5	3.5	3.5	3.5	3.5	3.5
General Purpose Equipment	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TOTAL LABORATORY FUNDING	**346.1**	**409.7**	**457.7**	**457.0**	**486.3**	**506.6**	**510.1**

Table VI(1)(b) Laboratory Personnel Summary

LABORATORY PERSONNEL SUMMARY							
(Personnel in FTE)	FY98	FY99	FY2000	FY2001	FY2002	FY2003	FY2004
DIRECT							
DOE Effort	812	883	977	990	1,031	1,050	1,043
Work for Other than DOE	425	555	549	551	533	519	516
TOTAL DIRECT	1,237	1,438	1,526	1,541	1,564	1,569	1,559
TOTAL INDIRECT	1,115	1,118	1,120	1,123	1,125	1,128	1,130
TOTAL PERSONNEL	**2,352**	**2,556**	**2,646**	**2,664**	**2,690**	**2,697**	**2,689**

Table VI(2)(a) Funding by Secretarial Officer

FUNDING BY SECRETARIAL OFFICER							
($ in Millions-BA)	FY98	FY99	FY2000	FY2001	FY2002	FY2003	FY2004
Office of Science (SC)							
Operating	178.6	196.3	216.2	230.5	242.1	251.2	259.1
Capital Equipment	23.7	22.8	45.6	44.3	44.7	47.8	45.7
Construction	7.7	10.3	11.6	11.8	32.4	42.6	40.9
Total	**210.0**	**229.4**	**273.4**	**286.6**	**319.2**	**341.6**	**345.7**
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Operating	19.0	21.7	22.7	24.7	25.6	26.9	28.0
Capital Equipment	0.1	–	–	–	–	–	–
Total	**19.1**	**21.7**	**22.7**	**24.7**	**25.6**	**26.9**	**28.0**
Assistant Secretary for Fossil Energy (FE)							
Operating	2.8	3.2	6.1	7.2	7.4	7.6	8.0
Total	**2.8**	**3.2**	**6.1**	**7.2**	**7.4**	**7.6**	**8.0**
Assistant Secretary for Environmental Restoration and Waste Management (EM)							
Operating	13.4	13.8	16.1	15.4	15.6	15.6	13.7
Capital Equipment	0.4	0.0	0.1	0.1	0.1	0.1	0.1
Total	**13.8**	**13.8**	**16.2**	**15.5**	**15.7**	**15.7**	**13.8**
Assistant Secretary for Defense Programs (DP)							
Construction	6.4	20.8	16.8	0.9	0.3	–	–
Total	**6.4**	**20.8**	**16.8**	**0.9**	**0.3**	–	–
Office of Nonproliferation and National Security (NN)							
Operating	3.7	3.2	3.8	2.7	2.7	2.8	2.8
Total	**3.7**	**3.2**	**3.8**	**2.7**	**2.7**	**2.8**	**2.8**
Assistant Secretary for Environment, Safety and Health (EH)							
Operating	1.2	0.6	0.6	0.6	0.6	0.6	0.6
Total	**1.2**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Work for Other DOE Contractors							
Operating	18.2	21.8	20.2	17.6	16.7	16.1	16.4
Capital Equipment	1.5	1.5	0.3	0.1	–	–	–
Construction	–	2.0	4.1	5.9	4.4	2.2	0.9
Total	**19.7**	**25.3**	**24.6**	**23.6**	**21.1**	**18.3**	**17.3**
Total DOE							
Operating	236.7	260.7	285.7	298.8	310.7	320.8	328.7
Capital Equipment	25.7	24.3	46.0	44.5	44.8	47.8	45.8
Construction	14.1	33.1	32.6	18.6	37.1	44.8	41.8
Total	**276.5**	**318.1**	**364.3**	**361.9**	**392.6**	**413.4**	**416.3**

Table VI(2)(b) Personnel by Secretarial Officer

PERSONNEL BY SECRETARIAL OFFICER							
Full-time Equivalents (FTE)	FY98	FY99	FY2000	FY2001	FY2002	FY2003	FY2004
Office of Science (SC)							
Direct FTE	617	675	762	778	821	843	834
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Direct FTE	83	95	96	101	102	104	105
Assistant Secretary for Fossil Energy (FE)							
Direct FTE	9	10	17	19	19	19	20
Assistant Secretary for Environmental Restoration and Waste Management (EM)							
Direct FTE	74	74	78	78	78	78	78
Assistant Secretary for Defense Programs (DP)							
Direct FTE	22	22	17	8	5	-	-
Office of Nonproliferation and National Security (NN)							
Direct FTE	4	4	4	3	3	3	3
Assistant Secretary for Environment, Safety, and Health (EH)							
Direct FTE	3	3	3	3	3	3	3
Total DOE							
Direct FTE	**812**	**883**	**977**	**990**	**1,031**	**1,050**	**1,043**
Work for Other DOE Contractors							
Direct FTE	93	119	116	111	99	87	81
Work for Others-Non-DOE							
Direct FTE	332	436	433	440	434	432	435
Work for Others-Total	425	555	549	551	533	519	516
Total Lab Direct	1,237	1,438	1,526	1,541	1,565	1,569	1,559
Total Lab Indirect	1,115	1,118	1,120	1,123	1,125	1,128	1,130
Total Lab Personnel	2,352	2,556	2,646	2,664	2,690	2,697	2,689

