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ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 2001—FY 2005

July 2000

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PREFACE

The FY 2001-2005 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 2001-2005 Institutional Plan reflects and complements the Department of Energy's own *Strategic Plan* (September 1997), the *Energy Research Strategic Plan* (1997), the *Strategic Plan of the Office of Science* (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 Strategic Planning section describes our strategic thinking in the areas of human resources; work force diversity; communications and trust; worker, public, environmental, and asset protection programs; and management practices. The Infrastructure Strategic Planning section describes the *Berkeley Lab Strategic Buildings Plan* and our site and facility needs. The Resource Projections are estimates of required budgetary authority for Berkeley Lab's research programs.

CONTENTS

I. DIRECTOR'S STATEMENT

As we enter the 21st century, Berkeley Lab is prepared to address some of the greatest scientific issues of our time: advancing nanoscience to synthesize materials with tailored functions; defining the properties of the universe; working with the advances in quantitative biology to create a new predictive science; managing global carbon balance; and making computation a vital tool for scientific discovery. These challenges are at the heart of our strategic roles for the Office of Science and the Department of Energy (DOE), and are the basis for our vision for the year 2010.

Our plans for the future are founded on our accomplishments as well as our vision. Two of the top five achievements in Chemistry in 1999, according to the American Chemical Society's Chemical Engineering News, were the discovery of elements 118 and 116, and determining the entire structure of the Ribosome at the Advanced Light Source. In 1998, *Science* magazine's "Breakthrough of the Year" was for discovering that the universe is expanding at an accelerating rate. In 1999, two of *Science* magazine's top ten breakthroughs were in biosciences on sequencing the *Drosophila* genome and the work on the Ribosome. At the Advanced Light Source, the Macromolecular Crystallography beamline has been identified by DOE's peer review panel as the most productive beamline in the world in terms of the number of protein structures discovered and the number of papers published.

These mission accomplishments reaffirm DOE's leadership theme of "Strength through Science." To sustain these efforts, the nation needs to invest in the physical sciences infrastructure that underpins our discoveries, and ultimately, the economic prosperity and the health of our citizens. The Laboratory, and the nation, will fall far short of its scientific goals if the infrastructure of previous generations is relied upon for a new generation of science. These next few years are a critical turning point: either towards advancement of the natural sciences through investment; or erosion through continued reliance on Atomic Energy Commission facilities constructed a half century ago.

Berkeley Lab management is committed to work with DOE and the nation's science leadership to address scientific infrastructure renewal. This refocusing of our efforts includes additional and redirected resources for achieving the Laboratory's critical management and planning outcomes:

- **Working with the Office of Science, we are committed to building the user infrastructure necessary for our national scientific facilities.** We have allocated significant Laboratory resources to completing the Users Mezzanine of the Advanced Light Source (ALS), opening the Berkeley Lab Computing Center for scientific and administrative computing, and providing additional offices and laboratories at the National Center for Electron Microscopy and the 88-Inch Cyclotron. Now, we must join with DOE to further address space and other infrastructure needs of the growing user base and facility needs. For example, the number of users at the ALS has more than tripled in three years to more than 800 and is expected to double to 1600 by 2004—with just the completion of existing and planned beamlines. These users require offices, laboratories, staging and storage areas; and the ALS itself must consolidate its operational staff from more than three outlying buildings.
- **Advance information technology to secure American scientific leadership this decade.** We will make the investments to provide the computational resources demanded by our users and apply our fundamental capabilities in computational science-of-scale to address the national challenges for nanoscience, climate prediction, combustion modeling, subsurface transport, functional genomics, accelerator physics, and other research areas. These computational capabilities are integral to the DOE system as well as the Laboratory's scientific divisions, and apply the resources of the National Energy Research Scientific Computing Center (NERSC) and the Energy Sciences Network (ESnet). We are committed to work with DOE to develop a facility that will bring together varied disciplines using computational tools in order to benefit from potential common algorithms to elements of complex problems. We must also plan for the development of large-scale computational infrastructure at the Laboratory's main site. The logical option is the

demolition of the Bevatron building to accommodate the anticipated scale of necessary computing sciences infrastructure.

- **Provide the resources for an astrophysics satellite program that will define the fundamental properties of the universe through the observations of supernova.** The observation of sufficient numbers of supernova events is necessary to measure the mass density, energy density, and curvature of the universe and to address the newly discovered dark energy of the universe. This program advances physical science beyond the current formulations of cosmology and physics. Based on a series of national scientific reviews, the developing Department of Energy/National Science Foundation/National Aeronautics and Space Administration (DOE/NSF/NASA) partnership for this satellite mission requires the resources for planning and experimental development critical to this new effort.
- **New investment is needed to advance a broad front of post-genomics science for a more predictive and quantitative understanding and control of biological systems.** This includes developing rapid throughput systems for determining macromolecular structure, developing the tools to understand the molecular machinery of cells, and quantitatively modeling intracellular and intercellular dynamics that are the basis of gene expression and disease. The advances in the life sciences during the next decades will be also be dependent on the investments in complementary studies in the physical and computing sciences.
- **Experimental facilities are needed for the development of forefront inertial confinement fusion science experiments to deliver a scientifically well founded basis for a fusion energy supply.** We are continuing experimentation to answer scientific questions on the 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. Without the necessary program of experimental facilities, the nation will lose one of the crucial options for dealing with a future that will be unsustainable with existing sources of imported crude oil and coal and the consequences of degrading the earth's atmosphere.
- **Provide a safe, secure, and environmentally sound institutional infrastructure.** Berkeley Lab's facilities have a value of nearly a billion dollars and require reinvestment benchmarked to the performance of leading institutions, including industry and not-for profit laboratories. Achieving DOE's recommended 2 to 4 percent re-investment rate will require doubling to quadrupling the availability of resources currently being provided. A new level of investment requires a commitment by DOE, the Office of Science, and the Laboratory to assure that our facilities and diverse human resources can meet all their DOE mission obligations.

The Laboratory's human and physical resources are being called upon to serve the National Laboratory System in an integrated way. Berkeley Lab works in close partnership with Oak Ridge, Jefferson Lab, Brookhaven, Argonne, and Los Alamos for the design and fabrication of the Spallation Neutron Source, and works with Los Alamos on the Dual Axis Radiographic Hydrodynamic Test Facility. The Laboratory's geoscience capabilities are being deployed with Livermore to address the fundamental science needed to understand and make use of carbon sequestration. 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, in partnership with several other laboratories.

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 the Laboratory's capabilities in computation and energy analysis are contributing to improved electric reliability through modeling and better technology.

Meeting these future challenges requires the best in human resources, community relations, and management policies. We have established outreach, training, and retention programs to encourage and fully respect 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 community colleges and secondary schools promise local and national benefits from DOE technology and scientific resources. We are engaged in proactive involvement with our community and have recently advanced a community task force to evaluate and contribute to our plans for monitoring tritium. We are continuing a vegetation management program in concert with our neighbors and an automatic aid agreement with the City of Berkeley to provide first response to fires in the vicinity of the Laboratory. We have also taken many steps to assure the security of information at Berkeley Lab, and are recognized for the quality and effectiveness of our cyber security monitoring 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. We are advancing the goals, objectives, and strategies of the *Strategic Plan of the Office of Science* and related plans for DOE technology programs. The priority needs for supporting the mission of the Office of Science and fulfilling our scientific vision for 2010 are reflected in this Institutional Plan. It is our vision that national laboratories work in partnership to develop consensus on scientific directions, and to seek the consequent long-term investments required to further the nation's scientific interests.

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, Gammasphere, 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 Solenoidal Tracker (STAR) detector now operating at the Relativistic Heavy Ion Collider (RHIC) 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 laboratories 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; radio frequency (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; nanotechnology and studies of complexity.
- **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, engineering and administrative services 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 as well as a wide range of other university, government, and industry users; 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, including carbon sequestration; 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 reliability and 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; studies of complex systems and nanotechnology; 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; functional genomics and sequencing studies; cellular differentiation; carcinogenesis and aging; hematopoiesis; subcelluar structure; DNA repair; diagnostic and functional imaging; bioengineering, 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.
- **Genomics:** Production sequencing for the human genome and the genomes of other organisms; microbial genomics; comparative and computational genomics; development of sequencing and genome database technologies.

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 and neutrino 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 institutional management.

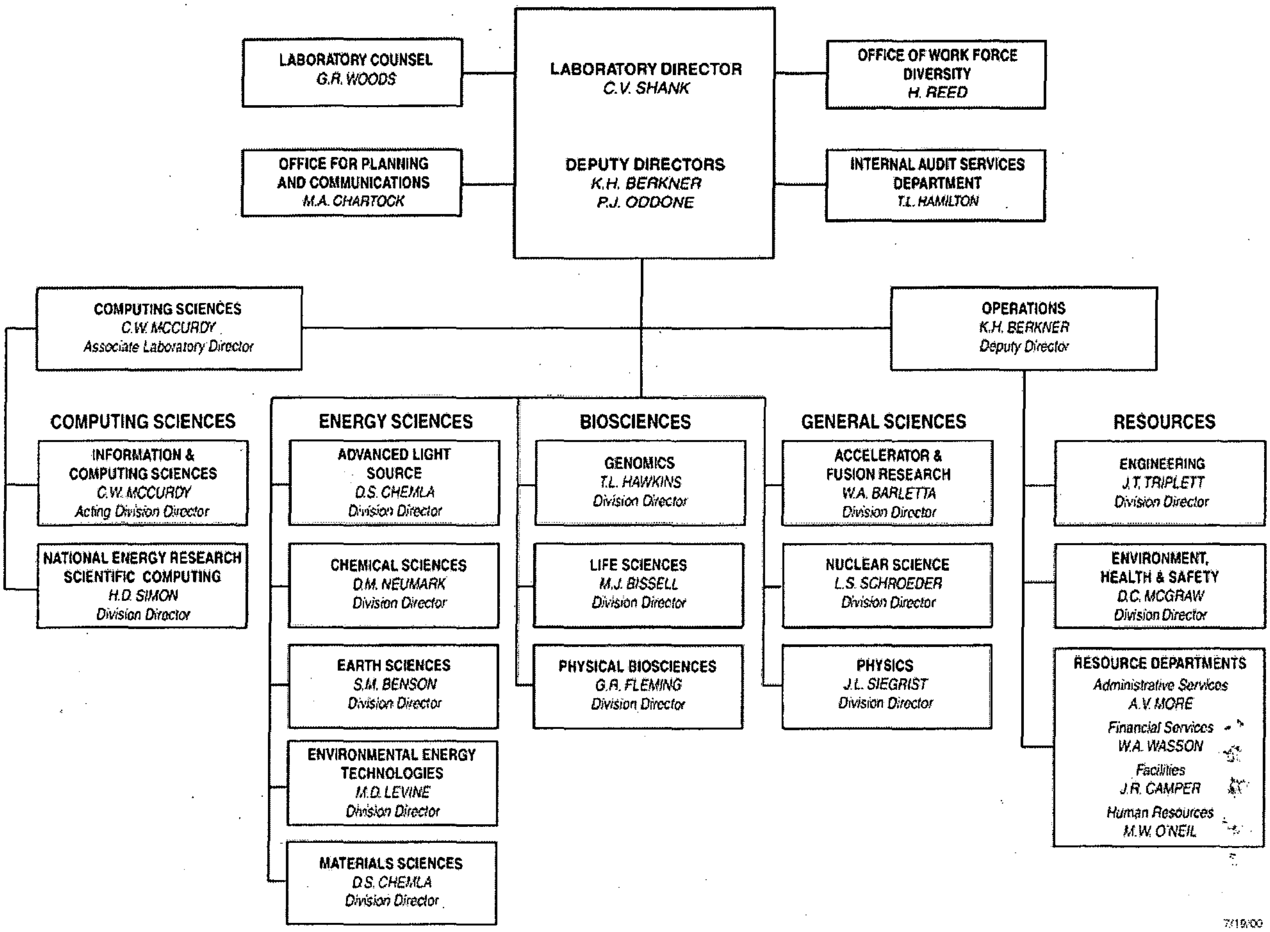

Figure II(1) Ernest Orlando Lawrence Berkeley National Laboratory Organization Chart

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 identifies 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.

- **Nanoscience and Complex Systems.** With the Office of Science, the Laboratory organized and participated in workshops to help lay the groundwork for a national initiative on nanoscience. 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 and the National Center for Electron Microscopy play leading roles both in our exploration of complexity and in contributing to the national structural biology effort (more than 300 users of the crystallography beamline alone).
- **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 a "Breakthrough of the Year." The STAR detector at Brookhaven's RHIC and the PEP II B Factory at SLAC have been commissioned and are taking data. Data collection has begun at the Sudbury Neutrino Observatory. In 1999, 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. 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 probe, 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.
- **Quantitative Biology.** Completion of the draft sequence of the human and *Drosophila* genomes, advances in structural biology, development of new simulation tools 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's new Physical Biosciences Division exploits 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 University of California (UC) at Berkeley campus, and are building our programs in computational biology to address this growing scientific opportunity. Completion of the draft human genome sequence has been so dramatic that the Joint Genome Institute (JGI) 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 energy 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 analysis tools developed here have saved billions of dollars in annual energy costs. Our recent findings on electric reliability research have contributed a basis for DOE recommendations on the next steps that DOE and the nation can take to improve reliability of the electric utility grid. 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. 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. The commitment for improved computing infrastructure has resulted in the establishment of Berkeley Lab's Oakland Science Center, which will house the new supercomputing acquisitions (and administrative computing equipment). 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 needed to deliver 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 *Strategic Plan* and *Research Portfolio* of the Office of Science and the program goals of our sponsoring offices.

SITUATION ANALYSIS: KEY CUSTOMERS

Berkeley Lab 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 are 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* and the *Science Portfolio* of the Office of Science, 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. The levels of funding provided by these offices is indicated in Section VII: Resource Projections and Tables.

Office of Basic Energy Sciences

Basic Energy Sciences programs in materials sciences 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 substantially increased 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 encompass 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 electrochemical processes and systems.

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.

In the FY 2001 budget, the Office of Science has proposed a set of coordinated investments focused on the scientific and computational problems that must be solved to address the critical scientific challenges in all of its research programs. The Office of Science has a long history of use of and accomplishments in scientific computing and has often served as a proving ground for many new computer technologies The Office of Science now intends to bring its experience and expertise to bear to realize the promise of terascale computers for its basic science programs.

To provide the large-scale resources needed by the scientific applications, the 0.5 teraflops Cray computer system currently in use at NERSC will be upgraded to a 5-teraflops IBM system in FY 2001. This facility has a distinguished history of service to the Office of Science research community, providing the community with general-purpose, high-end computing capabilities not available elsewhere in the Office of Science laboratory system. This upgrade can be achieved by making a modest additional investment in the NERSC budget. NERSC is also in the process of expanding its space to meet future requirements by use of an off-site building.

The Office of Advanced Scientific Computing Research also sponsors 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 Technology Research programs, to which Berkeley Lab makes important contributions.

Office of Biological and Environmental Research

Research at DOE's Joint Genome Institute successfully delivered on the national goal of a rough draft of the human genome sequence in March 2000. 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. The Center for Functional Imaging at Berkeley Lab is involved in developing advanced positron emission tomography (PET), single photon emission computed tomography (SPECT), and nuclear magnetic resonance imaging (MRI) systems with capabilities beyond those currently envisioned for commercial implementation. The purpose of this research is to apply new technologies to the study of atherosclerosis, heart disease, aging, neurological and psychiatric diseases, and cancer.

Berkeley Lab's Center for Functional Imaging is engaged in new studies in molecular biology and continuing work on improving radiopharmaceuticals and advanced instrumentation for application to medical science. New developments include:

- A compact and economical positron imaging device specially designed for high-resolution 3-D tomographic imaging of malignant tumors in the breasts and axillary nodes.
- A compact and economical positron imaging device specially designed for high-resolution 3-D tomographic imaging of tumors in the prostate.
- Twelve Tesla Nuclear Magnetic Resonance (NMR) Facility with capabilities to image the concentration of specific metabolites in the body and thereby determine the biochemical state of key organs in health, disease, and during treatment.

In parallel with an emerging national trend in molecular nuclear medicine, Berkeley Lab has initiated studies in four critical areas for DOE: using transgenic animal models to study the relationship between genomic variations and the occurrence of abnormal functions including cancer and other diseases. Research areas include examining the genetic basis 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; mammary biology; oncogenes and tumor suppressor genes; radiation and chemical carcinogenesis; and DNA repair. The research includes interspecies extrapolation and risk assessment in carcinogenesis; quantitative 3-D image analysis of the nucleus; interactions of genome and cellular microenvironment; protein annotation using machine learning methods; and structural genomics.

The Radiation Group 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.

Berkeley Lab will conduct research on boron neutron capture therapy as a potential treatment for glioblastoma multi-formae cancer. The Laboratory has 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.

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

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 including 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.

The Environmental Energy Technologies Division continues research on atmospheric aerosols and their implications for climate. In another climate-related effort, studies are underway on changes to land use and forestry. The goal of these studies is to illustrate the potential for carbon sequestration and emissions reduction for different types of mitigation options—by country and globally.

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 by 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. The work also includes studies of plasma heating by various methods, and support for networking and computing for fusion energy science.

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, the silicon tracker and pixel detector arrays.

The Low-Energy Ring for the B Factory at Stanford Linear Accelerator Center, is now operating along with the Babar Detector. Berkeley Lab has made essential contributions to the Babar Detector, and all components are performing well. The Berkeley Lab group is now moving onto physics analysis of the data.

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. The Berkeley Lab group is making an essential contribution to the Run II Upgrade through work on the tracking systems and offline software.

The Accelerator and Fusion Research Division conducts a program in accelerator research that addresses the challenges of very high field magnet designs and fabrication. Berkeley Lab leads a national program in superconducting materials development. Advanced investigations include optical accelerator and muon collider/neutrino factory research and development.

In addition, the Laboratory works with the High Energy Physics Office as landlord and steward for the Laboratory's General Purpose Equipment and General Plant Projects essential for the maintenance and scientific infrastructure of the Laboratory. The recent Landlord Activities Review highlighted the needs for full consideration of the infrastructure needs and operational issues before the Laboratory.

Nuclear science research at Berkeley Lab will continue to focus on the experimental and theoretical study of nuclear properties under extreme conditions and to use nuclei as a quantal system to test fundamental symmetries and to understand the weak interaction. Berkeley Lab research programs are closely coupled with national priorities as defined in the DOE/NSF 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. All of these activities are focused on maintaining Berkeley's traditional role in world-class nuclear physics.

The main focus of the relativistic nuclear collisions research program at Berkeley Lab is at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, which expects to run its first experiments this summer. Berkeley Lab is the lead laboratory for the Solenoidal Tracker at RHIC (STAR) detector designed to identify and study the phase transition between normal nuclear matter and quark matter (the so-called quark-gluon plasma). The STAR Time Projection Chamber (the heart of STAR), constructed by Berkeley Lab scientists and engineers, is ready and waiting for beam on day-1. Looking to the future, Berkeley Lab scientists are designing a next generation, high-resolution charge-coupled device (CCD)-based vertex detector to enable the measurement of the very short-lived D mesons in STAR.

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 (ECR) ion sources capable of producing high-charge-state ions of most elements. A third-generation ECR (VENUS) is under construction, with completion planned in 2001. VENUS will provide the nuclear science community with an enhanced capability of heavier projectiles at increased intensities.

Development of state-of-the-art instrumentation has enabled Laboratory scientists to carry out cutting-edge nuclear science research. A prime example is the Berkeley Gas-filled Separator (BGS) which made significant scientific discoveries in its first year of running—the discovery of the new elements 118 and 116. This was a major breakthrough in the quest for an island of superheavy nuclei and received worldwide attention. It was a major physics and chemistry story of the year. The BGS has ushered in a new era of heavy element studies at the 88-Inch Cyclotron.

The 8π gamma-ray array has now returned to Canada (in early 2000) after successfully completing 23 experiments involving 17 institutions at the 88-Inch Cyclotron. Its space is now occupied by Gammasphere, which has returned to Berkeley to continue its very successful operation as a national user facility for nuclear structure studies. Coupling some of the Gammasphere detectors to the target position of BGS will provide exciting new research capabilities at the 88-Inch Cyclotron. In order to pursue the physics of nuclei at high spin and angular momentum in even more detail with substantially improved efficiency, 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).

Forefront reaction studies and laser trapping of radioactive atoms to explore fundamental symmetries also present new physics opportunities. Research opportunities with radioactive beams are provided at the 88-Inch Cyclotron by Berkeley Experiments with Accelerated Radioactive Species (BEARS), which has provided ^{11}C beams with world-record intensity and energy, and by the ^{14}O-beam test stand. Lab researchers are also participating in plans for a national advanced radioactive beam facility, (see Section IV, Initiatives). To complement this effort, Berkeley Lab is also working to make the 88-Inch Cyclotron the premier stable beam facility (see Section IV, Initiatives).

Berkeley Lab is actively involved in a coordinated neutrino research program. The Sudbury Neutrino Observatory (SNO), an experiment to detect neutrinos from the sun and from supernovae, is now taking data in the SNO laboratory in Canada, 6800 feet underground. Berkeley Lab scientists have played a major role in the construction and are now deeply involved in the analysis of SNO's first physics results. This experiment is complemented by work on a new neutrino oscillation experiment in Japan—KamLAND—with Berkeley Lab providing the front-end electronics and project management for the U.S.

KamLAND collaboration. Lab scientists are also participating in the Cryogenic Underground Observatory for Rare Events (CUORE), to be staged in the Gran Sasso facility in Europe. When completed, it will be the world's most sensitive neutrinoless double beta decay experiment and will address the question of whether neutrinos are Majorana particles. Research and development continue on a next-generation high-energy neutrino detector called IceCube (see Section IV, Initiatives). The Laboratory conducts an advanced program in astrophysics that is directed to understand the origins and fate of matter and energy in the universe. The Laboratory is working with DOE, NSF and NASA to develop a Supernova Acceleration Probe to define the fundamental parameters of the universe, including the possible "dark energy."

Science Education for DOE

Berkeley Lab supports, develops, and implements programs that utilize the DOE scientific resources to improve mathematics, science, and technology education. The primary focus is on regional and national graduate and undergraduate research participation. Precollege programs support student achievement in the sciences and mathematics.

All programs and activities promote human resource development in scientific and technical areas essential for the fulfillment of DOE's mission. Diverse populations of students are served and promote the national need for a diverse science and engineering workforce. The Laboratory's Center for Science and Engineering Education conducts a national year-round Energy Research Undergraduate Laboratory Fellowship program. This program is coupled to a new initiative to meet the Nation's and California's demand for mathematics and science teachers through partnership with colleges and universities preparing undergraduates to enter teaching careers. Students, selected for their interest in teaching, receive a 10-week research assignment and support for translating their experience to the classroom. The Biotechnology, Environmental Science and Computer Community College initiative provides students from over 23 California community colleges with the opportunity for a 10-week research experience.

Education initiatives developed within DOE program areas to promote public understanding have produced nationally recognized instructional materials. Teacher training is provided along with student tours and programs. Local partnerships with inner city school districts are established to provide needed educational resources to teachers and students. Berkeley Laboratory staff have played leading roles in the development of the California Science Framework for K-12 Public Schools. The Center for Science and Engineering Education supports the development of educational leadership among the Laboratory program staff, and coordinates its efforts with the Office of Work Force Diversity to meet the Laboratory's diversity goals.

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, and participated in the preparation of the DOE Power Outage Study Team's report on policies to improve electric reliability.

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, as well as fundamental materials research for alternatives to existing room lighting. 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 lighting. In a relatively new effort, studies are underway on the energy use of home and office electronic equipment such as computers. 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. 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. New efforts are exploring more energy-efficient extraction techniques for the mining industry, and a Berkeley Lab-developed low nitrogen oxide emission natural gas burner for boilers, furnaces, and gas turbines (latter through Oak Ridge National Laboratory). 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 (ETR) Program, which seeks to advance the development of high-energy rechargeable batteries for use in electric vehicles. Performance goals for the ETR Program have been established by the U.S. Advanced Battery Consortium. In the new Advanced Technology Development (ATD) program, Berkeley Lab is working with other DOE multiprogram labs in studying the degradation mechanisms in high-power batteries for hybrid vehicles. Berkeley Lab is also working in conjunction with the other DOE 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, fuel cells, lightweight materials, and improved manufacturing techniques. Some of this work, in particular the characterization of diesel particulates, is applicable as well to heavy vehicles such as trucks and sport utility vehicles. This latter work is funded through Oak Ridge National Laboratory.

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 federal 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. Much of the work is funded through other DOE contractors (see below).

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. The research includes new catalytic processes for the sequestration of CO_2 and the simultaneous catalytic reduction of NO_2 and SO_2 from flue gas.

Berkeley Lab participates in a number of oil and gas projects through the Natural Gas and Oil Technology Partnership Program, an applied research program that emphasizes collaborative laboratory/industry efforts. The goal of this Partnership program, begun in 1989, is to bring advanced technologies developed at the labs to the stage where independent producers can use them to increase production or to decrease the uncertainties and costs for the drilling of new exploration and production wells. Because of its expertise in underground imaging technologies and research related to various aspects of heat and mass transport in the crust, including reservoir dynamics, the Earth Sciences Division leads several collaborative projects related to increasing oil and gas production. The earth science studies include the use of subsurface imaging, modeling, measurement and scaling of multiphase flow processes; integrated reservoir monitoring using seismic and cross-well electromagnetics; frequency-dependent seismic attributes of fluids in poorly consolidated sands; and the development of single-well seismic imaging technology. Through the Environmental Energy Technologies Division, Berkeley Lab also conducts research into the effect of petroleum production and refining activities on air quality, particularly on understanding and being able to predict the concentration of fine-grained, air-borne particulates down to 2.5 micron size. Determining the indoor concentrations is crucial since people spend 90% of the time indoors, 70% in homes.

Berkeley Lab has a Partnership effort underway to help the oil industry find more economical and efficient ways to lower the viscosity of heavy crude oils, and during the next five years, Berkeley Lab expects to participate in new Partnership projects related to the Ultra-Clean Fuels initiative.

Berkeley Lab also conducts oil and gas applied research over a wide range of topics outside the Partnership program. These projects include research into multiphase fluid flow at a state-of-the-science pore-scale rock imaging laboratory, enhanced oil recovery using foams to control oil and water mobilities, and development of instrumentation to accurately characterize emissions from oil storage tanks for the purposes of helping the petroleum industry meet air quality regulations.

Berkeley Lab will lead a new multi-lab and industry project to investigate the sequestration of carbon dioxide—a greenhouse gas—in geologic formations including depleted oil and gas reservoirs, brine formations, and coalbeds.

Environmental Restoration

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.

Berkeley Lab conducts a program of waste management, pollution prevention, and waste minimization in support of DOE objectives and goals and in compliance with State of California and University of California requirements. The goal of the program is to incorporate pollution prevention into the decision making process at every level in the organization. Specific pollution reduction goals are addressed through a program of pollution prevention awareness, recognition, information exchange, and training. The waste management program is planned to be transferred to the Office of Science.

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 (DARHT) at Los Alamos. Expertise in induction linacs is instrumental to this effort to deliver an advanced induction electron linac for the DARHT, which takes advantage of developments originating in the Office of Science fusion science program.

Office of Nonproliferation and National Security

DOE has a growing role in chemical and biological nonproliferation and detection of harmful agents. The purpose of the Laboratory's effort in this area is to develop the capacity to detect, 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. Several efforts are underway, including improving radiation detector materials, developing novel bichromic conjugated polymers for detecting biological agents, improving detector spectral performance and improving the software systems used in detection and identification of materials and objects such as ordinance. Also 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. An 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 work at Berkeley Lab is unclassified.

Berkeley Lab conducts research in support of the national DOE program on Initiatives for Proliferation Prevention. This research is conducted in partnership with other laboratories and with foreign organizations in countries where proliferation prevention is an important U.S. goal. Examples of the research include: treatment of nuclear and non-nuclear waste by electron beam assisted plasma chemistry, agricultural crop protection through microbially derived materials, and the development of magnet and accelerator systems for free electron lasers.

Other DOE Contractors

To optimize the use of the Integrated System of Laboratories, Berkeley Lab conducts research for DOE missions in partnership with other DOE Laboratories and contractors. Projects include:

- A multidisciplinary program of interrelated geoscience and geological engineering research important to the safe, long-term underground storage of high-level nuclear wastes in a program administered by TRW for the Office of Civilian Radioactive Waste Management. Coupled with ongoing DOE basic research, Berkeley Lab is contributing to technology, site characterization, and applied development research at the Yucca Mountain Project. The 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.
- Berkeley Lab has lead responsibility for research, design, and fabrication of the front end for the Spallation Neutron Source being constructed at the Oak Ridge National Laboratory.
- Berkeley Lab coordinates the Energy Sciences Network (ESnet) including projects with other DOE institutions on security and network access, maintaining ESnet lines, access and services (some of this work is funded by other contractors).
- Berkeley Lab is in collaboration with other laboratories for advanced research in diesel engine combustion, including the development of instrumentation to characterize exhaust particulate emissions.
- Berkeley Lab conducts research in collaboration with other laboratories for accelerator research, including beam characterization for radiobiological research at Brookhaven National Laboratory, ion source development, and magnetron development.
- Berkeley Lab conducts advanced detector and instrumentation research and development in partnership with many high energy and nuclear physics laboratories, these include vertex detectors, charge coupled device cameras, and detectors.
- Berkeley Lab conducts a range of earth sciences research with other laboratories, including salt dome imaging research and geothermal reservoir technology research.

In addition, the Laboratory performs collaborative research with other DOE laboratories in energy efficiency, chemical, material sciences, and environmental sciences, which includes the areas of sustainable energy development, efficient catalysts, subsurface characterization of contamination, and the effects of ultraviolet light.

Work for Others General Trends

Berkeley Lab has many unique facilities and scientific resources that are made available to other government agencies, universities, and industry in support of DOE's mission and consistent with its policies. The customers for this work and the associated areas of research complement DOE's science mission, and the levels of funding provided by these agencies is indicated in Section VII: Resource Projections and Tables.

The proportion of Work for Others is expected to remain approximately level (18-22 percent of the total Laboratory budget). The actual projections in the resource tables indicate best estimates of 18 to 20 percent. The Laboratory's DOE mission areas which hold the strongest interest for collaboration by other organizations include Biological and Environmental Research, Basic Energy Sciences, and in the future, High Energy and Nuclear Physics. Several key trends include:

- The Advanced Light Source is expected to increase its user base from 1000 users this year to 1600 by 2004. Concomitant with this increase are funds-in support in the areas of structural biology and x-ray crystallography from the National Institutes of Health and from private sources such as the Howard Hughes Medical Institute. Other users in materials sciences, chemistry, and environmental science can be expected, including funds-in for beamlines and potentially for beamline operation.

- Other sponsors of sequencing and functional genomics are interested in the Office of Basic Energy Research capabilities associated with the genome program at Berkeley Lab and the DOE Joint Genome Institute. The primary source of interest is the National Institutes of Health.
- Research in materials science is being sponsored by other agencies that takes advantage of the capabilities at the Advanced Light Source, the National Center for Electron Microscopy and the Center for X-ray Optics. Primary sponsors are the Defense Advanced Research Projects Agency and private industry. Cooperative Research and Development Agreements for this work are tabulated separately from Work for Others.

In the area of high energy physics, the Laboratory is working with DOE, NSF, and NASA to develop and implement a Supernova Acceleration Probe. Although most of the funding to the Laboratory is expected to come from DOE, there is the potential for additional NSF and NASA funds coming to the Laboratory. Because of the uncertainty in scope and budget, these Work for Others funds are not included in the projections at this time.

National Institutes of Health

DOE biosciences and environmental programs at Berkeley Lab are valuable 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 in many of its institutes.

- For the National Institute of General Medical Sciences, the Life Sciences Division conducts research in high-resolution electron crystallography of proteins. The research, using unique instrumentation and expertise, has lead to a breakthrough in revealing the structure of tubulin and other critical biological molecules.
- For the National Heart, Lung and Blood Institute, the Life Sciences Division is conducting research in cardiovascular flow and metabolism.
- For the National Institute of Diabetes and Digestive and Kidney Diseases, the Life Sciences Division is conducting research in red cell membrane studies to obtain a detailed understanding of the selected red cell skeletal proteins in regulating membrane function through characterization and manipulation of the corresponding cloned genes.
- For National Heart Lung and Blood Institute, the Life Sciences Division is conducting research on the metabolic and genetic origins of lipoprotein subclasses.

In addition, the NIH applies the Laboratory's unique resources to investigations of the human genome, and in the areas of carcinogenesis and mutagenesis. Berkeley Lab is central to the *Drosophila* genome project sponsored by NIH but funded through a Work for Others project with the University of California. 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, radio-pharmaceuticals related to advanced instrumentation and disease treatment, and use of nanocrystals in biological and biomedical imaging. Other programs involve 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. Other projects sponsored by NIH but funded through the University of California address wound healing, and the characterization and combustion of toxic compounds.

Berkeley Lab has recently 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.

Department of Defense

DOE's unique facilities at Berkeley Lab are valuable for unclassified research projects in the Department of Defense. The Center for X-ray Optics has received funding from the Defense Advanced Research Projects Agency (DARPA) for beamline development at the Advanced Light Source (in extreme ultraviolet interferometry and extreme ultraviolet metrology) and for electron-beam lithography. 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 (through Lawrence Livermore National Laboratory) 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). Other work supported by DARPA includes the application of combinatorial chemistry to advanced materials. The Office of Naval Research (ONR) supports optical scattering characterization of marine visibility.

Berkeley Lab also conducts research on cellular circuitry and sensing and on engineering new functions from nature. The Department of Defense supports a breast cancer research program. All the DOD research conducted at Berkeley Lab is not classified. The larger projects include:

- For the Office of Naval Research, the Physical Biosciences Division conducts a program for engineering biomolecules and biological processes to create novel cell-based sensory and signaling systems.
- For the Advanced Research Projects Agency, the Accelerator and Fusion Research Division conducts research on the production and manipulation of beamlets, which if coupled with beam reduction and acceleration systems, can provide novel maskless approaches to micro-lithography for high throughput semiconductor processing.
- For the Army Corps of Engineers, the Laboratory has established the Bioremediation Education Science and Technology program, which conducts research on sustainable approaches to developing new bioremediation technology. The research and training activities are conducted in partnership with several universities that serve underrepresented minorities.

National Aeronautics and Space Administration

Berkeley Lab conducts biological, astrophysical, and materials science research sponsored by NASA that is complementary to DOE's mission. 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, carbonaceous aerosols in the atmosphere, and remote sensing of land-use changes.

Another area of research is on the space radiation environment and its implications for human presence in space. The project utilizes unique radiobiological research expertise and instrumentation at Berkeley Lab. 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.

Environmental Protection Agency

Environmental research sponsored by the Environmental Protection Agency (EPA) directly complements DOE's environmental and energy-efficiency missions, 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, providing technical assistance to China in developing efficient energy technologies, 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. Berkeley Lab is sponsored by EPA to develop building energy-efficiency analysis software and a supporting website. One of the larger projects is a study of heating, ventilation, and air conduction systems that focuses on building sector market analysis potential. Other work supported by EPA includes mitigation strategies and technologies for urban heat islands, the analysis of real-world automobile emissions based on state data, and (through Columbia University) an analysis of indoor radon levels in homes.

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 underway to evaluate remediation techniques for the area's soil, with related research at Stillwater Marsh, Nevada.

Agency for International Development and Related Work

The U.S. Agency for International Development (USAID) is supporting a multi-year effort in which Berkeley Lab will perform research on improving the efficiency of energy use in developing countries. Related projects are underway for specific developing countries, such as for Sri Lanka with support from the Ceylon Electricity Board.

Other Federal Agencies

The U.S. Postal Service supports work on energy-efficient technologies for postal buildings. The Laboratory prepares geological information for the Nuclear Regulatory Commission. The Laboratory has contributed to the pine tree genome database and conducted tritium labeling for the Department of Agriculture. The Laboratory has contributed to a materials surface structure database for the Department of Commerce. The Laboratory conducts a particle data program and develops educational materials for the National Science Foundation.

State Organizations

The California Air Resources Board is funding (through the University of California) analysis of the effectiveness of the California Smog Check II program on reducing emissions from motor vehicles. A Memorandum of Understanding between the California Energy Commission (CEC) and DOE supports a larger role for Berkeley Lab in the CEC's Public Interest Energy Research (PIER) program, which receives funding from the California electric utilities. Certain energy-efficient buildings and other research projects of the type formerly supported by the California Institute for Energy Efficiency (CIEE) are now part of this program, and projects are underway. These include projects on energy-efficient down-lighting for California kitchens, thermal distribution systems in commercial buildings, next-generation power management user interface for office equipment, and an instrumented home energy rating and commissioning system. Major programs just getting underway address high-performance commercial building systems and electric system reliability.

Utility funding for some projects, such as research on natural gas burners with low nitrogen oxide emissions, buildings housing high-technology industries, and a desktop version of the light-rendering program *Radiance* 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.

Private Firms and Organizations

Berkeley Lab conducts research under the sponsorship of private firms and private organizations where its unique expertise or facilities are of specific value. For example, the Electric Power Research Institute sponsors studies on the reduction and oxidation involved in scale formation; oxygen depletion in compressed-air storage; diffusion-based sampling of semi-volatile and particulate carbonaceous species; and surface modification with metal plasma techniques. The Gas Research Institute supports databases on the influence of clays on seismic-wave attenuation in reservoir rocks. Some of the larger projects for the private sector include:

- Research on sustainable energy is being conducted by the Environmental Energy Technologies Division under sponsorship from the Energy Foundation.
- Research on the effects of individual genes on the physiological response to diary fat is being conducted by the Life Sciences Division under sponsorship of Children's Hospital of Oakland. The research studies the roles individual genes play in determining the effects of dietary fat on plasma lipoproteins and atherosclerosis.
- A DOE collaborative program on mass transport is being conducted by the Earth Sciences Division under support of the Power Reactor and Nuclear Fuel Development Corporation.
- Research for the development of an automated environment for the construction of sorted cDNA is being conducted by the Engineering Division under the sponsorship of the Amgen Corporation
- The design and construction of a beamline for biological crystallography at the Advanced Light Source is being conducted through the Physical Biosciences Division under sponsorship of the Novartis Institute for Functional Genomics.

Other studies include novel ion sources, studies of fuel oxidation, combinatorial chemistry for advanced materials, thermal management systems, silicon particle detectors, oil reservoir characterization, seismic cross-well monitoring, membrane protein studies, materials microcontamination studies, studies of radiation hardened circuits, and x-ray crystallographic studies and beamline development.