Table VI(3)(a) Office of Science Funding and Personnel

RESOURCES BY MAJOR PROGRAM							
($ in Millions–BA)	FY98	FY99	FY2000	FY2001	FY2002	FY2003	FY2004
AT Magnetic Fusion							
Operating	4.0	5.7	6.0	6.1	6.3	6.4	6.5
Capital Equipment	–	0.3	0.3	0.4	0.4	0.4	0.4
Construction	–	–	–	–	–	–	–
Total	**4.0**	**6.0**	**6.3**	**6.5**	**6.7**	**6.8**	**6.9**
KA High Energy Physics							
Operating	20.4	24.1	27.5	30.2	32.4	34.4	36.0
Capital Equipment	6.5	6.9	15.9	12.1	8.9	7.0	6.5
Construction	(0.6)	–	3.5	3.5	3.5	3.5	3.5
Total	**26.3**	**31.0**	**46.9**	**45.8**	**44.8**	**44.9**	**46.0**
KB Nuclear Physics							
Operating	16.6	16.0	18.0	19.4	20.3	21.0	22.0
Capital Equipment	3.3	3.4	3.9	5.4	9.6	14.5	13.6
Construction	3.8	3.8	0.3	0.5	0.5	0.5	0.5
Total	**23.7**	**23.2**	**22.2**	**25.3**	**30.4**	**36.0**	**36.1**
KC02 Materials Sciences							
Operating	43.5	45.3	46.6	53.0	55.4	57.9	60.4
Capital Equipment	3.8	3.5	13.4	14.0	14.1	14.2	14.3
Construction	1.7	1.7	1.7	3.7	3.8	3.9	4.0
Total	**49.0**	**50.5**	**61.7**	**70.7**	**73.3**	**76.0**	**78.7**
KC03 Chemical Sciences							
Operating	8.1	8.0	9.5	10.9	11.2	11.7	12.0
Capital Equipment	1.0	1.4	4.7	4.5	4.1	3.8	3.0
Total	**9.1**	**9.4**	**14.2**	**15.4**	**15.3**	**15.5**	**15.0**
KC04 Engineering and Geosciences							
Operating	2.5	2.4	2.9	3.5	4.0	4.5	4.6
Capital Equipment	0.5	0.7	0.4	0.4	0.4	0.4	0.4
Total	**3.0**	**3.1**	**3.3**	**3.9**	**4.4**	**4.9**	**5.0**
KC06 Energy Biosciences							
Operating	1.0	1.0	1.1	1.2	1.2	1.3	1.3
Capital Equipment	0.1	–	0.2	0.1	–	–	–
Total	**1.1**	**1.0**	**1.3**	**1.3**	**1.2**	**1.3**	**1.3**
KD Energy Research Analyses							
Operating	0.1	–	–	–	–	–	–
Total	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table VI(3)(a) Office of Science Funding and Personnel–*cont.*

RESOURCES BY MAJOR PROGRAM							
KG Multiprogram Energy Laboratories-Facilities Support							
Construction	2.4	4.9	6.1	4.1	24.6	34.7	32.9
Total	**2.4**	**4.9**	**6.1**	**4.1**	**24.6**	**34.7**	**32.9**
KJ Computational and Technology Research							
Operating	52.1	53.3	56.5	58.6	60.6	62.8	64.9
Capital Equipment	5.5	4.0	4.0	4.0	4.0	4.0	4.0
Construction	0.5	–	–	–	–	–	–
Total	**58.1**	**57.3**	**60.5**	**62.6**	**64.6**	**66.8**	**68.9**
KP Biological and Environmental Research							
Operating	30.4	40.2	46.9	46.4	49.2	50.0	50.1
Capital Equipment	3.2	2.6	2.8	3.6	3.3	3.4	3.5
Total	**33.6**	**42.8**	**49.7**	**50.0**	**52.5**	**53.4**	**53.6**
KT University and Science Education							
Operating	–	–	0.9	0.9	1.1	1.1	1.1
Total	**–**	**–**	**0.9**	**0.9**	**1.1**	**1.1**	**1.1**
KX Research Program Direction							
Operating	–	–	0.3	0.3	0.3	0.3	0.3
Total	**–**	**–**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Office of Science							
Operating	178.6	196.3	216.2	230.5	242.1	251.2	259.1
Capital Equipment	23.7	22.8	45.6	44.3	44.7	47.8	45.7
Construction	7.7	10.3	11.6	11.8	32.4	42.6	40.9
Total	**210.0**	**229.4**	**273.4**	**286.6**	**319.2**	**341.6**	**345.7**
Direct FTE	617	675	762	778	821	843	834