Universities

Berkeley Lab conducts research in partnership with universities and international organization where its unique expertise or facilities are of specific value to such collaborations. The projects are in many fields, include physics, chemistry, materials science, geosciences, and biology. In addition to the research projects, Berkeley Lab science education activities are conducted in partnership with the University of California (UC) and the State of California. The larger university and international organization sponsored projects are:

- The Laboratory, in a partnership with the University of California at Berkeley, has completed the sequencing and annotation of the euchromatic genome of *Drosophila melanogaster*. The results appeared in the March 24, 2000 issue of the journal *Science*.
- The Center for Nutritional Genomics is a partnership between Berkeley Lab, UC Berkeley, and the U.S. Department of Agriculture Western Human Nutrition Research Center. The mission of the Center is to identify the effects of nutrition on gene expression and function in humans and model

organisms, and to study the influence of genetic variation on human nutrition and optimal health. The Center will also investigate genetic modifications to enhance the nutritional value of plants. Among the goals of the Center is to generate novel insights relevant for clinical application, understand how to achieve optimum health, understand mechanisms of disease, and develop nutritionally enhanced foods.

- The newly established Center for Research and Education in Aging (CREA) will integrate the efforts of Laboratory and UC Berkeley geneticists, physiologists, cell and molecular biologists, and structural and computational biologists to understand the basic processes that are responsible for aging at the molecular, cellular, tissue, and organismic levels. CREA is designed to create a research training and education environment that will increase the number of advanced degrees in the area of aging research.

Other topics include: energy demand and transportation, atomic force microscopy, beamline development at the ALS, x-ray holography and tomography, genome studies, combustion science with low-emissions burners, physics detectors, subsurface monitoring, breast cancer, transgenic studies, cell aging, 10-meter telescope control systems, and atomic-scale studies of catalysts.

Cooperative Research and Development Agreements (CRADAs)

Berkeley Lab conducts research in support of Cooperative Research and Development Agreements with industry where its unique expertise or facilities are of specific value. The 50 projects currently underway are in many fields, including efficient building systems, physics, chemistry, materials science, geosciences, and biology. Some larger CRADAs (above $200K) are:

- **Coulter Pharmaceutical, Inc.** This collaboration targets the mechanism of the *erbB-2* receptor and its activator heregulin to inhibit tumor growth. The objective is to convey lead compounds generated through this interaction into novel drugs for the treatment of cancer.
- **Capintec, Inc.** The goal of this project is to develop a line of compact nuclear medical imaging devices. These include a miniature imaging probe for inter-operative detection of radionuclides to assist in cancer surgery, small compact cameras for detection of thyroid disease and breast cancer imaging, and a larger camera for cardiac and other nuclear medicine studies.
- **EUV Limited Liability Corporation.** This research with the Advanced Light Source and the Materials Sciences Division involves x-ray optics and metrology for optical systems for extreme ultraviolet light lithography.

Many of the CRADAs directly support science aligned with DOE mission goals, are based on Laboratory competencies, and include topics such as plasma deposition, novel scintillators, photon imaging advanced spectroscopy, cancer therapy, networking systems, electrochemistry, efficient lighting and windows, genomics and gene expression, x-ray optics, and microstructural analysis.

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 multiprogram 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 Basic Energy Sciences and an international user community, Berkeley Lab is delivering on the scientific productivity of the Advanced Light Source (ALS) for advances in many fields.** The scientific community has charted the directions of the ALS, redefining the scientific areas and beamline developments. A greatly expanded program in macromolecular crystallography is underway, and new research is being developed on highly correlated materials. The challenge will be to provide the infrastructure, including user support facilities for a growing user community that has increased four-fold to 1000 users since 1997 and is expected to increase to 2500 by the end of the next decade. A top priority is to effectively accommodate the space and facility needs of this community, including laboratories, offices, and instrumentation staging areas. A proposed ALS Nanoscience User Facility would support the main recommendation of the Basic Energy Sciences Advisory Committee Subpanel Review of the ALS "to support the ALS plan to have a new building adjacent to the machine to have more office space for users and laboratories for sample preparation and experiment staging."
- **With the Office of Advanced Scientific Computing and in partnership with the system of DOE national laboratories, information technology is becoming 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 modeling are integral to progress on nanoscience, climate prediction, combustion simulation and modeling, subsurface transport, genomics, 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.
- **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 nuclear science research program, Berkeley Lab is working to make possible a new era of research in unstable isotopes through a Rare Isotope Accelerator (RIA).** Berkeley Lab will also maintain a leadership role in low-energy nuclear physics with the 88-Inch Cyclotron. 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 RIA facility.
- **As part of the DOE's high energy physics program, Berkeley Lab has joined with other national partners in the international collaboration for the Large Hadron Collider at CERN.** Berkeley Lab is making essential contributions—in the areas of computing and silicon pixel detector systems—to the U.S. participation in the Large Hadron Collider scientific program to investigate the nature of electroweak symmetry breaking and the origins of mass.

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 the structure of biological molecules; how they work in assemblies as molecular machines; and how the three-dimensional architecture of cells is developed from the 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. New imaging technologies have been developed to determine the effect of low-dose radiation and other environmental factors.
- **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

- **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 with nanoscale dimensions.** This effort will, integrate capabilities in materials science, condensed matter physics, structural biology, and computation in order to understand and develop advanced materials through a range of methods. These approaches to nanoscience offer the prospect of developing arrays of atomically structured materials with tailor-made properties, providing new understanding of complex materials, and improving capabilities for design and synthesis.
- **Berkeley Lab provides world leadership in particle and 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. A Supernova Acceleration Probe is a key instrument for this effort

- **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.

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

- **Research Infrastructure.** Berkeley Lab's Strategic Buildings Plan advances DOE's science program goals through modernizing and constructing facilities while maintaining high standards of performance in safety and protection of the environment. Critical elements of the Berkeley Lab Strategic Buildings Plan are adequate space and facilities for users at the Laboratory's national user facilities, facilities to meet program goals for the 21st century, and modernization through program line-item projects and the Multiprogram Energy Laboratory Facilities Support program. Because the Strategic Buildings Plan is a critical element of the Laboratory's stewardship activities it is included as Section VII of this Institutional Plan and provides an integrated framework and priority structure for the Laboratory's infrastructure needs.
- **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 an Integrated 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 infrastructure for users 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 (ISM).** 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. Berkeley Lab has been among the first laboratories to fully implement its ISM, which has recently been validated.

- **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 new Environmental Sampling Task Force. An outgrowth of this effort has been the development of community review and a proposed sampling plan. 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; has renewed a partnership with the City for first response by the Laboratory's Fire Department; and—with DOE-Oakland—is a participant in the muti-agency Partnership for Parks. Berkeley Lab's Open House 2000 and Science Festival formed a centerpiece for outreach to the community and advanced education, Work Force Diversity and Human Resources objectives.
- **Cost-Effectiveness and Administrative Performance.** Berkeley Lab has established performance improvements, in concert with DOE, to address streamlined, efficient, and cost-effective management systems. The recent emphasis has been on reducing travel costs, which are projected to close below the travel cost ceiling for FY 2000. However, continued efforts at travel cost savings cannot be sustained without serious impacts on program performance.. We continue to work in partnership with a Laboratory/DOE Oakland Operations and Site Office Executive Streamlining Group, although much of the focus of the group has shifted to new security, foreign travel and conference requirements.
- **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 framework for divisional diversity plans has been issued, oriented towards strengthened recruitment and building a better work environment. A School-to-Work program with the Peralta Community College System is part of the effort to diversify and expand the pool of opportunities in biotechnology. The Administrative Services Department enables more consistent skill levels and expectations and provides improved opportunities for staff development, planning, and placement.
- **Site and Cyber Security.** Berkeley Lab has developed effective Site Security and Cyber Security Program Plans that protect our employees, visitors, equipment, facilities, and information. The Plans are tailored to the risks at the site and provide for full security protections while enabling the Laboratory to conduct its unclassified research mission as a Tier III laboratory (no classified research or information on-site).

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 infrastructure resources.** Working with the Laboratory Stewardship Committee we are working to secure the necessary infrastructure investments to meet the Laboratory's scientific mission requirements. With the Office of Science and Headquarters Program Offices, Oakland Operations Office and the Berkeley Site Office, the Laboratory is addressing issues of adequate on-site facilities to meet critical needs in research, computing and office space. The Strategic Buildings Plan provides a framework for progress and dialog on priority infrastructure issues.

- **Behavior-based worker safety, accident prevention, and environmental protection.** The Laboratory is working to instill continuous improvement in worker safety behavior, with a current focus on accident prevention, 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.
- **Delivering 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. Berkeley Lab is working with DOE to assure that effective and well-tailored security measures are provided for Tier III laboratories.
- **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. The recruiting staff has been strengthened, communications to more effectively address job needs and to reach employment pools has been enhanced, and new software systems have been added to improve information access both for recruitment and for training and retaining staff. The Laboratory is working at all levels, including its senior and mid-level managers and with its entire workforce—with efforts that included the Diversity Stand-down—to improve the recruitment and retention of a diverse workforce.
- **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.
- **Project Management**. Berkeley Lab is committed to outstanding project management and has a strong record of projects being delivered on scope, budget, and schedule, including, as examples, the Advanced Light Source, the B-Factory Low Energy Ring, the STAR Solenoidal Detector, Gammasphere, and Sudbury Neutrino Observatory components. Nevertheless, to assure continued performance, especially for its key Integrated Laboratory System partnership projects, it has added project management oversight staff and is conducting senior management reviews to assure performance and a continued reputation as location-of-choice for major science projects.
- **Waste minimization and pollution prevention program.** Under the sponsorship of the Office of Environmental Restoration and Waste Management, Berkeley Lab has conducted a program of waste management, pollution prevention, and waste minimization. The goal of the program has been to incorporate pollution prevention into the decision-making process at every level through a program of pollution prevention awareness, recognition, information exchange, and training. With the transfer of waste management to the Office of Science, funding of the program was terminated.
- **Travel Costs Ceilings.** Berkeley Lab is committed to low cost travel in order to deliver more resources to science programs and to implement the most cost-effective programs possible. Significant savings have been achieved with new ticketing arrangements and by curtailing or postponing travel. However, continuation of the current arbitrary cost ceilings will cause disruptions to program performance and are counterproductive to overall Laboratory performance and mission execution.

The planning efforts on administrative and operational issues are addressed in Section V, "Operations Strategic Planning;" Section VI addresses "Infrastructure Strategic Planning: the Strategic Buildings Plan"; 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

- Advanced Light Source Science Strategic Plan
  (Basic Energy Sciences)
- Structural Biology at Berkeley: World-Class Protein Crystallography and Spectroscopy
  (Biological and Environmental Research and Work for Others: NIH)
- Dynamic Atomic Resolution Microscopy at NCEM
  (Basic Energy Sciences)
- Center for Advanced Computation in High Energy and Nuclear Physics
  (High Energy and Nuclear Physics)
- Accelerators for the High Energy Physics Frontier
  (High Energy and Nuclear Physics)
- GRETA (Gamma-Ray Energy Tracking Array)
  (High Energy and Nuclear Physics)
- 21st Century Nuclear Physics Facility
  (High Energy and Nuclear Physics)
- Partnerships for Science Education
  (Office of Science and Work for Others)

Explore Matter and Energy

- Supernova Astrophysics: Supernova Acceleration Probe (SNAP)
  (High Energy and Nuclear Physics, Work for Others: NSF and NASA)
- Large-Scale Neutrino Detector
  (High Energy and Nuclear Physics, Work for Others)
- Complex Systems and Nanoscience
  (Basic Energy Sciences)
- Molecular Theory Center
  (Basic Energy Sciences)

- Microscopies of Molecular Machines (M^3): Structural Dynamics Studies of Transcription-Coupled DNA Repair
  (Biological and Environmental Research)
- Integrative Approaches to Functional Genomics and Proteomics
  (Biological and Environmental Research)
- Quantitative Spatial and Temporal Resolution of Multicellular Interactions
  (Biological and Environmental Research)
- Soft X-Ray High Resolution Structure Determination
  (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 and Healthy Buildings
  (Energy Efficiency and Renewables)

Protect Our Living Planet

- Carbon Science to Address Global Climate Change
  (Basic Energy Sciences and Biological and Environmental Research)
- Molecular Environmental Science
  (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)
- Computational and Theoretical Biology: Understanding Complex Biological Processes
  (Biological and Environmental Research)
- Advanced Characterization of Multi-Protein Complexes
  (Biological and Environmental Research)
- Air Quality: Particulate Matter and Tropospheric Ozone
  (Biological and Environmental Research, Fossil Energy, Energy Efficiency and Renewable Energy, and Work for Others: EPA)
- Biological Effects of Low Dose Ionizing Radiation
  (Biological and Environmental Research)

PROVIDE EXTRAORDINARY TOOLS FOR EXTRAORDINARY SCIENCE INITIATIVES

Advanced Light Source Science Strategic Plan

The soft x-ray and vacuum-ultraviolet (VUV) range of the spectrum offers tremendous promise for scientific advancement, as reported in February 2000 by the Basic Energy Sciences Advisory Committee Subpanel Review of the Advanced Light Source (ALS), which commented on the outstanding research and user support program being conducted at the ALS. For the past several years, the ALS user community has been developing key research directions for the future of ALS, which address 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.** Microarray 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. Many of these research directions support the energy mission of DOE in addressing energy development, conservation, and use; and are part of a regional collaborative effort through a Memorandum of Understanding with the Stanford Synchrotron Light Source.
- **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 collaborated to construct an ALS Strategic Plan that responds to the recommendations from the workshop, the ALS Science Policy Board that advises the Laboratory, and the most recent review of the ALS by a panel of the Basic Energy Sciences Advisory Committee (BESAC). Based on a series of semiannual planning meetings involving ALS management and representatives of the user community, the current plan provides for the installation of the full complement of insertion devices (undulators and wigglers) in the ALS storage ring; the replacement in three sectors of conventional bend magnets with superconducting bend magnets (superbends) in order to extend the spectral range of the ALS with high brightness to intermediate-energy x-rays in the 10-keV to 20-keV range, and full instrumentation of the insertion-device and superbend beamlines. In addition, the plans include several high-performance but cost-effective bend magnet beamlines.

A top priority is to effectively accommodate the needs of the Advanced Light Source user community. These needs include laboratories that support research at the ALS beamlines, offices, and instrumentation staging areas. The number of users at the ALS has more than quadrupled in three years to 900 and—just with the completion of currently funded beamlines—is expected to increase to 1600 users by FY 2003. By the end of the decade, the ALS will serve about 2500 users. The ALS Nanoscience User Facility supports the main recommendation of the Basic Energy Sciences Advisory Committee Subpanel Review of the ALS "to support the ALS plan to have a new building adjacent to the machine to have more office space for users and laboratories for sample preparation and experiment staging." The scope of the proposed facility includes laboratories to support users at the planned 55 beamlines, and to advance nanoscience in support of the National Nanoscience Initiative.

Two hundred offices will be provided for ALS scientists, nanoscience researchers, and for ALS experimental systems support and beamline/optical systems and endstation design personnel. In addition, conference rooms and user center support and training areas will be provided. The facility will be located immediately adjacent to the Advanced Light Source and will replace several existing substandard facilities constructed primarily during World War II. These wood frame structures are potential fire hazards with poor structural, mechanical, and electrical systems. The estimated scope is 90,000.

Rather than being a static document, the strategic plan is evolving over time as priorities shift to take into account the changing needs of users from industry, academia, and government laboratories and new scientific opportunities. As validated by the BESAC panel, three of the high priority aspects of the plan are reflected in recent proposals for experimental facilities that enable the ALS to address forefront scientific areas:

- **Molecular Environmental Science.** (This is part of a separate initiative described more fully in a later section.) The new interdisciplinary field of molecular environmental science (MES) has emerged in response to the need for basic research that underpins long-term solutions to environmental problems associated with energy development, conservation, and use and to remediation connected with the past use of energy resources. Nearly all of the important chemical reactions and processes in nature take place at complex interfaces or surfaces, often with water present. Understanding these interfacial processes at the molecular or atomic level is essential for developing the capabilities to control the transformations of environmental contaminants, preparation of catalysts, corrosion, and the behavior of biomaterials. With the first phase already partially funded, this proposal is a two-phase project to establish adjacent undulator beamlines equipped with specialized experimental end stations for microscopy and spectroscopy of complex, "wet" interfaces at the ALS. The new ALS facilities combined with the complementary MES facilities at the Stanford Synchrotron Radiation Laboratory (SSRL), will provide the MES user community with powerful tools for the study of molecular processes throughout a nearly complete synchrotron radiation energy region. The ALS and SSRL have a memorandum of understanding for the operation and development of the two facilities as both national and regional assets for MES.
- **Magnetic and Polymer Nanostructure Research.** The study of magnetism and the structure of polymers in thin films and at surfaces at length scales as short as 20 nm is now possible using a newly developed photoemission electron microscope (PEEM2) in combination with the spectroscopic techniques of x-ray magnetic circular dichroism (XMCD) and near-edge x-ray absorption fine structure (NEXAFS), respectively. While this instrument can address many important problems in magnetism, such as the origin of exchange biasing of ferromagnetic layers by antiferromagnetic substrates, there is a clear need for even higher spatial resolution to address important problems in both fields. A new proposal will establish at the ALS a state-of-the-art microscope facility with nanometer resolution and magnetic imaging capability. The facility will

include an elliptically polarized undulator (EPU), a new beamline optimized for this work, and an aberration-corrected PEEM.

- **Femtosecond (fs) 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). Based on the recent successful demonstration on a bend-magnet beamline at the ALS of the time-slicing method of producing femtosecond x-rays, this proposal establishes an in-vacuum, narrow-gap 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.

Also in conformance with the recommendations of the BESAC panel, the plan envisages aggressive exploitation of the superbend beamlines and the extended spectral range they provide:

- **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.

The six-year budget plan below does not support those elements of the strategic plan that are based on user proposals (whether from within the Laboratory or outside). The budget plan does assume one new beamline scientist, associate beamline scientist, post-doctoral associate, and mechanical technician in each of FY 2002 through FY 2005 to cover one new insertion-device and bend-magnet beamline in each of those years. The budget outlook includes Project Engineering and Design of the ALS Nanoscience User Facility.

Advanced Light Source Science Strategic Plan
Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	2005	Total
Operating	28.2	31.5	33.4	35.3	37.2	39.3	204.9
Equipment	1.6	1.9	4.0	4.2	4.3	4.5	20.5
ARIM/AIP	1.7	2.1	4.0	4.2	4.3	4.5	20.8
Construction**	0.0	0.0	5.7	7.9	**	**	**

*Preliminary estimate of total DOE Budget Authority (B&R code KC). There is also an estimated small amount of Work for Others resources.
**Construction figures are for Project Engineering and Design of the ALS Nanoscience User Facility. Construction costs will be identified following completion of the preliminary design.

Structural Biology at Berkeley: World-Class Protein Crystallography and Spectroscopy

In response to the explosion of synchrotron-based biological research, the Physical Biosciences Division (PBD) recently created a consortium to coordinate protein crystallographic and spectroscopic research at the ALS. By the summer of 2000, there will be three operational protein crystallography beamlines at the ALS, and over the next three years, this number is planned to grow to ten. This complement of beamlines will have a wide range of technical and experimental capabilities. The new structural biology consortium represents institutions currently operating, constructing, or developing beamlines for biological crystallography and spectroscopy, including Scripps/DOE, Howard Hughes Medical Institute, the University of California, the Genomics Institute of the Novartis Foundation, the National Institutes of Health and an international consortium of universities and research institutions. The Computational Crystallography Initiative, a project to develop expert systems for automated structure determination, is the first of what will be a select cadre of associated programs in technological innovation. Formed to ensure maximal flexibility, capability, and economy for the entire ALS biology effort, the consortium is also expected to provide national and international leadership in all matters relating to the practice of biological structure determination.