Table VI(3)(b) Energy Efficiency and Renewable Energy Funding and Personnel

ENERGY EFFICIENCY AND RENEWABLE ENERGY FUNDING AND PERSONNEL							
	1998	1999	2000	2001	2002	2003	2004
EB Solar and Renewable Resource Technologies							
Operating	1.1	1.8	1.9	3.5	3.6	3.9	4.0
Total	**1.1**	**1.8**	**1.9**	**3.5**	**3.6**	**3.9**	**4.0**
EC Building Technology, State and Community Sector							
Operating	10.3	11.8	11.7	12.0	12.4	13.2	13.8
Total	**10.3**	**11.8**	**11.7**	**12.0**	**12.4**	**13.2**	**13.8**
ED Industrial Sector							
Operating	2.0	2.2	1.2	1.1	1.2	1.2	1.3
Total	**2.0**	**2.2**	**1.2**	**1.1**	**1.2**	**1.2**	**1.3**
EE Transportation Sector							
Operating	3.6	4.2	5.7	5.9	6.1	6.1	6.3
Capital Equipment	0.1	–	–	–	–	–	–
Total	**3.7**	**4:2**	**5.7**	**5.9**	**6.1**	**6.1**	**6.3**
EL Federal Energy Management Program							
Operating	2.0	1.7	2.2	2.2	2.3	2.5	2.6
Total	**2.0**	**1.7**	**2.2**	**2.2**	**2.3**	**2.5**	**2.6**
Total, Assistant Secretary for Energy Efficiency and Renewable Energy							
Operating	19.0	21.7	22.7	24.7	25.6	26.9	28.0
Capital Equipment	0.1	–	–	–	–	–	–
Total	**19.1**	**21.7**	**22.7**	**24.7**	**25.6**	**26.9**	**28.0**
Direct FTE	83	95	96	101	102	104	105

Table VI(3)(c) Fossil Fuel and Other DOE Program Funding and Personnel

FOSSIL FUEL AND OTHER DOE PROGRAM FUNDING AND PERSONNEL

	1998	1999	2000	2001	2002	2003	2004
AA Coal							
Operating	0.2	0.3	0.5	0.5	0.5	0.5	0.6
Total	**0.2**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**	**0.6**
AB Gas							
Operating	0.6	0.5	1.1	1.3	1.4	1.4	1.5
Total	**0.6**	**0.5**	**1.1**	**1.3**	**1.4**	**1.4**	**1.5**
AC Petroleum							
Operating	2.0	2.4	4.5	5.4	5.5	5.7	5.9
Total	**2.0**	**2.4**	**4.5**	**5.4**	**5.5**	**5.7**	**5.9**
Total, Assistant Secretary for Fossil Energy							
Operating	2.8	3.2	6.1	7.2	7.4	7.6	8.0
Total	**2.8**	**3.2**	**6.1**	**7.2**	**7.4**	**7.6**	**8.0**
Direct FTE	9	10	17	19	19	19	20
EW Environmental Restoration and Management—Defense							
Operating	4.0	4.3	5.8	5.8	5.7	5.5	5.5
Capital Equipment	0.2	0.0	–	–	–	–	–
Total	**4.2**	**4.4**	**5.8**	**5.8**	**5.7**	**5.5**	**5.5**
EX Environmental Restoration and Management—Non-Defense							
Operating	9.4	9.4	10.2	9.6	9.9	10.1	8.1
Capital Equipment	0.2	0.0	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–
Total	**9.6**	**9.4**	**10.3**	**9.7**	**10.0**	**10.2**	**8.2**
Total, Assistant Secretary for Environmental Restoration and Waste Management							
Operating	13.4	13.8	16.1	15.4	15.6	15.6	13.7
Capital Equipment	0.4	0.0	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–
Total	**13.7**	**13.8**	**16.1**	**15.5**	**15.7**	**15.7**	**13.7**
Direct FTE	74	74	78	78	78	78	78
DP Defense Programs Activities							
Construction	6.4	20.8	16.8	0.9	0.3	–	–
Total	**6.4**	**20.8**	**16.8**	**0.9**	**0.3**	–	–

Table VI(3)(c) Fossil Fuel and Other DOE Program Funding and Personnel—*cont.*

	1998	1999	2000	2001	2002	2003	2004
Total, Assistant Secretary for Defense Programs							
Construction	6.4	20.8	16.8	0.9	0.3	–	–
Total	**6.4**	**20.8**	**16.8**	**0.9**	**0.3**	**–**	**–**
Direct FTE	22	22	17	8	5	–	–
GC Nonproliferation and National Security							
Operating	1.3	1.2	1.7	1.6	1.6	1.7	1.7
Total	**1.3**	**1.2**	**1.7**	**1.6**	**1.6**	**1.7**	**1.7**
GJ Arms Control and Nonproliferation							
Operating	2.4	2.0	2.1	1.1	1.1	1.1	1.1
Total	**2.4**	**2.0**	**2.1**	**1.1**	**1.1**	**1.1**	**1.1**
Total, Office of Nonproliferation and National Security							
Operating	3.7	3.2	3.8	2.7	2.7	2.8	2.8
Total	**3.7**	**3.2**	**3.8**	**2.7**	**2.7**	**2.8**	**2.8**
Direct FTE	4	4	4	3	3	3	3
HC Environment, Safety and Health (Non–Defense)							
Operating	1.2	0.6	0.6	0.6	0.6	0.6	0.6
Total	**1.2**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Total, Assistant Secretary for Environment, Safety and Health							
Operating	1.2	0.6	0.6	0.6	0.6	0.6	0.6
Total	**1.2**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Direct FTE	3	3	3	3	3	3	3