Within this group, PBD has two "home" facilities: the Macromolecular Crystallography Facility (MCF) and BioSpec. The MCF is a national facility for the study and advancement of protein crystallography. Since its began operations in 1997, the MCF has hosted over 300 hundred users from more than 62 research groups; more than 120 structures have been solved, over 40 of them from multiple-wavelength anomalous diffraction (MAD). This record, together with its large number of high-impact papers in major journals such as *Nature, Science,* and *Cell* make the facility fully competitive with protein crystallography facilities worldwide. The recent BESAC subpanel review of the ALS commended the protein crystallography program of the MCF as "outstanding."

Technological developments continue to enhance the capabilities and the capacity of the MCF. 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 will revolutionize the field of protein crystallography. When completed, 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 ALS superbend project for protein crystallography. 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 first superbend beamlines are being built for the Howard Hughes Medical Institute. They are expected to become operational in, respectively, the summer of 2000 and January, 2001.

To expedite user access, Berkeley Lab and Stanford's Synchrotron Radiation Laboratory, are planning a beamline-sharing arrangement tentatively titled, "BaySynch."

BioSpec recently became fully operational as a biological spectroscopy facility. BioSpec uses x-ray spectroscopy and other spectroscopic tools to probe the structure and mechanisms of metal containing enzymes. These systems include the cluster involved in photosynthesis, enzymes important for carbon monoxide and hydrogen metabolism and the enzymes critical for nitrogen fixation. Because the metals studied are very dilute, BioSpec is often on the leading edge of new technology development, especially in the areas of instrumentation sensitivity.

The record of biological research at the ALS stands with the best. Fully realized, these facilities will serve as a research resource with capabilities for structural biology studies that match or exceed other synchrotrons in the United States.

Structural Biology at Berkeley: World-Class Protein Crystallography and Spectroscopy Resource Requirements($M)*

Category	2001	2002	2003	2004	2005	Total
DOE Operating	1.2	1.2	1.2	1.2	1.2	6.0
WFO Operating	1.9	2.8	3.0	3.3	3.3	14.3
WFO Construction	6.4	4.0	0.0	0.0	0.0	10.4

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP) and Work for Others

Dynamic Atomic Resolution Microscopy at NCEM

The National Center for Electron Microscopy (NCEM)'s electron beam instrumentation provides unique research tools to the scientific community. Electrons interact strongly with matter, can be focused to form images or can be very small probes with extremely high brightness. Electron-optical instrumentation is thus indispensable for nanoscale characterization and a natural complement to the photon and neutron beam characterization tools at DOE's major user 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.

In a joint effort with Oak Ridge and Argonne National Laboratories 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 and for a range of important new materials with short bond lengths, and in different orientations as necessary for 3-D reconstruction.

NCEM plans to integrate electron-optical instrumentation with a forefront effort in computing to develop unique new capabilities for quantitative atomic scale imaging. These new capabilities will include:

- atomic structure refinement from nanocrystals and defects;
- real-time *in-situ* observation of atomic-level mechanisms and dynamics; and
- 3-D reconstruction at atomic resolution.

Advanced tools such as these will provide opportunities for groundbreaking research and aid in the development of advanced materials and the discovery of new phenomena.

Two major approaches toward quantitative sub-Angstrom imaging will be pursued in parallel:

- In the high-voltage approach to atomic resolution, a third-generation 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 sub-Angstrom resolution. The instrument will offer the unique advantages of increased penetration depth for both high-resolution and diffraction contrast imaging, decreased ionization damage, and the ability to perform *in-situ* dynamic experiments. These capabilities are indispensable to overcome thin foil artifacts that often limit the use of lower-voltage instruments. As the only modern high-voltage microscope in the U.S., this machine will become 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 0.5Å 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. As a forefront development project, with a single "beam line," this machine is expected to serve a more limited user community than the high-voltage instrument. Complementary instruments optimized for different performance criteria will be installed at the three sister facilities.

Both new instruments will be designed for atomic scale imaging in real time, opening up exciting new research opportunities based on the ability to observe the atomic mechanisms that underlie the behavior of materials in the nanoscale regime. In support of this goal, NCEM plans further development of its research focus on *in-situ* microcharacterization. The design of novel techniques and specialized stages will provide unique capabilities for high-resolution analysis of mechanisms and dynamics in materials. Specific focus areas will be imaging of magnetic materials with NCEM's one-of-a-kind spin-polarized low-energy electron microscope (SPLEEM) and the ability to perform quantitative Lorentz imaging in a field-free environment. Unique new *in-situ* capabilities will be developed by applying forefront technologies such as microlithography, focused ion beams, or piezo-electric manipulators to build novel geometries for key experiments. The resulting array of cutting-edge scientific tools will enable breakthroughs in fundamental and applied research. Examples of breakthrough opportunities include *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.

Recent experience with NCEM's One-Angstrom Microscope has shown that at resolution levels near and below 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 launch a major program in this area with specialized instrumentation such as microlithography, a focused ion beam instrument, 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.

To prepare 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 five 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	2001	2002	2003	2004	2005	Total
Operating	1.5	1.5	2.0	2.0	2.0	9.0
Equipment	10.0	13.0	3.0	1.0	2.0	29.0
Construction	3.0	4.0	0.0	0.0	0.0	7.0

*Preliminary estimate of Budget Authority (B&R Code KCO2)

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: cosmology, accelerator physics, and large-scale data management.

The initial focus of the cosmology program is on the creation of a virtual center for integrative cosmology. This center will bring together scientists working in both the observational and simulation aspects of cosmology and astrophysics. The center will provide data handling and analysis facilities for a diverse program in observational cosmology including the determination of cosmological parameters from the observation of supernova and the study of the cosmic microwave background. The center will also provide facilities for the simulation of supernova and for the validation of computational models. The center will be closely integrated with NERSC and with the DOE program, *Scientific Discovery through Advanced Computation.* Through the use of collaboration technology and data sharing/visualization, the virtual center will bring together scientists from across the DOE and university community.

The long-term effort in cosmology will also include 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.

The second important thrust area is in the simulation of advanced accelerators. 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.

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 scientist to try a simple new analysis idea.

The virtual center will 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. This work will build on considerable Berkeley Lab expertise in data handling and network-based distributed systems including the new NERSC program in Data Grids.

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

Category	2001	2002	2003	2004	2005	Total
Operating	2.0	5.0	5.0	5.0	5.0	21.0

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

Accelerators for the High Energy Physics Frontier

Berkeley Lab scientists and engineers advance national scientific objective in High Energy Physics through research and development on frontier experimental systems and concepts for particle accelerators and detectors. The effort supports the mission of DOE's Office of Science, 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. Several new programs have been recommended, including a Neutrino Factory and research on the Next Linear Collider (NLC), Berkeley Lab is collaborating with other institutions to develop an experimental program and accelerator design approaches for these frontier facilities.

Berkeley Lab is one of the "sponsoring" Laboratories of the Neutrino Factory and Muon Collider Collaboration, whose purpose is carrying out a research and development program aimed at developing an intense neutrino source based on the novel concept of a muon storage ring—denoted a Neutrino Factory. The interest in building accelerators based on muon beams stems from their unusual and favorable properties compared with either electrons or protons. Although the muon is a fundamental particle, it is some 200 times more massive than the electron. This means that synchrotron radiation energy loss in a circular ring is reduced by this factor compared with electrons, making a modest sized circular accelerator for muons economically favorable compared with an electron machine. This markedly extends the energy "reach" of such a storage ring or collider. Compared with protons, which are composite particles, a muon has available all of its beam energy to make new particles in a collision, whereas a proton collider would require ten times higher energy to have the corresponding energy available for new particle production. The muon has one other property that differs from the standard beam particles—it is unstable and decays with a lifetime of about two microseconds when at rest. This is a challenge for the design of an accelerator, but it also gives rise to an important physics opportunity. The decay products include both electron and muon neutrinos in a well-known proportion. If the muons decay in a straight section of a storage ring oriented toward a suitable detector, they create an intense beam of neutrinos. Recent experiments in Japan have given quite strong indications that neutrinos "oscillate" (change from one type to another), and thus that they have non-zero mass. This reflects physics beyond the Standard Model and has implications for cosmology as well. A beam of neutrinos aimed at a detector far from the source (say, 2000 km) will permit detailed investigation and thus detailed understanding of the effect.

Berkeley Lab has core competencies in many areas needed to design and construct a Neutrino Factory, including expertise in simulations and theory, and in the design of radiofrequency (rf) hardware and diagnostics devices, superconducting magnets, and induction linacs. We have been designated by DOE to be the site of the Project Office for managing the research and development work of the Neutrino Factory and Muon Collider Collaboration. Both the Collaboration Spokesperson and the Project Manager are Berkeley Lab staff.

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, Fermi National Laboratory 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. Even with rapid accelerators, this energy, 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. This property is essential to achieve the extremely large collision rates (luminosity) needed for physics studies. Our work on the damping rings includes the radio-frequency (rf) power 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 research and development effort needed to support the conceptual and engineering design of a prototype detector. Because of the early nature of the project, resource requirements for these activities have not yet been defined for this activity.

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 and is expected to be especially important for advanced nuclear structure studies in the RIA era. Researchers at Berkeley Lab 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. After operating at Argonne National Laboratory from late 1997 to early 2000, Gammasphere is now back at the 88-Inch Cyclotron to continue its forefront research program and service a broad spectrum of nuclear scientists from universities and institutions around the world. Communities in both the United States and Europe are working on the next generation of detector arrays to open up new scientific opportunities.

A new concept for a gamma-ray energy tracking detector is being developed by the Berkeley Lab nuclear structure group, in association with others in the community. It is a shell consisting of closely packed, highly segmented germanium detectors and uses the new concept of gamma-ray tracking to determine the location and energy of every interaction point for all gamma rays detected. It represents an advance in detector development that may well be comparable to that seen when germanium detectors were first introduced. The full 4π GRETA array (comprising ~100 segmented germanium crystals) could reach a total efficiency of approximately 60%, which will give it a resolving power 1000 times larger than that of current arrays. research and development efforts have demonstrated the proof-of-principle and a proposal has been submitted to DOE (March 2000) to construct the GRETA Module Cluster consisting of three modules, each with its own cryostat and three highly segmented coaxial germanium crystals. The Module Cluster represents a first-generation energy tracking detector that will allow a greatly expanded physics program to be carried out and is also an essential next step towards a full 4π tracking array. In particular, the Module Cluster will allow the study of the evolution of shell structure in neutron-rich nuclei and investigation of the structure of other new exotic nuclei. In combination with the Berkeley Gas-filled Separator (BGS) at the 88-Inch Cyclotron, it will provide the opportunity to study the structure of very heavy nuclei, up to Z=102 and possibly 104.

A comprehensive series of measurements (primarily carried out on a 36-segment single-crystal GRETA prototype) and simulations have demonstrated that it is possible to build a gamma-ray tracking detector today. The proof-of-principle was achieved in four key areas: (1) the manufacture of both segmented detectors and pre-amplifiers that can provide the high-quality signals needed to resolve and locate individual interaction points, (2) the use of signal processing methods to determine the position, energy and time of gamma-ray interactions based on pulse shape digitization and digital signal processing, (3) the development of a tracking algorithm that uses the energy and position information to identify interaction points belonging to a particular gamma ray, and (4) the design and packing schemes for both the Module Cluster and for the full 4π GRETA array.

To be in a position to exploit the science opportunities in a timely manner we must move forward with construction. With the requested funding profile, the Module Cluster could be available for physics in FY2002. Assuming its success, we would then expect to begin construction of the full GRETA array in FY2004 (TEC ~$30M). Such a 4π device is seen as an essential detector for nuclear structure studies at an advanced radioactive beam facility such as RIA.

GRETA Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	0.0	0.2	0.5	0.6	0.6	1.9
Construction	1.5	1.2	0.0	7.0	7.0	16.7

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

21st Century Nuclear Physics Facility

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. In order to remain at the forefront of the field and maintain a world-class nuclear physics capability at the Berkeley Lab well into the 21st century, we are currently exploring two concepts. One is a leading role in the advanced radioactive beam facility now known as RIA, (Rare Isotope Accelerator, formerly ISL or ISOL). The second avenue being explored is development of a complementary Premier Stable Beam Facility.

Rare Isotope Accelerator (RIA)

The concept for such a radioactive beam facility is presently being evaluated and has evolved 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. These fragments can be used directly for high-energy fragmentation studies, or be slowed down by a gas cell technique, 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 could 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. In addition, Berkeley Lab has offered to host the conceptual design review activity.

The RIA R&D Coordinating Committee (chaired by Jay Marx, at the request of DOE nuclear physics) recently developed a three-year research and development plan for the radioactive beam facility. The Committee identified the Berkeley Lab as the lead research and development laboratory on an ECR ion source and low energy beam transport (LEBT) for the heavy-ion driver. VENUS, the third-generation ECR source now being constructed for use at the 88-Inch Cyclotron, can serve as a prototype for the RIA ECR and provide data on the intensity, charge state distributions and emittance of beams such as bismuth and uranium, which are the most challenging for the RIA project. With the addition of a gyrotron, which can provide 10 kW of 28 GHz microwave power, VENUS could demonstrate the performance levels planned for RIA. Calculations to model the extraction, transport and charge-state separation as well as emittance measurements on existing ECR ion source/LEBT systems, which must preserve the source emittance and match into the radio-frequency quadrupole (RFQ), will also be done. Other contributions to the research and development effort include the development and testing of low-frequency RFQ structures and a careful study of the design issues for the fragment separator system. Several activities now underway at the 88-Inch Cyclotron will provide valuable information and research and development infrastructure for RIA. These include the Intense Radioactive Ion Source (IRIS)—an exotic ion test stand presently developing beams of radioactive ^{14}O for fundamental nuclear physics measurements—and the Berkeley Experiments with Accelerated Radioactive Species (BEARS) experiments and infrastructure.

We expect to play a strong role in both the science and the technology of an eventual RIA, wherever it is sited. Research and development on the next generation gamma-ray detector, Gamma-Ray Energy Tracking Array (GRETA), for nuclear structure studies is being carried out. We are working toward a prototype of this device (see GRETA Initiative) which could be used in early studies with radioactive beams presently available at Berkeley and elsewhere as well as providing a certification under actual experimental conditions for GRETA. A full-scale GRETA, with its enhanced overall efficiency and superior tracking capability, would be one of the major pieces of instrumentation to address RIA physics. Another device being considered is a Time Projection Chamber(TPC), to record all of the charged particles produced in an asymmetric reaction with low intensity radioactive beams. Such a device would build on the existing substantial expertise at Berkeley on TPCs and their associated electronics.

Resource requirements for a RIA facility are currently under discussion by DOE and members of the interested national laboratory system. It is expected that these will be included in the next Long Range Plan for Nuclear Physics (expected in 2001). We have indicated here the resource requirements for our participation in the various RIA activities, including construction of the new facility.

Stable Beam Facility

Berkeley Lab will maintain a leadership role in low-energy nuclear physics no matter where RIA is sited. Key nuclear physics directions identified by the scientific community are in nuclear astrophysics, nuclear structure, exotic nuclei, and heavy elements. As noted above, these will require both stable and radioactive beams. Therefore, we envision the need for a premier stable beam facility to complement the planned RIA facility and we are working to ensure that the facility of choice will be at Berkeley Lab—either the 88-Inch Cyclotron or its replacement accelerator.

The 88-Inch Cyclotron has been continually upgraded and improved over the years. For example, Electron Cyclotron Resonance (ECR) ion source development has resulted in two state-of-the art ECR sources for the cyclotron. The third-generation ECR source (VENUS) will be completed next year. Not only has this ECR development benefited the Cyclotron's user community, but it has also become a resource for the entire country and the world. Cyclotron development projects in recent years have focused on increasing the intensity of medium to heavy mass beams both out of the ECR source and through the Cyclotron. These projects proved crucial to the recent discovery of elements 116 and 118. At the present time, the 88-Inch Cyclotron is the only U.S. accelerator capable of generating the several hundred particle-nanoamp beams of ^{86}Kr necessary for this discovery. A project is planned to significantly increase the beam intensities for moderate mass ions and increase the energy for more massive ions (A=150) from the cyclotron. The discovery of element 118 has generated great theoretical and experimental interest in exploring the production of heavy elements with more symmetric reactions. This will require intense beams up to mass 150. The project will also extend the mass range for beams above the Coulomb barrier out to uranium, thereby providing a full suite of stable beams for nuclear structure studies.

A design study is currently in progress to explore all options for assuring that Berkeley Lab will have DOE's premier stable beam facility well into the 21st century. One element of the study is to identify and make an engineering evaluation of potential improvements and added capabilities to make the 88-Inch Cyclotron the premier stable beam facility. Another option being considered is construction of a more modern accelerator. Resource requirements will be identified when a final plan has been developed.

21st Century Nuclear Physics Facility Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	2005	Total
Operating	0.6	1.5	4.8	4.8	5.6	6.0	23.3
Construction	0.0	0.0	2.0	10.0	20.0	30.0	62.0

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

Partnerships for Science Education

Advances in science and technology are moving rapidly and leaving our education institutions and students unprepared to keep pace for participating in DOE's science and engineering workforce or understanding the technical issues of the era. Diverse populations of undergraduate science and engineering students must be better served and scientific literacy among graduating high school students must be advanced. Through partnerships with targeted colleges, universities, and school districts, and by providing research opportunities for undergraduate students and teachers, Berkeley Laboratory is able to enrich the education of a diverse population of hundreds of undergraduate students and to leverage its impact for thousands of precollege students annually.

Scientific research and technology development at the Berkeley Lab is both mission oriented and multidisciplinary. The DOE research problems being addressed and the tools being used represent the latest thinking and techniques in science. Students who have the opportunity to work as research participants, not only learn how to carry out research but they are learning the skills and gaining the knowledge that is needed for the future workforce. Teachers and future teachers who have these same opportunities see modern contexts for the core content of science that their students are expected to know. California and many other states have moved to standards-based accountability systems. Students respond positively to updated science lessons and are better prepared for science related career choices, often choose to learn more science, and have a better understanding of science as a way of knowing and a system based on testing and experiments. All are better citizens prepared to make decisions based on scientific evidence.

Through the Center for Science and Engineering Education partnerships with minority-serving colleges and universities, with California community colleges and with regional school districts can be formed. These partnerships will be designed to provide research participation opportunities in scientific and technical groups at the Laboratory. Cooperation with the Berkeley Lab Office of Work Force Diversity will ensure awareness of career opportunities at the Berkeley Lab. Greater numbers of ethnic minorities underrepresented in science and engineering careers will participate in the current undergraduate programs. Specific partnerships are being formalized with the American Association of Community Colleges, with NSF preservice teacher programs and including colleges and universities in California that are preparing science and mathematics teachers. Partnerships with regional school districts will include working with entire middle school and high school faculty through teacher leaders who gain familiarity with the Berkeley Lab and become teacher associates and advocates for the Laboratory's work and a positive benefit for the nation.

Through partnerships and in exchange for research participation opportunities for their students and faculty, institutions will offer course credit to students, develop and update their curriculum and courses, provide additional financial support for faculty and often create new instructional materials tied to the DOE research at Berkeley Lab that forms the basis for web-based dissemination across the nation.

Partnerships for Science Education
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	0.5	0.7	0.7	0.8	0.8	4.3
Work for Others	0.5	0.5	0.5	0.5	0.5	2.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KX, WFO)

EXPLORE MATTER AND ENERGY INITIATIVES

Supernova Astrophysics: Supernova Acceleration Probe (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) would be a space-based 1.8m telescope with a one square degree field-of-view with one 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 CCDs 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 CCDs 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 CCDs have very low sensitivity.

After several years of research and development, the project schedule calls for 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 DOE's Office of Science/High Energy and Nuclear Physics program, NSF, and NASA.

Supernova Astrophysics: Supernova Acceleration Probe (SNAP) Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	2005	Total***
DOE	**	1.1	2.0	3.8	26.3	26.3	59.5
NSF	0.0	1.1	2.8	6.2	26.3	26.3	62.7
NASA	0.0	0.0	0.0	0.0	23.0	23.0	46.0

*Preliminary estimate of Berkeley Lab Budget Authority KA and Work for Others/NSF & NASA. Profile projected steady state for each partner FY05 to FY07 for launch. Full scope of science partners is under development.
**Possible preliminary funding being discussed with DOE/SC.
***Contingency budgets not included in spending profiles.

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 are being 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 41 advanced digital optical modules was installed in Antarctic ice during the 1999/2000 Austral summer in collaboration with the AMANDA group. The installation was successful and these modules are sending waveform information to the surface. 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, called IceCube, to be installed in South Polar ice was submitted to the National Science Foundation in November 1999 by the AMANDA collaboration. Berkeley Lab scientists joined with their AMANDA colleagues in the preparation of the scientific case for the km-scale detector and its technical design. Construction may be expected to begin in FY 2002 and extend over five to eight years.

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

Category	2001	2002	2003	2004	2005	Total
Operating	1.4	1.6	1.6	1.6	1.6	7.8
Construction	0.0	15.0	18.0	18.0	18.0	69.0

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

Complex Systems and Nanoscience

In support of the *Strategic Plan of the Office of Science* 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?
- **Nature's 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?

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 applying these efforts to largely physical systems. Key targets are sensors as well as 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 capabilities 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	2001	2002	2003	2004	2005	Total
Operating	4.0	4.0	4.0	4.0	4.0	20.0
Construction and equipment	1.0	1.0	1.0	1.0	1.0	5.0

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

Molecular Theory Center

The impact of theory in chemistry, biology, and materials science is widely recognized and will only continue to grow. The significance of the field is being brought about both by developments in theoretical methodology and by a dramatic increase in computational power. The National Energy Research Scientific Computing Center (NERSC) provides a unique opportunity to unify many if not all of the theoretical efforts at the Laboratory and the Department of Energy. To do so, however, requires intellectual links to and between these efforts, links that highlight interdisciplinary overlaps. There are, for example, significant commonalties between the problems addressed in computational biology and those considered in treating the dynamics of phase transitions in nanoclusters. Similarly, there are overlaps between the theory of advanced materials and the theory of chemical structure and dynamics.

Overlaps like these can be nurtured and exploited through a group of centers organized around NERSC, as illustrated below. Whether or not this entire structure is eventually created, it will be beneficial to at least begin with a Molecular Theory Center. This interdisciplinary center would interface with and strengthen a broad spectrum of DOE research in chemistry, biology, and materials science.

Several specific areas of focus at the Laboratory illustrate the benefits of an interdisciplinary center devoted to molecular theory. One is the current interest in developing computational algorithms for interpreting the immense data set created by the Human Genome Project. Excitement in materials science over possible practical applications of nanoclusters highlights a second area where interdisciplinary connections would be fruitful. A third area concerns the interest in mechanisms of biological catalysis. For these and other areas, strong intellectual ties between different theoretical and computational disciplines will significantly facilitate advancement. At the present time in the United States these ties are largely absent, but they would evolve naturally from a Molecular Theory Center associated with NERSC.

By means of a multi-divisional collaboration, we propose to create a Molecular Theory Center for the purpose of advancing theoretical methodology and applicability, and widely communicating these advances. Research at the Center will be carried out in a coordinated parallel fashion. Scientists from differing disciplines will collaborate to achieve a particular objective, employing frequent communication and shared learning from the progress in each individual area. A Molecular Theory Center with representation from chemistry, physics/materials, and biology, and with a knowledgeable and inspiring director, will provide the structure for this communication to develop. A program of focused workshops, bringing together leading scientists from around the world, will facilitate broader communication. The Center will provide a model for what can be accomplished throughout the Laboratory and throughout DOE.

Molecular Theory Center Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	0.5	1.0	2.0	4.0	5.0	12.5

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

Microscopies of Molecular Machines (M^3): Structural Dynamics Studies of Transcription-Coupled DNA Repair

The search to understand the complexity and dynamics of the living cell from its molecular components has accelerated greatly in recent years. Completion of genome projects and the development of high-throughput structural biology methods have resulted in a data explosion.

Yet, these efforts will not proportionally increase our understanding of how cells work. The reason is that the cell is not just a collection of many diffusing molecular components undergoing second order reactions. During the last few years, biologists have become increasingly aware that the cell is organized in a *modular* fashion. Each of its central functions (e.g. replication, transcription, translation, protein translocation, recombination, splicing, protein folding and degradation, cellular transport and growth, intracellular and intercellular signaling, etc.) is performed by complex molecular assemblies or central units consisting of numerous interacting components that behave as small, self-contained *molecular machines*.

Future research in biology will be increasingly directed toward elucidating the inner workings of these molecular machines. In this endeavor, traditional methods in structural biology, while providing the high-resolution structures of many of the individual components, will not suffice to elucidate the complex motions, the multiple interactions and, generally, the structural dynamics of these systems. The aim of this initiative is to employ innovative microscopies to characterize the structural dynamics of molecular machines. Cryo-electron microscopy, atomic force microscopy, optical tweezers microscopy and single molecule fluorescence microscopy are the selected methodologies for this study. Together, these techniques span a range of spatial and temporal resolution that will provide a uniquely detailed description of the DNA repair process. The use of these novel methodologies is synergistic, so that the information from one will be used as input for the others. Their combined use will provide a particularly powerful method to address the complexity of multi-molecular assemblies.

The research will be directed toward: (1) structural and dynamical studies of the transcription-coupled DNA repair machinery, (2) methodology development required for the progress of this study, and (3) development of a conceptual design report for the creation of a National Center for Modern Microscopies at Berkeley Lab. Components of this research are:

- **Replication.** Replication is the essential process that insures the passage of information contained in DNA from one generation to the next. This process is catalyzed by a complex molecular machinery capable of copying the DNA chains with extraordinary speed, efficiency, and fidelity.
- **Transcription.** A central quest in cell biology is understanding how the original cell of an organism—the fertilized egg—gives rise to a myriad of cell types, each using different subsets of genes to produce different mixtures of proteins. The answer lies in the complex mechanism of gene transcription regulation.
- **DNA Repair**. The cell contains specialized molecular machinery designed to preserve the integrity of their DNA against misincorporation and damage by internal or external sources. DNA is extremely susceptible to environmental damage: ionizing radiation often breaks the DNA backbone, mutagens and chemical carcinogens may alter the structure of the DNA bases, ultraviolet radiation can covalently bond the two DNA strands, etc. DNA repair involves enzymes that "patrol" the DNA searching for errors, others that remove the damaged section, and finally those that synthesize new DNA.

A natural extension of the methodologies described above is the creation of a national user facility. The successful application of these tools and techniques will create an increasing demand in the scientific community for access to a central resource that provides state-of-the-art instrumentation and training. This will create and make accessible a core of expertise and a nexus of technologies unavailable anywhere else in the nation. The innately interdisciplinary environment in research and development, experience in user facilities management, close ties to a major academic center (the UC Berkeley campus), and convergence of scientific expertise make this site ideal for a national center.

This novel approach to combine complementary, innovative microscopies to elucidate interrelated aspects of the structural dynamics of molecular machines is the first of its kind ever attempted. Support of this proposal will place DOE at the forefront of the technological developments that will address the next generation of biological problems: how molecular machines work. The specific biological problems and technological solutions described in this proposal all aim at addressing issues at the heart of the DOE mission. The study of the structural dynamics of the molecular machinery of DNA repair addresses the fundamental biological issues that comprise DOE's programs on the effects of radiation and chemical damage to biological systems.

Microscopies of Molecular Machines (M^3)Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
DOE Operating	1.0	1.0	1.0	1.0	1.0	5.0
DOE Equipment	0.0	0.2	0.2	0.2	0.2	0.8
Work for Others	2.8	2.8	2.8	2.8	2.8	14.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP, and Work for Others)

Integrative Approaches to Functional Genomics and Proteomics

Since January 1999, the DOE's Joint Genome Institute (JGI) has increased its production rates by more than 20-fold to approximately 25 million raw bases per day, with an essentially constant budget. With this dramatic progress on the human and model organism genome sequencing goals, opportunities arise to further decipher the coded proteins and non-coding elements being revealed, as well as their structure and function, and disseminate this useful information to the greater biomedical community. Now that the JGI has achieved efficient multi-megabase daily sequencing capacity, genomes from medically important microbes, such as the recently sequenced bacterium *Enterococcus faecium* (the leading cause of hospital-acquired infections) will be rapidly unraveled. Leveraging this productivity, this initiative seeks to integrate cross-species comparisons of non-coding regions, microbial physiology and combinatorial chemistry. The overall goal is to advance the next phase of genomic and proteomic data capture and interpretation and thus realize significant benefits for DOE's biological and environmental research agenda.

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. A goal will be to develop a publicly accessible database that will serve as a repository of "annotated" non-coding regulatory sequences that have been identified through cross species sequence comparisons and biological investigations. In parallel, a cross-species resequencing program will be established to verify such sequences as well as *in vivo* and *in vitro* approaches for testing the function of sequences identified from sequence comparisons and/or computational analysis.

Another program objective is a predictive understanding of biochemical and cellular function in a bacterial cell. Long-term goals include biological function prediction from their genomic sequence, elucidation of bacteria roles in a micro-ecosystem and a comprehensive understanding of the interaction of a cell with its surroundings. Examples include metabolic and photosynthetic studies of *Prochlorococcus marinus*, acetone metabolism, *Clostridium acetobutylicum* vs. *C. perfringens* and virulence, *Y. pestis* vs. *Y. pseudotuberculosis*. Other important investigations will focus on the development of metrics for stress-related transcription and message decay rates and the identification of regulatory motifs through simultaneous analysis of transcript kinetics, abundance measurements, and genome sequences. Yeast will be the starting point of these studies followed by other organisms up the evolutionary tree.

Recent advancements in combinatorial small molecule library synthesis, pioneered in the Department of Chemistry at UC Berkeley, are enabling the rapid generation of large compound libraries for screening against biological targets. The technique represents a rich opportunity for exploiting the functional information emerging from the JGI's sequencing efforts. The goal is to adapt combinatorial small molecule strategies to the rapid identification of natural ligands or substrates for newly identified receptors and enzymes. In addition, such strategies will be used to identify cell-permeable small molecules that selectively activate or inactivate target proteins and therefore serve as powerful "chemical genetic" tools for elucidating the function of the protein in whole cells and even in animals. In this fashion, the application of combinatorial small molecule libraries will greatly accelerate the rate at which we can define the functions of gene products and their complex interactions within a physiological environment. Initial targets will be proteases, kineses and sulfotransferases, all of which appear to participate in fundamental regulatory processes within cells.

This broad initiative, utilizing unique capabilities of the Berkeley Lab, will entail a highly interactive program coordinated between the Life Sciences, Physical Biosciences, Genomics, and National Energy Research Scientific Computing Center Divisions. Central to the success of this initiative is the integration of these diverse strategies with those congruent with the mission of the JGI and the related ongoing efforts at Lawrence Livermore and Los Alamos National Laboratories.

Integrative Approaches to Functional Genomics and Proteomics
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	1.0	1.3	1.5	1.8	2.3	7.8

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

Quantitative Spatial and Temporal Resolution of Multicellular Interactions

The challenge of the post-genomic era is understanding how the genome is regulated to produce the myriad of cell and tissue phenotypes. To use genomic information to understand the biology of complex organisms, the biological responses and signaling pathways in cells need to be studied in context, that is, within a proper tissue structure. This information will then be used to more accurately predict health effects following exposure to ionizing radiation and environmental contaminants.

The purpose of this initiative is to provide an integrated resource in imaging of biological models in context. In the post-sequencing era, quantitative imaging of complex biological materials is a critical problem. Currently, sequential measurements obtained with different microscopy techniques preclude detailed analysis of multidimensional responses (e.g., time and space). Quantitation of spatial and temporal concurrent behavior of multiple markers in large populations of multicellular aggregates is hampered by labor-intensive methods, a lack of quantitative tools, and the inability to index information. Ideally one would track the kinetics and quantities of multiple target proteins, their cellular context, and morphological features in large populations. Future innovation is needed at the intersection of cell and molecular biology, microscopy, data acquisition strategies, image analysis, and high speed computing.

This imaging initiative will use multi-divisional expertise in Life Sciences, NERSC and Material Sciences Divisions to develop novel imaging algorithms coupled to visual servoing—dynamic manipulation of experimental parameters based on the analysis of image content—an experimental feedback loop. High-speed recording and analysis will allow the development of essential capabilities for simultaneous quantitative analysis of large multicellular populations. Ultimately, this technology will lead to the understanding of complex responses and accurate prediction of consequences in humans.

Cell and molecular biology experiments will be performed in a matrix in which various concentrations and durations of modulators of specific pathways are used to perturb the multicellular system. Most current biology is conducted using cells cultured in monolayers on traditional tissue culture plastic. These non-physiological models impede the ability to predict in vivo responses from model systems. The same cells cultured in two dimensions (i.e. monolayers) versus three dimensions (e.g. multicellular tumor spheroids) differ in their responses to ionizing radiation, viral infection, cytotoxic drugs, and chemotherapeutic agents. Berkley Lab has led the way in promoting and developing three-dimensional cell culture models that more accurately reflect *in vivo* biology, beginning with the establishment 15 years ago of physiologically functional reconstituted mammary gland in culture. At a given time, the cells are viewed and analyzed for their ability to proliferate, organize, express selected proteins, or respond to additional stimuli using laser-scanning confocal microscopy to analyze fixed specimens. However, the high-intensity laser light required by laser-scanning confocal microscopy can harm living specimens and many fluorescence preparations bleach easily. Alternatively, two-photon excitation microscopy can be used to obtain dynamic observations in living three-dimensional aggregates. However, it is not well suited to high-throughput or measurements of large populations.

Thus, a gap currently exists in our ability to quantify the response of tissues and complex, three-dimensional cultures in a manner suitable for statistical testing of hypotheses relating multiple responses to stimuli. Inherent biological variability and genomic instability are additional factors that support the requirement for large population analysis. Visualization of three-dimensional relationships between living cells during experiments could also lead to new insights about functional relationships. Ideally, these experiments could be performed on-the-fly so that time sequence information could be evaluated.

New methodology is needed for high-throughput, dynamic evaluations of large numbers of live multicellular specimens. Deconvolution of digital images obtained by optical microscopy of thick specimens can remove blur or haze contributed by the out-of-focus image planes to render a more accurate image.

This initiative will combine deconvolution with new Berkley Lab capabilities in visual servoing, high-speed recording and analysis will permit the development of essential capabilities for simultaneous quantitative analysis of large multicellular populations. The critical requirements are to:

- implement dynamic imaging methods based on deconvolution;
- eliminate and reduce manual measurements over large populations of three-dimensional, multicellular aggregates;
- improve quality control through reducing inter-observer as well as intra-observer variation;
- provide robust measurements for statistical tests of hypotheses; and
- allow data mining and visualization on a multidimensional database.

Rapid analysis of individual cells in relation to their multicellular organization and functional context, is the next giant step toward construction of functional genomic models.

Quantitative Spatial and Temporal Resolution of Multicellular Interactions Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	0.4	0.6	0.7	0.9	1.5	4.1

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

Soft X-Ray High Resolution Structure Determination

For understanding cell function, it is critical to capture information about the organization of cells, the location of proteins and nucleic acids in cells, and modifications in response to biochemical signals. Molecular biology, biochemistry, and structural biology help provide information about isolated molecules, but microscopy techniques are required to garner information about the function of these molecules within cells. Soft x-ray microscopy represents an emerging technology capable of shedding light on these questions of biological importance.

While the use of fluorescently labeled antibodies to determine the location of proteins in cells using light microscopy has made a major contribution to our understanding of cell structure and function, it is limited by the spatial resolution of the light microscope (200 nm). To obtain higher resolution information about the location of proteins, the only available tool has been transmission electron microscopy (TEM). Although antibody localization by TEM is extremely powerful, it also has significant limitations. Other methods are time consuming and fail to provide adequate resolution. Soft X-ray microscopy provides high spatial resolution of cytoplasmic and nuclear proteins, yet requires minimal processing of the cells—bridging the gap between light and electron microscopy.

The high-resolution soft x-ray microscope (XM-1) built by the Center for X-ray Optics (CXRO) at Berkeley Lab uses bending magnet radiation from the Advanced Light Source, a third generation synchrotron facility. It is a conventional transmission microscope in which the sample is illuminated with incoherent soft x-rays from a condenser zone plate that acts as a linear monochromator. The transmitted photons are enlarged by a zone plate lens and the image is formed on an x-ray sensitive CCD detector connected to a computer to generate a digital image.

Soft x-ray microscopy takes advantage of x-rays in the water window, the range of photon energies between the K-shell absorption edges of carbon (284 eV) and oxygen (543 eV) for imaging whole, hydrated cells. In this energy range, organic matter absorbs approximately an order-of-magnitude more strongly than water. Operating at photon energies just below the oxygen edge, e.g. 517 eV (which corresponds to a wavelength of λ = 2.4 nm) enables examination of thick, hydrated cells, in near-natural environment without the need for chemical or metallic contrast enhancement procedures. Photons at this energy readily penetrate the aqueous environment, while encountering significant absorption from carbon- and nitrogen-containing organic material or dense metallic particles, such as silver and gold. For x-rays with 517 eV photon energy, the 1/e attenuation lengths of water, organic material, and silver are about 10 µm, 0.5 µm, and 50 nm, respectively. Thus, unlabeled cellular structures from silver-enhanced gold label without contrast enhancement techniques can be clearly distinguished. Dark field scanning x-ray microscopy is used to detect gold-labeled proteins in dehydrated cells and TEM is used to study gold-labeled proteins on the surface of hydrated cells. TEM can also be used to examine the subcellular distribution of cytoplasmic and nuclear proteins in whole, hydrated cells at 25 nm resolution — eight times better than that provided by visible light microscopes. Although the photoelectric absorption damages the sample, the penetration depth of these soft x-rays is ideally suited to image whole cells up to 10 microns thick—either chemically fixed cells in an aqueous environment, or cryofixed cells in vitreous ice, at atmospheric pressure.

This initiative is designed to address questions regarding structure-function relationships of proteins in a wide variety of cells and tissues. We anticipate x-ray microscopy will be a powerful tool for correlative microscopy projects. With transmission x-ray microscopy directed at localizing proteins using silver-enhanced gold labeling protocols in whole, hydrated cells at 25 nm resolution, we can obtain unique, three-dimensional information about the location of proteins in whole cells at high resolution. We will examine the dynamics of fluorescently-tagged proteins, such as green fluorescent protein (GFP) constructs of newly discovered proteins with unknown functions, in live cells. These cells can then be fixed, labeled with commercially available antibodies to GFP, and then examined in the x-ray microscope to determine the subcellular localization of that protein. The ability to perform such structure-function analyses will be critical to determine the function of the vast number of newly identified proteins over the next five years.

Soft X-Ray High Resolution Structure Determination Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	0.5	0.5	0.5	0.5	0.5	2.4

*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 and the Princeton Plasma Physics 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 three 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 Lawrence Livermore National Laboratory, 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 mid FY 2003.

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	2000	2001	2002	2003	2004	2005	Total
Operating**	5.8	9.2	5.8	5.3	4.8	4.9	35.8
Construction	0.0	1.1	8.7	10.1	11.6	35.8	67.3

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

**Operating profile includes ongoing Heavy Ion Fusion program operating and equipment funding, which is anticipated to decrease due to increase in the IRE activity/funding as Engineering staff moves to the IRE program.