Table VI(4) Work for Others Funding and Personnel

WORK FOR OTHERS FUNDING AND PERSONNEL	1998	1999	2000	2002	2002	2003	2004
Work for Other DOE Contractors							
Operating	18.2	21.8	20.2	17.6	16.7	16.1	16.4
Capital Equipment	1.5	1.5	0.3	0.1	–	–	–
Construction	–	2.0	4.1	5.9	4.4	2.2	0.9
Total	**19.7**	**25.3**	**24.6**	**23.6**	**21.1**	**18.3**	**17.3**
Direct FTE	93	119	116	111	99	87	81
Work for Others—Federal Agencies							
Department of Defense	13.6	13.1	12.2	10.5	10.4	10.6	10.6
Capital Equipment	–	10.6	–	–	–	–	–
EPA	5.3	5.5	5.6	6.2	6.5	6.9	7.1
Department of Interior	0.3	1.0	1.3	1.4	1.4	1.4	1.4
NASA	6.5	7.4	6.1	6.1	6.3	6.2	6.3
National Institutes of Health	14.7	18.6	26.1	28.0	27.2	25.7	26.0
National Science Foundation	0.6	0.2	0.2	0.2	0.2	0.2	0.2
Other Federal	0.5	4.8	5.7	6.8	6.5	6.7	6.0
Capital Equipment	–	–	–	–	–	–	–
Total Federal Operating	41.5	50.6	57.2	59.2	58.5	57.7	57.6
Capital Equipment	–	10.6	–	–	–	–	–
Construction	–	–	–	–	–	–	–
Total	**41.5**	**61.2**	**57.2**	**59.2**	**58.5**	**57.7**	**57.6**
Work for Others—Non-Federal Agencies							
Universities	13.5	10.6	16.6	17.8	17.9	17.5	17.9
State/Local Gov't/Non-Profit	2.0	2.2	3.0	2.7	2.6	2.0	1.9
Domestic	3.5	3.8	2.8	1.4	1.2	1.3	1.3
Other Non-Federal	9.1	12.2	13.9	14.0	13.5	14.6	15.0
Total Non-Federal Operating	28.1	28.8	36.3	35.9	35.2	35.4	36.1
Capital Equipment	–	.5	–	–	–	–	–
Construction	–	1.0	–	–	–	–	–
Total	**28.1**	**30.3**	**36.3**	**35.9**	**35.2**	**35.4**	**36.1**
Work for Others—Non-DOE Contractors							
Operating	69.6	79.4	93.5	95.1	93.7	93.1	93.7
Capital Equipment	–	11.1	–	–	–	–	–
Construction	–	1.0	–	–	–	–	–
Total	**69.6**	**91.5**	**93.5**	**95.1**	**93.7**	**93.1**	**93.7**
Direct FTE	332	436	433	440	434	432	435

Table VI(5)(a) Subcontracting and Procurement

SUBCONTRACTING AND PROCUREMENT				
($ in Millions-Obligated)	FY 1998	FY 1999	FY 2000	FY 2001
Subcontracting and Procurement from:				
Universities	9.6	9.8	10.0	10.2
All Others	144.9	147.8	150.8	153.9
Transfers to Other DOE Facilities	2.5	2.6	2.6	2.7
Total External Subcontracts and Procurement	157.0	160.2	163.4	166.8

Table VI(5)(b) Small and Disadvantaged Business Procurement

SMALL AND DISADVANTAGED BUSINESS PROCUREMENT		
($ in Millions-B/A)	FY 1998	FY 1999
Procurement from Small and Disadvantaged Business	50.0	37.0
Percent of Annual Procurement	44.2%	32.0%
Available Subcontracting Dollars	113.3	115.5

Table VI(6) Experimenters at Designated User Facilities (FY 1998)

EXPERIMENTERS AT DESIGNATED USER FACILITIES

	Number of Experimenters	Number of Organizations	Percentage of Use
Advanced Light Source			
Laboratory	143	4	25%
Other DOE Laboratories	49	7	12%
Other U.S. Government	2	2	<1%
University	235	55	36%
Industry	79	32	12%
Foreign Laboratory	33	24	5%
Foreign University	89	46	6%
Foreign Industry	14	13	2%
Other	15	7	2%
Total	**659**	**190**	**100%**
National Energy Research Scientific Computing*			
Laboratory	87	4	8%
Other DOE Laboratories	149	17	58%
Other U.S. Government	9	6	3%
University	180	76	31%
Industry	20	12	<1%
Other	2	2	<1%
Foreign University	1	1	<1%
Total	**448**	**117**	**100%**
88-Inch Cyclotron			
Laboratory	66	1	59%
Other DOE Laboratories	4	2	<1%
Other U.S. Government	14	3	13%
University	57	12	9%
Industry	26	12	3%
Foreign Laboratory	10	7	1%
Foreign University	29	11	15%
Foreign Industry	1	1	<1%
Total	**207**	**49**	**100%**

*NERSC data is available for Number of Projects (approximately the number of Principal Investigators). There were over six times as many individual users as number of projects.