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 perform work in the following areas:

- Reliability technology issues and needs assessment, including the creation of multiyear national research and development plans to guide the research of the consortium.
- Real-time system monitoring and control.
- Integration of distributed energy systems.
- Reliability and markets.

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, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, and a consortium of leading universities involved in power systems engineering (including Cornell University, University of California at Berkeley, University of Illinois at Urbana-Champaign, University of Wisconsin at Madison, and Washington State University). A major collaborative effort with the Electric Power Research Institution on reliability research and development is also under active discussion.

Electric Reliability Performance Systems Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	8.0	15.0	20.0	25.0	25.0	93.0

*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 new function in photosynthesis, and the obstacles toward progress in the harnessing of sunlight and its conversion to alternative fuels.

The first investigation 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	2001	2002	2003	2004	2005	Total
Operating	0.6	0.6	0.6	0.6	0.6	3.1
Equipment	0.1	0.1	0.1	0.1	0.1	0.4

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

Advanced Energy-Efficient and Healthy Buildings

Energy use in buildings accounts for about 35% of total energy consumption in the U.S. and over 65% of electricity use. Despite advances in energy efficiency, the energy use in the commercial sector continues to rise due to increases in building stock and a shift to greater use of electricity. 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 creating new efficient technologies and tools, and then moving these energy-efficient building technologies from the laboratory 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 utilize compact fluorescent lamps, and methods for reducing energy losses in duct systems. Similarly, ongoing work is expected to lead to the introduction of a series of new building products and design methods in the marketplace.

The Advanced Energy-Efficient Building Technologies Initiative builds on these past successes and ongoing efforts by taking a new perspective on building performance and 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 technologies to improve the entire process from design through construction, startup, operation, maintenance, and renovation. "Life-cycle" information systems will feed design intent into construction and then utilize commissioning data to efficiently guide ongoing building operations. 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. Cheaper and more abundant networked sensors to monitor lighting, indoor air quality, occupancy, and temperature, etc. will couple to control systems that use real-time performance data, automated diagnostics and the benchmarked "life cycle" information to optimize building performance and occupant comfort. An increased effort will be focussed on improving the health and performance of building occupants. This will involve expanding research on the interrelationships among indoor air quality, lighting quality, ventilation, and building characteristics, with an increased emphasis on collaborative research on building-related health and performance outcomes. New tools and technologies will also be applied in high-value and critical building conditions, specifically to improve the performance of the growing number of "hi-tech" buildings, e.g. biotech and semiconductor manufacturers, and to assist under emergency conditions in buildings such as helping to determine optimal response to toxic chemical releases. These tools and integrated systems will not only achieve energy and cost savings of over 30% but—based on new rigorous studies of occupant performance in buildings—they will be used to make adjustments in design and operations that will improve health, comfort, and productivity in our building stock, providing even greater returns to the U.S. economy.

Lighting accounts for 25% of all electricity used in the U.S. Despite past achievements there continue to be opportunities for breakthrough advances that apply Berkeley Lab's cutting edge basic science skills to energy efficiency solutions. Laboratory researchers expect to help lead a growing national effort to develop a new generation of light-emitting diodes (LEDs), both inorganic and organic (OLED), to achieve performance levels approaching 200 lumens per watt (l/W). (Conventional incandescent lamps are rated at 15 l/W and the best white discharge lamps operate in the range of 100 to 130 l/W). Red LEDs are commercially available today and new green and blue LEDs are emerging, making a "white light" LED a viable technology for applications where cost and efficiency are not critical. However, fundamental breakthroughs in materials science and in device design and integration will be required to achieve required cost and efficiency performance targets (200 l/W) that could potentially capture 50% savings in U.S. lighting energy consumption. Berkeley Lab's experience in the area of lighting applications and its materials capabilities, with UC colleagues, in development and characterization of both LEDs and OLEDs should be critical to the national effort.

Advanced Energy-Efficient and Healthy Buildings
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	3.0	5.0	5.0	5.0	5.0	23.0

*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 worldwide 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 in order 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 major regions and encompass many microclimates that respond differently to climate change. Berkeley Lab will address such shortcomings by establishing a NASA Regional Earth Science Application Center (RESAC), with participation from scientists at UC Berkeley and UC Santa Barbara. Researchers will utilize NASA and National Oceanic and Atmospheric Administration (NOAA) satellites and products to address short-term (2 to 3 day) weather and streamflow predictions, seasonal hydroclimate forecasts, and long-term atmospheric carbon dioxide, climate, and stream flow projected simulations. One of the immediate problems is to develop reliable stream-flow predictions for flood-prone river systems in California, but the weather and streamflow prediction research will be extended to areas outside California (e.g. Colorado River) and will add to the understanding of the effects of anthropogenic sources of carbon on weather. This will include the implementation of isotopic tracers in both the mesoscale atmospheric model and the hydrologic streamflow model. Studies on California's Russian River and American River watersheds have already shown that good correlations can be obtained between predicted and observed rainfall and streamflows.

Complementing our Partnerships with the joint DOE Center on Terrestrial Carbon Sequestration (at Oakridge (ORNL), Pacific Northwest (PNNL) and Argonne National Laboratories (ANL). Berkeley Lab's program will focus on designing and implementing a carbon measurement network at the DOE Atmospheric Radiation Measurement (ARM) Southern Great Plains Site that will advance understanding of the carbon cycle, including understanding the controls of CO_2 fluxes and carbon sequestration by the oceans and terrestrial biosphere. One of the main thrusts of the Laboratory's terrestrial carbon sequestration will be to used 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 by agricultural and forestry practices, land use, and climate change.

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 of 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	2000	2001	2002	2003	2004	2005	Total
Operating	2.0	5.0	10.0	10.0	10.0	10.0	47.0

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

Molecular Environmental Science

The interdisciplinary field of molecular environmental science has emerged in response to the need for basic research that underpins long-term scientific solutions to environmental problems associated with energy development, conservation, and use, and related remediation connected with the past use of energy resources. Most of the important chemical reactions and processes in nature take place at complex interfaces, often with water present. Understanding these interfacial processes at the molecular level is essential for developing the capabilities to control the transformations of environmental contaminants, corrosion, and the behavior of biomaterials in these complex systems. The objectives of molecular environmental science research are to provide information on the chemical and physical forms (speciation), spatial distribution, and reactivity of important molecular species in natural and man-made materials, and to develop a fundamental understanding of chemical and biological molecular-scale environmental processes that affect the stability, transformations, mobility, and potential toxicity of these molecular species. This proposal is to establish a molecular environmental science facility at the Advanced Light Source (ALS) to provide the powerful tools needed for the 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.

Important applications of synchrotron radiation spectroscopy and microscopy to molecular environmental science have been made over the past several years at all of the Department of Energy light sources. Based on the success of these efforts and the unique information about 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 the vacuum ultraviolet (VUV)/soft x-ray region. Several national workshops have critically addressed molecular environmental science in the VUV/soft x-ray region, examining specific issues with respect to the scientific merit, capabilities, opportunities, needs, and future prospects for molecular environmental science-synchrotron radiation research in this spectral regime. Specifically, because chemical reactions at the surface of natural solids play dominant roles in many environmental processes, molecular-level studies of chemical reactions at interfaces (solid-liquid, solid-gas, liquid-gas) are an important focus of molecular environmental science research. The third-generation, high-brightness synchrotron radiation sources, improved vacuum techniques, and improved detectors provide the opportunity for new applications of surface science methods to molecular environmental science issues in the VUV/soft x-ray region.

A VUV/soft x-ray user facility for molecular environmental science research is being constructed at the ALS. When fully completed, the ALS molecular environmental science facility (ALS-MES) will consist of two beamlines optimized for a variety of important applications. These beamlines will take advantage of the spectral brightness of the ALS in the 75 eV to 4000 eV energy range, which includes the K-edges of B, C, N, O, Na, Al, Si, P, S, Cl, and K, as well as the L-edges of the first-row transition elements. In Phase I of the ALS-MES project that is already partially funded, the 75 to 1500 eV beamline and end stations will be designed and fabricated. Furthermore, the necessary infrastructure for supporting molecular environmental science experiments and users at the ALS will be established. The Phase I beamline will provide unique opportunities for the use of spectromicroscopy, x-ray photoelectron, x-ray emission spectroscopy, and x-ray absorption fine structure spectroscopy techniques for molecular environmental science investigations. After completion of the low-energy beamline, the Phase II effort will follow building the 1 to 4 keV beamline and end stations.

The new ALS facility combined with the complementary molecular environmental science facilities at the Stanford Synchrotron Radiation Laboratory (SSRL), will provide the molecular environmental science user community with powerful tools and opportunities to study molecular processes throughout almost all of the synchrotron radiation energy regime. The ALS and SSRL have a memorandum of understanding for the operation and development of the two facilities as both national and regional assets for molecular environmental science.

Molecular Environmental Science Resource Requirements ($M)*

Category	2000	2001	2002	2003	2004	2005	Total
DOE Operating	0.2	0.4	0.4	0.4	0.8	0.8	3.0
WFO Operating	0.2	0.2	0.2	0.2	0.2	0.3	1.3
DOE Construction	2.3**	1.8	2.0	0.0	0.0	0.0	6.1
WFO Construction	0.0	1.8	1.3	3.2	3.2	0.0	9.5

Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC03, KP, WFO)
** Includes previous FY1999 amounts

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 including 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. Complementing our partnerships with the joint DOE Center on Terrestrial Carbon Sequestration (at ORNL, PNNL, and ANL), 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.

Berkeley Lab has also initiated the GEO-SEQ Project, a joint study with Lawrence Livermore and Oak Ridge National Laboratories, along with twelve industrial and academic partners, to investigate the feasibility and collateral benefits, for the long-term storage of CO_2 in depleted oil and gas reservoirs, brine formations, and coalbeds.

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	2001	2002	2003	2004	2005	Total
Operating	2.0	4.0	6.0	6.0	6.0	24.0

*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	2000	2001	2002	2003	2004	2005	Total
Operating	2.5	2.5	3.0	3.0	3.0	3.0	17.0

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

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 partial 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. In addition, 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, *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: Understanding Complex Biological Processes Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
DOE Operating	0.3	0.3	0.4	0.5	0.5	2.0
WFO 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 interrelated 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 ~10^{17} floating point operations (~10^5 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 worldwide.

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

Category	2001	2002	2003	2004	2005	Total
Operating	0.9	4.8	4.8	3.8	3.8	18.0
Construction	2.0	2.2	0.0	0.0	0.0	4.2

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

Air Quality: Particulate Matter and Tropospheric Ozone

Air quality is a national concern because of air pollution's associated health impacts, its effect on the environment, and the significant costs of control measures. Air quality and national energy policy are inextricably connected because the origin of most pollutants and/or their precursors is attributable to combustion, and combustion is responsible for approximately 90% of the energy consumed nationally. Furthermore, there are significant air quality issues of concern to the U.S. in the international arena, for example with Mexico, Canada, and the Pacific Rim, since the U.S. can be impacted by emissions to and from those countries. Because of increasing concerns over particular pollutants, new U.S. air quality standards have been promulgated for ozone and particulate matter (PM), especially PM having diameters less than 2.5 microns (PM-2.5). In addition, there is renewed interest in air quality-related values associated with visibility and acid deposition.

In many instances the science base is inadequate for decision-makers to set good policy. In response, Berkeley Lab has launched an initiative in air quality research. Our vision is to build a program that takes advantage of current expertise in advanced instrumentation, high performance computing, modeling, modeling uncertainty, indoor environment, combustion and emissions, and analyses. The initiative also incorporates the talent on the Berkeley campus, including that in the recently established Center for Atmospheric Sciences.

The initiative builds upon the Laboratory's recent growth in air quality field studies and related research. For example, the Laboratory has the critical role in the larger San Joaquin Valley study to develop and field test a physically-based semi-empirical model to predict distributions of concentrations of outdoor PM-2.5 in single-family, residential buildings based on outdoor measurements of PM-2.5. This research will enable better estimates of human exposure to outdoor particles. Berkeley Lab researchers have considerable expertise in particle dynamics, chemistry, and measurement that can lead to even more substantial contributions to understanding the role of particles in the indoor, urban, regional, and global environments. In another effort, researchers are developing the underlying science to identify the most appropriate modeling, analyses, and monitoring approaches for characterizing the oil and gas industry's contributions to visibility changes in the west.

In a recently initiated project, research is underway to understand how changes in spatial and temporal scales affect atmospheric phenomena, and the role of biogenic emissions in the formation of secondary aerosol formation. Emphasis will be placed on understanding the coupling between ozone and PM-2.5 with respect to their common reaction precursors, reaction pathways, and meteorology. As part of this effort, Berkeley Lab will participate in the Central California Ozone Study to be conducted during summer of 2000. Other research is examining better approaches for characterizing and quantifying diesel emissions, and determining if there is any evidence that daily mortality that has been associated with PM-2.5 is related to the chemical composition of the PM.

The initiative expands upon this existing work and focuses on the two air quality issues of present major concern: airborne particulate matter and tropospheric ozone.

Airborne particulate matter. The airborne PM of concern results almost entirely from combustion processes. There is a need to improve modeling and monitoring in order to link sources to exposure. The research will address source identification, the modeling of particle formation and transport, more extensive modeling of the indoor/outdoor interface, and linking the results to human health effects research. In the case of the indoor/outdoor interface, it is noted that people spend most of their time indoors. The research will address our current inability to correlate indoor exposures to outdoor concentrations. The research will also address the composition and size distribution of PM. At present we have virtually no knowledge of the actual agent(s) causing for the observed health effects or the actual mechanisms by which these agents act.

Tropospheric ozone. Tropospheric ozone results from photochemical processes in which the precursors are nitrogen oxides (NOx) and volatile organic compounds (VOCs). NOx is an emission resulting from combustion processes and thus, at least in principle, can be controlled. VOCs are both of anthropogenic origin (e.g., unburned hydrocarbons from combustion) and of natural origin (e.g., from trees and plants) and thus only partially controllable. Research is needed on improving the agreement between modeling of the photochemical process and measurements. Contributing to the model uncertainty is that the models are based on short episodes and uncertain emissions inventories. A critical need is to carry out continuous measurements as a basis for refining models. Also needed is an improved understanding of regional transport and the chemistry of the ozone precursors. Finally, research is needed to characterize the nature of the coupling between tropospheric ozone and fine particles. All of this research will lead to improved control strategies for VOCs, NOx, and particulates. Current strategies have largely failed to attain existing air quality standards. What may seem like the straightforward strategy of reducing NOx emissions can actually increase ozone concentrations in certain circumstances. Similarly, a control strategy for reducing ozone levels may increase particulate levels, and vice versa.

Air Quality: Particulate Matter and Tropospheric Ozone
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	2.5	3.0	3.5	3.5	3.5	16.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source KP, FE, EE, WFO/EPA)

Biological Effects of Low Dose Ionizing Radiation

Berkeley Lab efforts complement those made by other national laboratories and universities to address the health risks to the public and workers from low dose radiation, to provide opportunities for major cost reductions by decreasing DOE's environmentally problematic byproducts, and to reduce the time required to achieve mission goals. The research program at Berkeley Lab is based on recent advances in modern molecular and tissue biology and instrumentation.

Radiation can affect biological material at many levels—from molecules to tissue. Tissue response to radiation is a composite of genetic damage, cell loss, and induced gene products. Our studies, using precise cell biology techniques to microscopically map complex patterns of radiation-induced gene expression, demonstrate that tissue response to ionizing radiation is rapid, global, tissue specific and sensitive to doses as low as 0.1 Gy. A clear understanding of risk estimation requires multidisciplinary study and an integrated computational and experimental approach. Experimental studies are discerning the basic mechanisms associated with exposure to low-level ionizing radiation (LLIR), including new phenomena specific to low doses. A computational model of low dose risk is being developed that will help develop scientifically defensible tools to determine radiation risk.

A critical step in studying radiation response is to identify and characterize mechanisms and gene products in three different crucial repair pathways for DNA double-strand breaks (DSBs) and other oxidative lesions. Our efforts related to this goal are to (1) characterize components of multiprotein complexes for DNA damage sensing and DSB after LLIR exposure; (2) investigate cellular parameters for the efficiency and fidelity of DSB at very low levels of damage, including possible inducibility and overlap with transcription-coupled repair; and (3) characterize base excision repair and its relationship to the adaptive response, the bystander effect, and spontaneous and induced mutagenesis. Recently, information from studies of the fidelity of DSB repair had been successfully included in computational modeling of the 46 chromosomes in interphase.

Concurrent with the repair studies, we are also taking advantage of recent advances in gene expression detection technology—such as cDNA microarray, and the development of transgenic mouse models for DNA repair and damage-signaling pathways—to correlate specific gene expression patterns throughout the genome. We are attempting to identify the cellular and molecular targets that mediate bystander efforts in response to LLIR exposure. We will then test a hypothesis that the biological endpoints of bystander effects are mediated by reactive oxygen species and are targeted to DNA directly. We will use mammary gland from different genetic backgrounds as well as 3-D models of human mammary epithelial cells to identify common determinants of radiation susceptibility. In addition, the mechanisms of repair of DSBs and base damage induced by LLIR, their associated damage sensing pathways, and the protein-protein interactions critical for their function will be considered, creating the foundation for structure-function analyses of critical repair proteins.

A bioinformatics framework of image acquisition, annotation, analysis and image database will be created that registers information about multiple targets, positional references, and morphological features. This will also allow the development of tools to query the data for common patterns and relationships between different tissues probed with the same antibodies or DNA probes. In addition, information from samples imaged can be related with different imaging modalities such as immunofluorescence, soft X-ray, and histological dyes. Interrogation of this database will allow users to generate and test new hypotheses regarding radiation response. Used in conjunction with animal models of known radiation susceptibility, this innovative approach will enable construction of phenotype databases necessary to identify biological responses to low dose and low dose-rate radiation exposure.

Biological Effects of Low Dose Ionizing Radiation
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	Total
Operating	1.5	1.6	1.6	1.7	1.7	8.1

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

V. OPERATIONS 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 (ES&H) programs fully support DOE's strategies for ensuring that safety and health of workers and the protection of the environment are integrated into all work the Laboratory does. One (ES&H) program strives to aggressively address historic contamination. Excellence and timely implementation of ES&H 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 ES&H programs correspond to and cooperate with the DOE goals in support of this vision. Program priorities are set and followed in accordance with DOE's ES&H and Infrastructure Management Plan. Strategic Planning 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 ES&H efforts. The vision of the program, which is implemented by the Environment, Health, and Safety (EH&S) Division, sets a high standard of performance:

> Berkeley Lab is an internationally renowned research facility and a national treasure. It requires a world class Environment, Health, and Safety organization that works as a partner with the Laboratory's research and development divisions/departments to provide cost-effective, customer-focused services that enable the creation of world class science. To be world class, EH&S staff must have the same dedication, professionalism, integrity, and intellectual curiosity as the researchers who established Berkeley Lab's scientific reputation.

The primary objective of the ES&H program 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 EH&S Division supports and acts as a partner with line management as it meets direct responsibilities 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. Of equal importance, the EH&S Division supports and provides expertise directly to each Laboratory worker who seeks ES&H advice and help, or who voices a concern.

In carrying out its primary mission, the Division is committed to six basic objectives:

- 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 our 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 its 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.

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 used 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 and radioactive 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 Laboratory 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 Laboratory 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 developed a Counterintelligence Program 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 attend required Counterintelligence briefings and security awareness training.

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 Environmental Sampling Project Task Force, 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.

An Open House and Science Festival, a biannual event staged most recently in the spring of 2000, brings the messages of the possibilities in science education and careers, the value of research, and the DOE missions to thousands of visitors and stakeholders in the Bay Area.

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 employees make additional commitments to their communities through participation in the annual Berkeley Lab Shares, a charity giving campaign that in 1999 raised $100,000 for local agencies and programs. The campaign especially includes those local charities that are dedicated to educational and scientific causes.

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 the Berkeley Lab's programmatic initiatives. The Human Resources (HR) Department is an integral part of the Berkeley Lab Operations' Divisions and Departments that provide the infrastructure to support the Laboratory's programs and research efforts.

The objectives of the Human Resources Department are to help make the Berkeley Laboratory the location of choice for employees and others; and to help create and support an environment in which all employees view themselves as part of the same team, with significant common goals, dedicated to making a Berkeley Lab that works and that allows researchers to concentrate on research.

In order to achieve these objectives, we provide comprehensive, integrated Human Resources service to the institution as a whole with a strong emphasis on strategic planning, consulting, responsive customer service and effective relations with Laboratory Management, the University of California, the Department of Energy and other customers and colleagues.

The functional areas of the Human Resources Department are: Compensation, Benefits, Employee Relations, Labor Relations, Recruitment, Payroll, International Researchers and Scholars, and HR Information Systems. In all of these areas, we strive to build and maintain quality and cost-effective programs, to keep the Laboratory in compliance with applicable laws and regulations, and to provide services that meet the Laboratory's business requirements.

The Human Resources Department works with the Work Force Diversity Office to support and develop work/life programs and to expand our efforts to create a climate in which diversity in the work force is valued.

The Berkeley Laboratory's Human Resources Performance Measures are utilized to help us improve performance. Our Performance Objective revolves around the effectiveness of Human Resources Operations, specifically, to help ensure that our programs, systems, and processes support the Laboratory's programmatic and business needs.

Table V(1) LABORATORY STAFF COMPOSITION (FY 1999)

Full & Part Time Employees	Total		PhD		MS/MA		BS/BA		Other	
Scientists*	841	(23%)	758	(90%)	44	(5%)	34	(4%)	5	(1%)
Faculty	261	(7%)	255	(98%)	4	(2%)	1	(<1%)	1	(<1%)
Professional*	497	(14%)	72	(14%)	154	(31%)	182	(37%)	89	(18%)
Executive	8	(<1%)	8	(100%)	-	-	-	-	-	-
Administrative	556	(15%)	21	(4%)	87	(16%)	198	(36%)	250	(45%)
Technical	934	(26%)	15	(2%)	107	(11%)	244	(26%)	568	(61%)
All Other	509	(14%)	20	(4%)	85	(17%)	208	(41%)	196	(39%)
Grand Total	3606	(100%)	1149	(32%)	481	(13%)	867	(24%)	1109	(31%)

* Berkeley Lab has made significant changes in its job family structure as related specifically to the former classification for "Engineers." This classification has been supplanted by Berkeley Lab's current "Scientists" and "Professional" classifications.

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 1999)

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	109	36	92	34	15	2	4	1	6	0	5	1	0	0
	75.17%	24.83%	63.45%	23.45%	10.34%	1.38%	2.76%	0.69%	4.14%	0.00%	3.45%	0.69%	0.00%	0.00%
Total male and female	145		126		17		5		6		6		0	
	100%		86.90%		11.72%		3.45%		4.14%		4.14%		0.00%	
PROFESSIONALS														
Scientists/Engineers	748	152	584	109	164	43	14	5	12	7	136	30	2	1
	83.11%	16.89%	64.89%	12.11%	18.22%	4.78%	1.56%	0.56%	1.33%	0.78%	15.11%	3.33%	0.22%	0.11%
Total male and female	900		693		207		19		19		166		3	
	100%		77.00%		23.00%		2.11%		2.11%		18.44%		0.33%	
Management/Administrative	132	244	132	176	51	68	4	16	7	11	39	39	1	2
	35.11%	64.89%	35.11%	46.81%	13.56%	18.09%	1.06%	4.26%	1.86%	2.93%	10.37%	10.37%	0.27%	0.53%
Total male and female	376		308		119		20		18		78		3	
	100%		81.91%		31.65%		5.32%		4.79%		20.74%		0.80%	
TECHNICIANS	318	62	246	39	72	23	17	3	20	5	35	14	0	1
	83.68%	16.32%	64.74%	10.26%	18.95%	6.05%	4.47%	0.79%	5.26%	1.32%	9.21%	3.68%	0.00%	0.26%
Total male and female	380		285		95		20		25		49		1	
	100%		75.00%		25.00%		5.26%		6.58%		12.89%		0.26%	
CLERICAL	39	227	26	119	13	108	7	59	4	20	1	29	1	0
	14.66%	85.34%	9.77%	44.74%	4.89%	40.60%	2.63%	22.18%	1.50%	7.52%	0.38%	10.90%	0.38%	0.00%
Total male and female	266		145		121		66		24		30		1	
	100%		54.51%		45.49%		24.81%		9.02%		11.28%		0.38%	
CRAFTSMEN/LABORERS	115	1	87	1	28	0	7	0	14	0	5	0	2	0
	99.14%	0.86%	75.00%	0.86%	24.14%	0.00%	6.03%	0.00%	12.07%	0.00%	4.31%	0.00%	1.72%	0.00%
Total male and female	116		88		28		7		14		5		2	
	100%		75.86%		24.14%		6.03%		12.07%		4.31%		1.72%	
SVC. WORKERS/APPRENTICES	44	15	19	5	25	10	13	5	8	3	4	2	0	0
	74.57%	25.43%	32.20%	8.47%	42.37%	16.95%	22.03%	8.47%	13.56%	5.08%	6.78%	3.39%	0.00%	0.00%
Total male and female	59		24		35		18		11		6		0	
	100%		40.68%		59.32%		30.51%		18.64%		10.17%		0.00%	
Total All Categories	**2242**		**1669**		**622**		**155**		**117**		**340**		**10**	
	100%		**74.44%**		**27.74%**		**6.91%**		**5.22%**		**15.17%**		**0.45%**	

Source: May 8th 2000 download from Peoplesoft Database. Figures are based on end of fiscal years 1999.

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 Lab 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 very 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 1999, Berkeley Lab reported 105 new inventions, filed 28 new U.S. patent applications and had 31 patents issued. A total of 51 new licenses and options were executed. These are generally typical, although the number of disclosures has increased significantly in the last few years as the Intellectual Property Management program at the Laboratory has acquired greater visibility and researchers are submitting a greater number of disclosures; and numbers of licenses has increased partly due to an increase in nonexclusive software licenses.

Table V(3) Intellectual Property Management

Category	FY 1998	FY 1999	FY 2000 (est.)	FY 2001 (est.)	FY 2002 (est.)
Number of New Licenses*	40	51	50	50	50
License Income ($K)**	561	672	800	960	1150
Invention Disclosures	86	105	100	100	100
U.S. Patent Applications ***	23	28	20	25	25
U.S. Patents Issued	13	31	30	20	20

*Includes options
**Cash in only (i.e., not including fair market value of non-cash income). Also, does not include direct reimbursement of patent costs.
***Not including provisional patent applications or continuation applications

Fiscal Year 1999 saw income from licensing ($672 K) grow approximately 20% in comparison to the FY 1998 figures. We expect to see further strong 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 or other intellectual property protection 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(4) Distribution of Net* Licensing Income

	FY 98 and Prior Disclosure	FY 99 and Subsequent Disclosure
Inventor Payments	42.5%	35%
Research and Development	42.5%	65%
Education	0%	0%
ORTA administration	15%	0%

* Gross income less cost of intellectual property protection such as patenting or copyright registration costs

One exciting result is the exclusive license by Berkeley Lab's Technology Transfer Department of a technique for vastly increasing the sensitivity of magnetic resonance imaging (MRI) to Nycomed Amersham Imaging, a leader in *in vivo* diagnostic imaging products. This MRI technology is emblematic of Berkeley Lab's strength in multidisciplinary research; a large team of scientists from both the Berkeley Lab Materials Sciences and Life Sciences Divisions collaborated on this invention. The novel technique uses "hyperpolarized" xenon gas dissolved in an FDA-approved injectable fluid to create samples that remain highly polarized for a matter of minutes or more. This provides adequate time to image complex structures and enables much-improved imaging of physiological phenomena in the blood system and in tissues specific to the heart, brain, and other organs. The Berkeley Lab research team has already performed successful MRI of molecules of anesthetic entering human blood cells; they have also obtained high-resolution, time-resolved signals from hyperpolarized xenon injected directly into blood vessels and tissues.

VI. INFRASTRUCTURE STRATEGIC PLANNING: STRATEGIC BUILDINGS PLAN

The infrastructure for the system of DOE National Laboratories supports some of the most productive scientific institutions in the nation, yet the continued reliance on an aged and decaying physical plant makes recruitment and retention of scientists and engineers difficult, and is becoming a barrier towards achieving programmatic goals. As indicated in the *Strategic Plan of the Office of Science,* a key objective for this system is to "provide leading research facilities and instrumentation to expand the frontiers of the natural sciences." The Laboratory's infrastructure planning and management is directed towards sustaining the Office of Science mission and this strategic objective.

STRATEGIC BUILDINGS PLAN GOALS

In order to sustain the Laboratory's contributions to these DOE missions, the *Berkeley Lab Strategic Buildings Plan* has been prepared, and is summarized in this chapter, together with information on the condition of buildings. The Plan describes facilities investments that must be made to sustain these contributions and fulfill the strategic plans of DOE and the Office of Science. The principal goals of the *Berkeley Lab Strategic Buildings Plan* are to:

- Provide laboratories and office systems appropriate to Berkeley Lab's research roles for DOE
- Support the growing user community at the Laboratory's scientific facilities
- Provide an environment that is safe, efficient, and enabling for staff, guests, and the community

The scientific drivers and buildings identified in this Plan advance DOE missions and the Office of Science programs, principally for the Offices of Basic Energy Sciences, Biological and Environmental Research, High Energy and Nuclear Physics, Advanced Scientific Computing Research, and Fusion Energy Science. In addition, technology advancements made by the Laboratory support the Energy Efficiency and Renewable Energy Programs and the Office of Civilian Radioactive Waste Management and other elements of DOE. The potential new construction included in this report supports the DOE *Strategic Plan* and the *Science Portfolio* and *Strategic Plan of the Office of Science.* The purpose is to indicate the Laboratory's current and anticipated needs for approximately the next ten years.

This *Strategic Buildings Plan* summarizes the programmatic drivers and research facility needs that must be incorporated into the planning for Berkeley Lab and for DOE managers. The information included in this *Strategic Buildings Plan* has been developed primarily through the scientific, facilities, and management organizations and will continue to be refined with scientific divisions, resource departments, and DOE.

INFRASTRUCTURE AND CHANGING SCIENTIFIC ROLES

Berkeley Lab's 82-hectare (200-acre) main site is immediately adjacent to the University of California (UC) at Berkeley. The main site encompasses 1.7 million gross square feet (mgsf). In 2000, there were 112 buildings of conventional construction and 108 trailers and other structures at the main site. Additional space on the UC Berkeley campus includes 90,000 gross square feet (gsf); and 260,000 gsf are located in leased buildings in the cities of Berkeley, Oakland, and Walnut Creek.

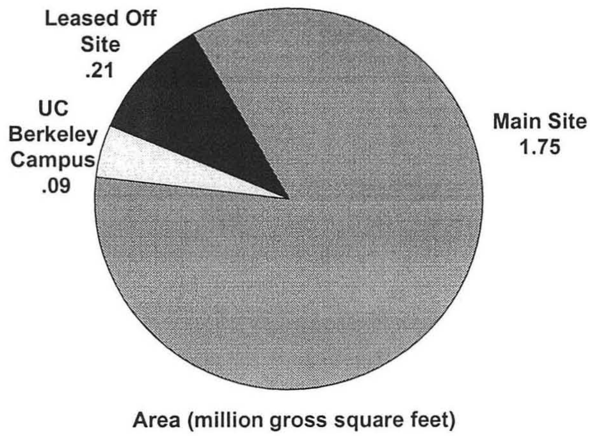

Figure VI(1) Laboratory Space Distribution

Berkeley Lab's scientific missions have changed since the first facilities were constructed for the 184-Inch Cyclotron and the Manhattan project in the early 1940s. The challenge to the Laboratory in achieving its current multiprogram Office of Science mission is that more than 70 percent, or 1.2 mgsf of the Laboratory's total current space of 1.7 mgsf was constructed prior to 1970, when the Laboratory was a single-purpose Atomic Energy Commission facility. The evolution of the Laboratory is shown below.

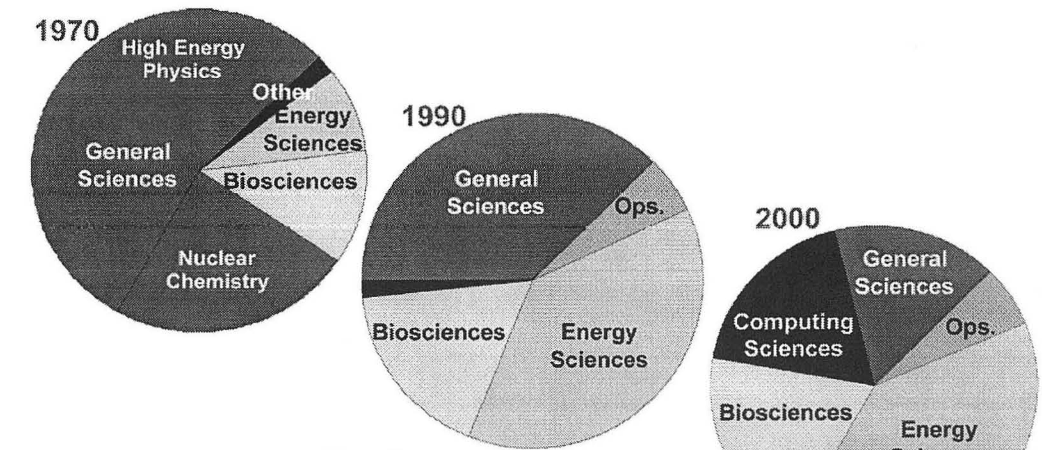

Figure VI(2) Change in Berkeley Lab Programmatic Areas

Many of the main site buildings are no longer appropriate to the current research program and are reaching the end of their service life. These facilities do not have the mechanical systems (e.g. air handling, heating, cooling, and plumbing) and electrical systems necessary to effectively or efficiently conduct the current research. Many of these systems are vital to providing adequate cleanliness, fume removal, treatment, power, gas handling, and other operations necessary for experimental programs. In other instances, the buildings are not structurally satisfactory, including buildings that are condemned or have occupancy limitations. Frequently, the buildings were intended for temporary occupancy or for specialized functions that are no longer being conducted. Use of unsatisfactory space is costly, and requires reliance on administrative controls to ensure that operational safety requirements continue to be attained.

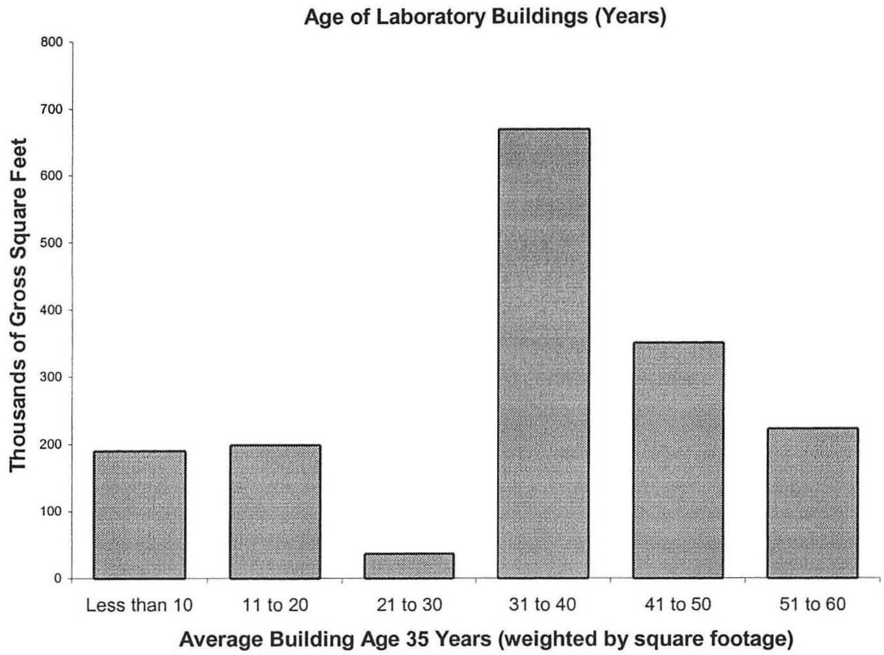

Figure VI(3) Age of Laboratory Buildings, Modulars, and Trailers

The most significant facility no longer serving DOE programs is the Bevatron, which encompasses 10 percent of the Laboratory's space and occupies a central location that should serve priority DOE missions, including those described below. Except for the Bevatron accelerator, all occupiable offices, laboratories, and support facilities at Berkeley Lab are 100 percent utilized.

The total replacement value of the facilities is $1038M, as reported in the Facilities Information Management System (FIMS), and the value of the equipment in the facilities is $470M. On an annual basis, the Laboratory invests $5M in non-capital projects in the buildings. The DOE Office of High Energy Physics provides $3.5M for General Plant Projects. The Multiprogram Energy Laboratory Facilities Support Program (MELFS) provides an average of $4M (based on the past 7 years). Collectively, these resources provide a 1.2 percent annual investment rate or a turnover time of 83 years (excluding additional program construction funds).

The 2000 replacement plant value of Berkeley Lab facilities is estimated to be $806 million. This includes all on- and off-site buildings occupied by Berkeley Lab. The replacement plant value of the Berkeley Lab hill site infrastructure includes all site improvements, utilities, communication systems, and accelerators.

Approximately 331,000 square feet of Berkeley Lab's space (at the main site) is substandard and in need of replacement. See Figure VI(4). 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, 89% of computer space, 97% of wet lab space, and 84% of dry lab space are rated as adequate or functional in 2000. 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).

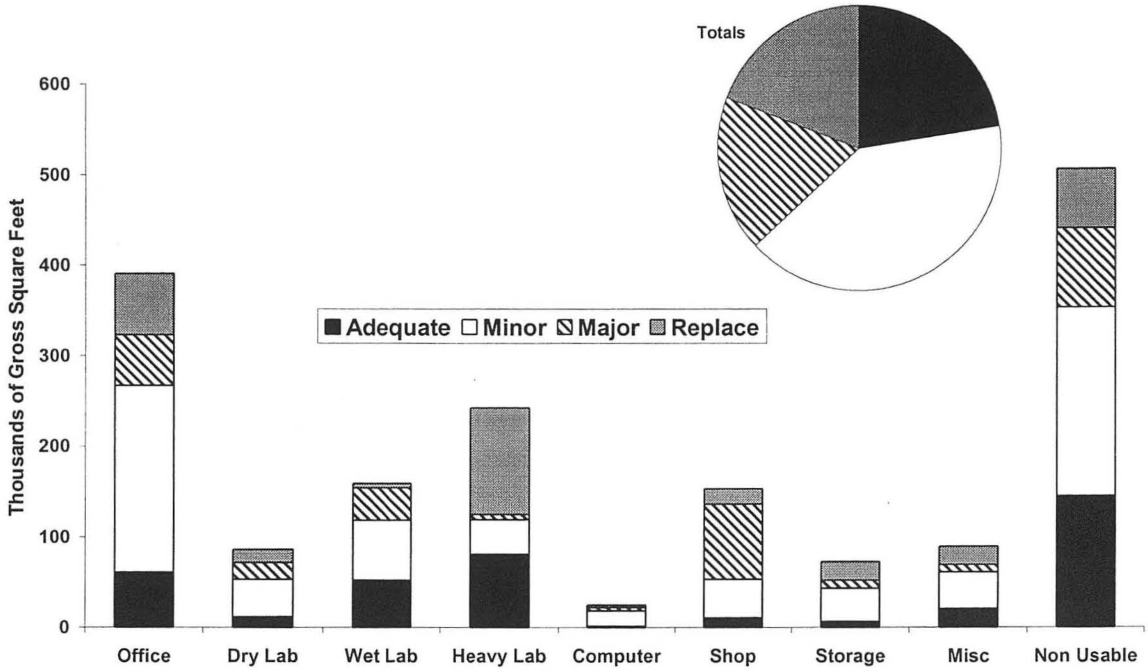

Figure VI(4) Use and Condition of Laboratory Space

Guidelines for placing a facility into a particular category are as follows: Adequate< 10% of Replacement Plant Value (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.