Table VI(6) Experimenters at Designated User Facilities—*cont.*

	Number of Experimenters	Number of Organizations	Percentage of Use
National Center for Electron Microscopy			
Laboratory	75	1	35%
Other DOE Laboratories	4	4	2%
Other U.S. Government	6	2	3%
University	87	15	40%
Industry	8	8	4%
Foreign Laboratory	2	1	1%
Foreign University	34	25	15%
Foreign Industry			
Other			
Total	**216**	**56**	**100%**
National Tritium Labeling Facility+			
Laboratory	2	1	.5%
Other DOE Laboratories	1	1	.5%
Other U.S. Government	1	1	1%
University	5	3	3%
Industry	6	4	10%
Foreign Industry	3	3	.5%
Other	3	2	2%
Total	**21**	**15**	**17.50%**
Grand Total			
Laboratory	**373**	**11**	**31%**
Other DOE Laboratories	**207**	**31**	**17%**
Non DOE U.S. Government	**32**	**14**	**5%**
University	**564**	**161**	**29%**
Industry	**139**	**67**	**7%**
Foreign Laboratory	**45**	**32**	**2%**
Foreign University	**153**	**83**	**9%**
Foreign Industry	**18**	**17**	**>1%**
Other	**19**	**11**	**>1%**
Total	**1550**	**427**	**100%**

+National Tritium Labeling Facility statistics are for formal Users of the Service Functions per NIH criteria. Balance of use is for the additional activities of Core Research and Collaboration which also involve both people within LBNL and at other institutions.

Table VI(7) University and Science Education

UNIVERSITY AND SCIENCE EDUCATION

	FY1998			FY1999		
	Total	Minorities	Women	Total	Minorities	Women
PRE-COLLEGE PROGRAMS						
Student Programs	8	2	7	7	5	3
Teacher Programs	28	7	17	42	10	24
Special Programs	850	n/a	n/a	1500	n/a	n/a
UNDERGRADUATE PROGRAMS						
Student Programs	76	24	44	89	20	40
Special Programs	–	–	–	–	–	–
POSTGRADUATE PROGRAMS						
Post Doctoral Programs	225	79	42	242	88	46
Faculty Programs	1	–	1	1	–	1

Laboratory Profile: Lawrence Berkeley National Laboratory

Laboratory Information

Location: Berkeley, California
No. of Full-Time Employees: 3345
PhD FTE: 1053 Non PhD FTE: 1190
Contractor: University of California
Accountable Program Office: Office of Science
Field Office: Oakland
Web Site: www.lbl.gov

Funding Sources

Office of Science 210.1
Energy Efficiency 18.9
Environmental Management 10.3
Fossil Energy 2.8
Nonproliferation & National Security 3.7
Defense Programs 6.4
Other DOE 3.8
Non DOE Funding 67.0

Description

Berkeley Lab is unique among the multiprogram laboratories with its close proximity to a major research university, the University of California at Berkeley. The Laboratory's principal role for DOE is fundamental science, including developing powerful experimental and computational systems for exploring properties of matter, deepening understanding of molecular interactions and synthesis, and gaining insights into biological molecules, cells, and tissues. The Lab is a major contributor of research on energy resources, including the earth's structure and energy reservoirs, fusion, combustion of fuels, and keys to efficient energy storage and use. The Lab is extensively involved in environmental research, including subsurface contaminant transport, bioremediation and indoor air quality. User facilities include the Advanced Light Source, National Energy Research Scientific Computing Center, National Center for Electron Microscopy, 88-Inch Cyclotron, Biomedical Isotope Facility and National Tritium Labeling Facility. Our multidisciplinary research environment and unique location serve to strengthen partnerships with industry, universities and government laboratories. Partnerships include the Joint Genome Institute and programs in advanced accelerator and detector systems, x-ray lithography, high-speed networking and computer architectures, building and lighting systems, and science education.

Distinctive Competencies and Major Facilities

MAJOR FACILITIES

Advanced Light Source: One of the world's brightest sources of ultraviolet light, soft x-rays and a powerful source of higher energy x-rays, serving as an excellent probe of the electronic properties of atoms, molecules, surfaces and condensed matter, and a powerful tool for determining the structure of macromolecules. 850 scientists are users on the ALS.

National Energy Research Scientific Computing Center and the Energy Sciences Network: Providing leading-edge computational resources, science and services; and national network for the scientific community. 3200 scientists are users at NERSC.

88-Inch Cyclotron: Produces the widest range of high-intensity and heavy ions in the US for nuclear science. Hosts over 200 users.

National Center for Electron Microscopy: One Angstrom, High-Voltage, Spin Polarized Low Energy, and Atomic Resolution Electron Microscopes. The facility hosts about 220 users annually.

National Tritium Labeling Facility: Prepares tritiated compounds as tracers for use in biosciences and health research.

Biomedical Isotope Facility: Provides short-lived tracers for high resolution Positron Emission Tomographies medical imaging.

DISTINCTIVE COMPETENCIES

Computational Science & Networking: Computational fluid dynamics and chemistry; applied mathematics; visualization; network research.

Particle and Photon Beams: Design of accelerators; induction linacs for fusion; beam dynamics; magnet design; x-ray optics.

Bioscience and Biotechnology: Structural biology and crystallography; genomics; cytogenetics; medical imaging.

Characterization, Synthesis, and Theory of Materials: Alloys; heterostructures; superconducting, magnetic, & nanostructural materials.

Advanced Technologies for Energy Supply and Energy Efficiency: Geo-resources; building technologies; electrochemistry; energy analysis.

Chemical Dynamics, Catalysis, & Surface Science: Reaction dynamics; photochemistry; surface structures; heterogeneous catalysis.

Advanced Detector Systems: Detectors for high-energy physics, nuclear science, and astrophysics; particle and photon detection.

Environmental Assessment & Remediation: Global environment; indoor air; subsurface remediation; nuclear waste isolation; actinides.

Funding by Activity

Use millions of dollars, rounded to one decimal place

	FY 96	FY 97	FY 98	FY 99
R&D and Operations	188.0	207.8	211.0	206.4
Construction	31.4	14.0	16.0	25.5
Capital	34.4	31.8	22.2	16.7
Non-DOE Funds	60.6	57.6	67.0	69.1
External Performers	6.0	7.7	6.8	7.0
Total	320.4	318.9	323.0	324.7

DOE Mission Footprint

Non-DOE funds included

Science and Technology	79.6%
Energy Resources	8.6%
Environmental Quality	8.7%
National Security	3.1%
(Total DOE Mission Footrpint $244.9 M) Total	100.0%

NOTE: Differences may exist between data in this Profile and in the Institutional Plan due to varying reporting instructions and definitions.

Key Research and Development Activities

Science and Technology

Berkeley Lab's principal role as a fundamental science laboratory originated in supporting DOE missions in high energy and nuclear physics (particle physics), and continued with its pre-eminence in computation (first supercomputer available on the internet), the frontiers of physical chemistry and materials science and radiobiology, and the geoscience of complex environments. Berkeley Lab's science role continues to support DOE's mandate to apply the most powerful tools for advances in genomics, particle physics and astrophysics, nanomaterials, chemical dynamics, and heterogeneous subsurface environments.

* High throughput genome sequencing and macromolecular structure determination; functional genomics, molecular and cell biology; cellular differentiation, carcinogenesis and aging; subcellular structure; biochemical reaction networks, diagnostic imaging; boron neutron capture therapy
* Detector systems for high energy and nuclear physics and astrophysics; accelerators for physics research; theoretical particle and nuclear physics; superheavy element science; nuclear data evaluation
* High performance computing and computer science, and high-speed networks for scientific information systems, imaging and visualization; virtual laboratories; remote experimentation and databases
* Molecular design, synthesis and characterization of materials; low dimensional materials, materials physics and chemistry research, structure of materials, x-ray optics and advanced spectroscopy
* Fundamental chemistry and chemical physics and reaction dynamics; surface science and catalysis; reactivity of transient species; electron spectroscopy; actinide chemistry
* Ion beam science and technology development with medical and plasma applications
* Structure and dynamics of the Earth, geochemistry, geophysical imaging, and isotope geochemistry

Energy Resources

Berkeley Lab supports DOE's energy role beginning with its pioneering work in the geosciences and geothermal energy; the applications of physical science to energy efficiency; the development of heavy ion drivers and high current ion beams for fusion energy; and international analysis of energy supply and demand. Berkeley Lab now brings powerful instrumentation and computational tools to advance these areas and to move ahead on DOE's missions for developing the next generation of batteries, building systems, fusion and fossil energy sources.

* Heavy ion drivers for inertial fusion energy including induction acceleration, beam manipulation, and beam combining technologies
* Buildings energy efficiency-windows and lighting systems including advanced thin films, superwindows, and novel illumination sources
* Electrochemical energy storage, photochemistry for high-performance rechargeable batteries and fuel cells
* Petroleum reservoir characterization and georesources through improved geophysical imaging and geologic transport models
* Electric reliability research through grid computer modeling and new technologies to improve grid performance
* Energy consumption and supply analysis in specific industries and technology areas, and in developing countries

Environmental Quality

Berkeley Lab has contributed to DOE's environmental quality mission through its discoveries on the importance of radon and indoor air quality, the potential impact of upper atmospheric emissions on atmospheric chemistry, and the mechanisms of contaminant transport through heterogeneous subsurface environments. Berkeley Lab now brings powerful computational and experimental tools for understanding risks at Yucca Mountain, the formation and control of contaminants from combustion and in flue gases, and the testing of global climate models.

* Subsurface characterization and the geologic isolation of high-level nuclear waste
* Contaminant transport, fate, and effects; physicochemical processes; repository performance
* Environmental biotechnology and environmental remediation technology
* Oceanic carbon sequestration, global emissions analysis and global climate change modeling
* Emissions and combustion control science and systems development

National Security

Working jointly with the DOE's national security laboratories, LBNL researchers perform non-classified research in support of critical national security and nonproliferation missions. This research encompasses:

* Detector development for portable lightweight gamma ray spectrometers
* Membrane-based calorimetric sensors for the detection of biological materials
* Laser fluorescence and nuclear detection capabilities for capillary electrophoresis
* Predictive tools to understand the dispersion of toxic agents in buildings

Significant Accomplishments

Crystallographic Studies of Protein Structures: Determination of more than 100 protein structures with rapid protein crystallography at the Advanced Light Source; including unique hyperthermophile proteins and many enzymes and drug design targets. 1997-1999

Tubulin Structure: Electronic diffraction determination of the structure of Tubulin, a key protein of the cytoskeleton and the nucleoskeleton; X-ray studies revealing the structure of the cytoskeleton and the nucleoskeleton, and their importance in intracellular transport. 1996-1998

Accelerated Expansion of the Universe: Discovery and measurement of the most distant supernovas which give experimental evidence that the universe may expand forever. This research by the Supernova Cosmology Project was named "Breakthrough of the Year for 1998" by Science Magazine. 1995-1998

Extracellular Matrix and Breast Cancer: Development of evidence that the extracellular matrix is important to the phenotypic expression of breast cancer cells. This theory holds that there is a direct link between the development of breast cancer and a network of fibrous and globular proteins surrounding breast cells called the "extracellular matrix" or ECM. The ECM is crucial to the normal functioning of cells and loss of or damage to the ECM can lead to malignancy. Each new ECM experiment has yielded valuable knowledge about both normal and breast cancer cells. 1980-1998

Anisotropy of the Cosmic Background Radiation: The systematic observation of ripples in the radiation afterglow of the primeval explosion that began the universe. These ripples are "hot" and "cold" regions in space, more than 1200 million light years across with temperature differences of a hundred-thousandth of a degree. They are thought to be the primordial seeds from which our present-day universe grew. The ripples came from data collected by Berkeley Lab's experimental equipment mounted inside NASA's Cosmic Background Explorer (COBE) satellite. 1975-1998

Billions of Dollars in Annual Energy Savings: Nationally significant energy savings through development of the most efficient window technology currently available, building energy analysis models now widely used, and transfer of advanced fluorescent lighting technology to industry. 1995-1998

Dominant Gene Link in Heart Disease: Identified first link between heart disease and a single dominant gene, showing that atherosclerosis results from a mix of behavioral, environmental and genetic factors. 1992-1998

First Directed Beams of Femtosecond X-rays: Strobe-like pulses of x-rays lasting only a few hundred millionths of a billionth of a second that can be used to study ultra-fast physical and chemical processes. 1990-1998

Transgeneic Mouse Models: A team of Berkeley Lab cell biologists and geneticists developed the first transgenic mouse that fully mimics all the symptoms of human sickle cell disease. 1996-1997

Subsurface Imaging: Systems for measuring and subsequent control of subsurface environmental processes including the highest resolution subsurface imaging, accurate prediction of subsurface transport, and cost effective solutions to containment of inorganic soils contamination. 1980-1997

Top Quark Detection: The discovery of the top quark, the last of six quarks predicted by the Standard Model of particle physics and one of the fundamental building blocks of matter, involved Berkeley Lab scientists and engineers in both of the project's experiments--the Collider Detector Facility (CDF) and the D-Zero. One of Berkeley Lab's most important contributions was the design of a sophisticated microchip for the Silicon Vertex Detector, an extremely high resolution instrument in the central CDF detector system. 1980-1996

Discovering Radon Exposure: Berkeley Lab was where the threat to American homes posed by radon was discovered. Studies have shown that radon enters buildings through cracks and pores in foundations. Exposure to radon gas in U.S. homes is thought to account for as many as 10,000 cases of lung cancer each year. Reliable predictions of the danger areas are needed for a cost-effective nationwide remediation program. 1985-1996

Catalytic Antibodies: Research that effectively expanded the genetic code from the 20 amino acids that nature provides to an exotic and potentially limitless array of synthetic amino acids won the Department of Energy's Lawrence Memorial Award for the Berkeley Lab. A Berkeley chemist invented a technique that made possible the incorporation of unnatural amino acids with novel physical and chemical properties into proteins by combining important features of catalytic antibodies and hybrid enzymes that he synthesized. 1985-1995

Predicting the Performance of Materials: Berkeley Lab scientists created the first-ever harder-than-diamond crystals and proved that computer models can play an effective role in the development of new materials. The new superhard crystal, a compound of carbon and nitrogen, was made from a recipe arrived at solely by theoretical calculations. A Berkeley Lab solid-state physicist was able to calculate that substituting carbon for silicon in the crystal structure of silicon-nitride would yield a super-hard carbon-nitride. Without this model, experimentalists might never have tried carbon-nitride. 1980-1995

The Multicast Backbone (M-Bone): An amazing new technology called the Multicast Backbone or M-Bone was developed by a team that included a Berkeley Lab computer scientist. M-Bone makes possible an electronic window through which users worldwide can not only see and talk to one another, but can work together on a shared "whiteboard." M-bone is designed to dynamically construct what are called " information distribution trees" using the shortest and most efficient routes. 1985-1995

"Stereotactic Radiosurgery": Pioneered the use of accelerated beams of ions as a scalpel on cancers and blood clots in ocular melanoma and arteriovenous malformations of the brain that conventional surgery can't touch. 1970-1992

World's Largest Optical Telescopes: Design and prototype of the Keck telescopes. Each features a segmented mirror measuring 10 meters across that functions as a single optical element. 1980-1985

Cause of Dinosaur Extinction: Through neutron activation methods, extraterrestrial iridium was discovered in the layer of sediments at the Cretaceous Tertiary boundary (65 million years ago) in many regions on the globe, establishing the hypothesis that the mass extinction of the dinosaurs (and other species) was initiated by a meteor impact(s), a view now widely accepted among scientists. 1981

High Energy Physics and Nuclear Science: Discovery of the antiproton and the particle resonances. 1956-1965 Discovery of 15 elements, including elements 118 and 116 and the island of nuclear stability, and numerous isotopes of medical and technological value. 1935-1999

Examples of Partnerships, Collaborations, and CRADAs

Category/Mission	*Partner*	*Description*
Research partnerships from academia, government and industry underlie many of the Berkeley Lab's programs. We have more than 4000 scientists from throughout the world who are users at our national facilities (remotely and on site), more than 2000 participating guests working at the Berkeley Lab, with over 1000 guests from academia demonstrating our close relations with universities. Berkeley Lab has more than 100 Collaborative Research and Development Agreements, many in the energy, biotechnology, semiconductor and computer -related industries.		
Science and Technology	Univ. California, Berkeley	Sequencing the *Drosophila* genome
	UC San Francisco	Transgenic mouse model of Sickle Cell Anemia
	Many universities	ATLAS detector for Large Hadron Collider
	Many universities	BABAR detector system for B-meson decay
	Many universities	Solenoidal detector for the Relativistic Heavy Ion Collider (RHIC)
	Ford Motor, Cummings Engine	Diesel Collaboratory - Computation partnership
	National Cancer Institute/ NIH	Chemical carcinogens; human mammary cell studies; progesterone receptors
	LLNL & LANL	Joint Genome Institute
	Fermilab	Silicon vertex detector upgrades for D-Zero and CDF experiments
	ORNL, BNL, LANL, ANL	Spallation Neutron Source
	State of California	Integrated science partnership in energy research
	Chiron	High throughput assay for screening novel anti-cancer compounds
	Amgen Inc.	Structure of the erythropoietin receptor
	Intel & IBM	X-ray photoemission microscopes at the Advanced Light Source
	CERN	NA-30 detector, magnets, ATLAS for Large Hadron Collider
	AMES	Heat capacity research, quasicrystals
	ORNL, ANL	DOE 2000 Collaboratory, interactive virtual labs
Energy Resources	Several universities	Inertial fusion energy research
	AID	Energy efficiency in foreign countries
	Scripps Inst. of Oceanography	Subsurface imaging of salt domes with marine magnetotellurics
	Many companies	Crosshole and surface to borehole electromagnetic sensing
Environmental Quality	Jackson State University, Ana Mendez University/DOD	Bioremediation, Education, Science and Technology (BEST)
	U.S. EPA	Volatile organic emissions research, HVAC analysis, cool roofs and efficient lighting
	PNNL	Environmental microbiology studies
	California State Water Board	Sacramento river delta environmental quality improvement
	TRW Env. Safety Systems	Yucca Mountain characterization studies
National Security	Batelle Memorial Institute	Detection of bacteria in the environment
	DOD/ARPA	Terrain image navigation database

Performance Metrics

Research-to-Support Ratio

	------FY 94-97, Actual------				---FY 98-00, Projected---		
	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00
Ratio	1.75	2.4	2.31	2.5	2.5	------	------

Percent of Technical Labor on Research

	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00
Percent	95%	95%	95%	95%	95%	------	------

Average Cost per Research FTE

	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00
Whole $	128	126	124	120	120	------	------
Constant FY $	144	138	133	125	123	------	------

VIII. ACKNOWLEDGMENTS

Institutional planning at Berkeley Lab is conducted as an annual management activity based on technical information contributed by Berkeley Lab's Divisions (see organization chart (Figure II(1)). Preparation of reporting documents is coordinated through the Office of Planning and Communications.

The following divisional staff coordinated information and assisted in preparation of the Institutional Plan:

Accelerator and Fusion Research	Joseph Chew, Alan Jackson
Advanced Light Source	Benjamin Feinberg, James Krupnick
Computing Sciences	David Stevens, Frank Hale
Chemical Sciences	Susan Torrano
Earth Sciences	Norman Goldstein
Environmental Energy Technologies	Donald Grether
Engineering	Dennis Peterson
Environment, Health, and Safety	Jack Bartley
Life Sciences	David Gilbert
Materials Sciences	Jeri Edgar
Nuclear Science	Janis Dairiki
Physical Biosciences	Kristin Balder-Froid
Physics	Cathy Thompson

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Assessment and Assurance	Otis Wong
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Educational Programs	Roland Otto
Facilities Planning	Laura Chen, Daniel Kevin
Laboratory Directed Research and Development	Todd Hansen
Technology Transfer	Cheryl Fragiadakis
Work Force Diversity	Harry Reed
Planning and Analysis	Karin Levy

Direct all correspondence regarding the Institutional Plan to:

Michael A. Chartock, Head
Office of Planning and Communications, MS 50A-4119
Ernest Orlando Lawrence Berkeley National Laboratory
1 Cyclotron Road
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/Publications/Institutional-Plan/