BUILDINGS FOR DOE PROGRAMS

The critical scientific investments that advance the Laboratory's facilities stem from the value of the Laboratory's research to the DOE program offices. The *Berkeley Lab Strategic Buildings Plan* is based on scientific drivers for DOE missions. In a number of instances, without new scientific investments that advance the research frontier, the unsatisfactory and decaying infrastructure threatens the scientific contributions to the program offices.

The priorities established in this strategic plan are based on the science mission and program benefits; the urgency and timing of scientific demand, including the adequacy of exiting facilities to satisfy interim needs and avoid risks of program failure; and the potential for improving working conditions and efficiency. The collective strategy and priorities are based on continuing scientific program evaluation and planning, facilities conditions and siting assessments, and a determination of the consequent priorities for the *Strategic Buildings Plan*. Complementary to this planning is the evaluation of projects with a risk prioritization matrix to assure that program, environmental, safety, and security risks are considered in establishing priorities. The process to assign priorities is represented below.

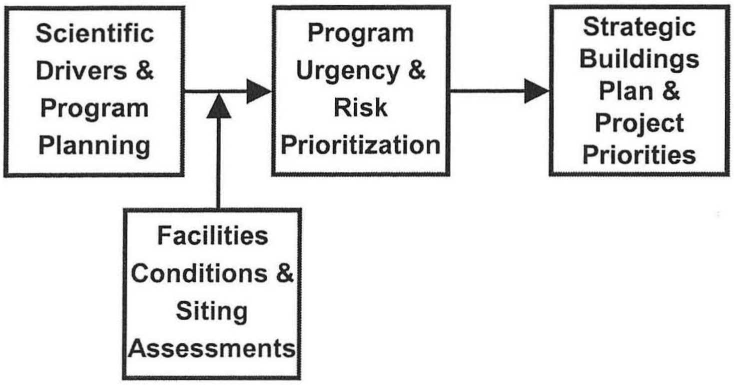

Figure VI(5) The Strategic Buildings Plan Process

Basic Energy Sciences

The Laboratory's research for the Office of Basic Energy Sciences is addressing national needs for advanced instrumentation, development of nanoscience, understanding of the global environment, and more efficient recovery and use of energy resources. The research requires full support for users at the Advanced Light Source (ALS) and the National Center for Electron Microscopy. A critical need is a building to address the needs of the rapidly growing user community at the ALS. See Figure VI(6). Such a user support facility would meet the needs of the ALS user community while contributing to the national goals in advancing nanoscience.

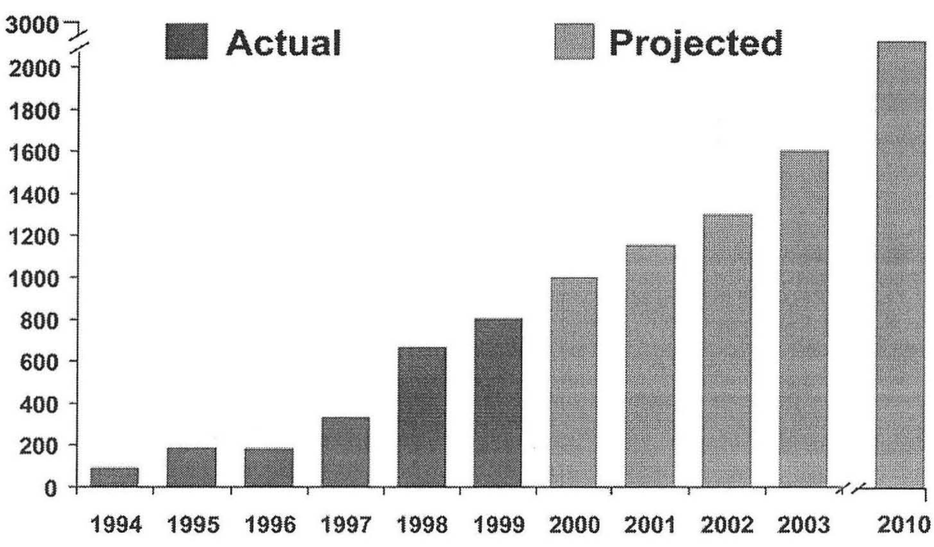

Figure VI(6) Growth in Advanced Light Source Users

Advanced Light Source Nanoscience User Facility

A *Berkeley Lab Strategic Buildings Plan* priority is to effectively accommodate the needs of the Advanced Light Source user community. These needs include laboratories that support research at the ALS beamlines, offices, and instrumentation staging areas. The number of users at the ALS has more than quadrupled in three years to 900 and—just with the completion of currently funded beamlines—is expected to increase to 1600 users by FY 2003. By the end of the decade, the ALS will serve about 2500 users.

ALS users make important contributions in many fields, including frontier research in emerging areas of nanoscience and complex systems, the new post-genomic biology, environmental science, surface science and chemistry, optics and magnetic materials, other areas of the natural sciences, and technology development.

The growth of ALS users and ALS science directly supports the National Nanotechnology Initiative. To advance DOE's role in this initiative, an interdisciplinary nanosciences program will build on the major user facilities at Berkeley Lab. The ALS, the National Center for Electron Microscopy (NCEM), and the National Energy Research Scientific Computing Center (NERSC) comprise an unparalleled suite of tools for the characterization and modeling of nanoscale materials. In addition, more than 50 internationally recognized senior investigators at Berkeley Lab and University of California at Berkeley have, over the past decade, been developing a broad program in the fields of nanoscale science and technology. The ALS Nanoscience User Facility will provide modern laboratory space in close proximity to the ALS, enabling the interdisciplinary research that will lead to new atomic-scale materials.

The ALS Nanoscience User Facility supports the main recommendation of the Basic Energy Sciences Advisory Committee Subpanel Review of the ALS "to support the ALS plan to have a new building adjacent to the machine to have more office space for users and laboratories for sample preparation and experiment staging."

The scope of the proposed facility includes laboratories to support users at the planned 55 beamlines. The flexible laboratory space will enable nanomaterials sample fabrication and preliminary characterization; environmental science research; microbiology and cellular systems research and sample preparation; lithography materials preparation; magnetic and optical materials preparation; crystallography facilities including robotics for protein sample preparation and crystallization; general purpose spectroscopy facilities; reaction dynamics support laboratories; and solid-state materials preparation laboratories.

Two hundred offices and cubicles will be provided for the needs of the 2500 visiting ALS scientists the nanoscience researchers, and for experimental systems support and beamline/optical systems design personnel. In addition, conference rooms and user center support and training areas will be provided. The estimated scope is 90,000 gsf.

The facility will be located immediately adjacent to the Advanced Light Source and replace several existing substandard facilities constructed primarily during World War II. These wood frame structures are potential fire hazards with poor structural, mechanical, and electrical systems.

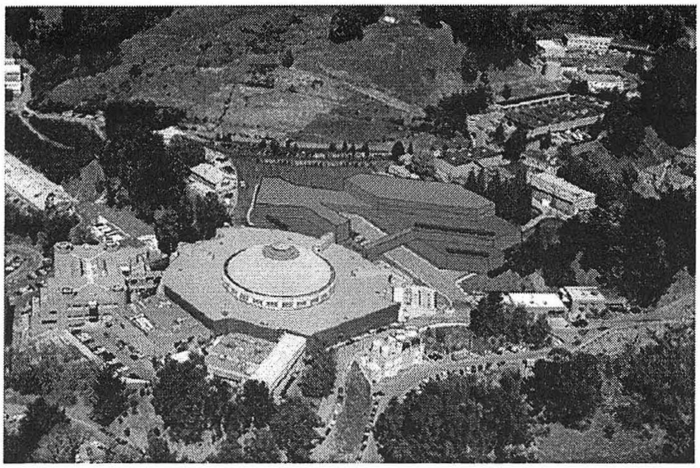

Figure VI(7) Advanced Light Source Nanoscience User Facility Representation

Biological and Environmental Research

The Laboratory's bioscience research advances are revealing the sequence of the genomes of key species; the structures of dozens of proteins and their complexes; the importance of environment and genetics in cancer; and the relationship between structure and function in many biological processes. Functional imaging, the development of new instrumentation and simulation tools, and other techniques are providing a basis for creating a new level of understanding of biological systems from the molecular scale to the complete organism.

Advanced Biosciences Research Building

Several emerging goals for the Office of Biological and Environmental Research work at Berkeley Lab are the basis for the new research building. These goals are to discover how the genome is regulated in cells, tissues, and organisms; and to understand the network of pathways and interactions of the cellular machinery. Providing the enabling laboratories, and physical, computational, and other research tools can make the next advances in biology a reality in these key areas:

- Recently, comparative genomic analysis is beginning to reveal that many genomic sequences not coding proteins are retained in many species and have important adaptive value. These regulatory sequences control protein synthesis, cell and tissue development, and consequently normal and diseased functions. Key areas of investigation needed in functional genomics include cellular and molecular biology research on damage to cellular systems; advanced imaging and analytical studies to determine the health risks of low-dose radiation; and how oxidative byproducts affect normal physiological processes.
- Berkeley Lab scientists will begin to develop comprehensive analytical and predictive models that will catalog and integrate the internal chemical machinery, transport, assembly, and control systems that allow cells to respond to their environment and assemble them to carry out specialized functions. This information and the computational analogs of cells can be used to address DOE needs in microbial bioremediation, carbon sequestration, and in health related research.

Achieving the goals for advances in structural and functional genomics and to understand the integrated function of microbial and eukaryotic cells requires a new Advanced Biosciences Research Building. This building will provide the laboratories and offices needed for multidisciplinary cell and molecular biology research, functional genomics and transgenics, functional imaging and advanced imaging technology, and other biosciences needs. In addition to general-purpose laboratories and offices, transgenic studies are of increasing importance to understand the functions of the genome.

With the exception of the new Genome Sciences Building, much of the existing Life Sciences and Physical Biosciences Divisions space was constructed from the 1940s through the 1970s and is reaching the end of its service life. The seismic performance and infrastructure problems of Building 1 (Donner Laboratory), Building 3 (Calvin Laboratory), and Building 83 (Cell Culture Building) have resulted in the need for plans to replace these facilities.

The total area of these facilities occupied by Berkeley Lab personnel is 42,000 gsf. The Advanced Biosciences Research Building provides the laboratories for the new program in biology and will replace the existing outmoded space.

Existing biosciences facilities planned for replacement by the proposed Advanced Biosciences Research Building:

Building	Staff	Area (gsf)
Building 1	117	25,000
Building 3	45	10,000
Building 83	20	7,000
Total	182	42,000

The proposed 45,000 gsf Advanced Biosciences Research Building will provide for modern, efficient, and safe conduct of biological research programs at Berkeley Lab. The facility will include approximately 40 laboratories and 130 offices for the conduct of research in structural biology, functional genomics, and biomedical research. The arrangement of laboratories and offices will provide for integrating macromolecular structure, biological dynamics, computational and theoretical biology, advanced microscopies, and cell biology. The flexible laboratory space will enable research to address the genetic basis of disease; cell, molecular, and radiation biology related to cancer etiology; and cell and tissue growth and differentiation. Laboratories will conduct research on the extracellular matrix, oncogenes and tumor suppressor genes, radiation and chemical carcinogenesis, and DNA repair. The estimated cost of the facility is $45M.

In addition, a complete rehabilitation of the mechanical and electrical systems and of some of the laboratories in Building 74 is required. Building 74 is a key facility for sustaining the Office of Biological and Environmental Research programs in general biology and health effects research at Berkeley Lab.

High Energy and Nuclear Physics

High energy and nuclear physics programs are at the heart of the Laboratory's core capabilities and are providing leadership for DOE scientific programs in several areas. The Berkeley-led Supernova Cosmology Project shared Science magazine's citation as a "Breakthrough of the Year." The Solenoidal Tracker (STAR) detector at Brookhaven's Relativistic Heavy Ion Collider and the B-Factory at the Stanford Linear Accelerator Center have been commissioned and are taking data. In 1999, the discovery of superheavy elements 116 and 118 at the 88-Inch Cyclotron made headlines around the world. In addition to its contributions for accelerators at the B-Factory, the European Center for Nuclear Research (CERN) and elsewhere, the Laboratory is investigating optical technologies using laser-plasma acceleration as a new direction for high energy accelerators of the future. A 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 probe, moving earth-bound observations to space. The Laboratory must also provide for leadership in the frontiers of core high energy and nuclear physics efforts, including accelerator systems and ion beams for many applications.

Ion Beams Laboratory at a Rehabilitated SuperHILAC Building

The Office of Science requires the most advanced accelerator front ends and ion sources for new and upgraded accelerators for High Energy and Nuclear Physics and for other Science programs. The efforts focus on the development of high current sources, controlled time structure, beam stability, and a wide range of ion species for varied and new scientific applications. To address this scientific need, a strategic priority for Berkeley Lab is an Ion Beams Laboratory at a Rehabilitated SuperHILAC Building. The Ion Beams Laboratory addresses the scientific needs and the necessary relocation of existing beam test stands and research facilities that will be displaced (largely from the demolition of Buildings 4, 5, 14, and 16) by the Advanced Light Source Nanoscience User Facility. The rehabilitated facility will require removal of the SuperHILAC and its support systems, upgrades to utilities and the addition of walls, offices, and beam assembly and testing facilities. An important component is an office addition to the 71 complex of approximately 28,000 gsf. This office structure, to be built on an existing foundation, is estimated to cost approximately $12M.

Astrophysics Research Building

The Laboratory is advancing astrophysics through a multidisciplinary program that is studying many fundamental parameters of matter and energy. These studies include supernova observations, cosmic microwave background radiation studies, neutrino physics, dark matter searches, high energy nuclear astrophysics, theoretical astrophysics, and geoastrophysics. Some key instrumentation and detector technologies being developed that are a part of this work are high-resistivity charge-coupled device (CCD) automated telescopes, a proposed supernova astrophysics satellite probe, the KamLAND neutrino detector, and the cubic kilometer neutrino detector.

The scientific impact of this area of research is revolutionizing the understanding of matter, energy, and the universe. The Laboratory is now poised to gain an understanding of the forces that created the big bang and the dark energy that is accelerating the expansion of the universe, and the underlying energy density, mass density, and geometry of the universe. The effective and efficient conduct of the program will require a new facility for astrophysics, primarily for offices but with laboratories and staging areas for instrumentation development. These staging areas should provide for instrument assembly under conditions appropriate to the high sensitivity and complexity of the detector systems required. The facility will include the offices, meeting areas, and control systems for the earth-based and satellite-based programs. The building will require space and communications utility systems for modern communications and conferencing requirements. The estimated cost of the 40,000 gsf facility is approximately $80M (including clean rooms and other equipment).

Advanced Accelerator Research Building

A new office, fabrication, and testing facility is required in order to advance the understanding of the properties of matter through the coming generations of accelerator systems. This building will include the offices, equipment fabrication, assembly, and testing areas to support new accelerator systems concepts and components that are needed. The facility will address new concepts such as optical accelerators, integrated design systems, novel ion source concepts, advanced power sources, innovative magnet systems, high vacuum systems, and other advanced components for the Office of High Energy and Nuclear Physics. Key examples of the program elements include:

- **Superconducting Magnets.** The complete "melt-to-magnet" capabilities of Berkeley Lab's program (that is, everything from materials science through design, fabrication, and testing of magnets) will greatly benefit the next-generation high energy physics projects. The program requires the quality space and infrastructure to conduct the basic research and magnet fabrication that is essential for the next generations of accelerators, such as the Large Hadron Collider and future generations, such as a muon collider.
- **Advanced Accelerator Concepts, Fabrication, and Testing.** Berkeley Lab scientists require modern facilities for the fabrication, assembly, and testing of advanced accelerators such as the two-beam

and optical accelerators and advanced cooling rings systems, as examples. These facilities are needed for beam dynamics studies and for radio frequency power, feedback, cooling, vacuum, and other critical accelerator systems.

The proposed Advanced Accelerator Research Building will provide the necessary modern infrastructure to efficiently and successfully address High Energy and Nuclear Physics program needs while replacing facilities that are nearing the end of their service life. The buildings now used for accelerator research that were constructed during the Manhattan Project and the first decade of the Atomic Energy Commission do not meet structural or electrical and mechanical systems standards.

The buildings that need to be replaced are tabulated below and total 22,800 gsf. The cost of the new facility is approximately $25 M.

Facility	Staff	Area (gsf)
71 trailers (1973)	55	5,800
Building 53 (1944)	9	7,000
Building 27 (1944)	1	3,300
Building 52 (1944)	2	6,700
Total	67	22,800

Bevatron Decontamination and Demolition

The Bevatron comprises 164,000 gsf of Laboratory space, about 10 percent of the space on the main site. Since it ceased operation in 1992, the Bevatron has been largely abandoned by the Department of Energy, with no source of funds for its D&D. A key element of the *Strategic Buildings Plan* is the demolition of the Bevatron facility so that the space can be utilized productively for the construction of the Computing Infrastructure Building—a mission critical facility that must be available to meet the computing infrastructure needs of the 21st century (see below). The cost of the project is dependent on the potential for recycling components of this facility and the extent of environmental cleanup that may be required.

Stable Heavy Ion Beams Facility

The frontier of nuclear physics offers the prospect of dramatic advancements in nuclear astrophysics, understanding nuclear structure, the investigation of exotic nuclei, exploring fundamental symmetries and symmetry breaking, and the extension of heavy element research well into the "Island of Stability." In order to chart these regions of nuclear science, a new low-energy accelerator with very high-intensity, stable, heavy-ion beams over the full mass range of the elements is required. Such an accelerator can produce extremely large cross sections that are ideal for the search for new elements and for exploring the "Island of Stability" that opens new physics beyond the capability of any existing facility. Such a 21st century high-current stable beam facility is also ideal for the production of previously unobserved radioactive nuclei to explore physics beyond the standard model and to study the structure of nuclei with unbound protons beyond the proton drip line. The Laboratory is now investigating the optimum characteristics of such an accelerator that would best address the scientific opportunities. A promising approach to produce higher intensity stable beams would be to construct a heavy ion linear accelerator with superconducting radio-frequency (rf) cavities injected by an electron cyclotron resonance (ECR) ion source and a radio-frequency quadrupole (RFQ) front end. Although several sites are promising for the facility, the most likely location for the accelerator is adjacent to the 88-Inch Cyclotron, which enables utilization of existing experimental caves, detector, and support infrastructure.

Advanced Scientific Computing Research

Berkeley Lab advances the power of high-performance computing as an important tool for scientific discovery in Office of Science programs. A key element of DOE's program at Berkeley Lab is the National Energy Research Scientific Computing Center (NERSC), an extremely powerful computing environment incorporating high-performance computing capability, capacity, storage resources, and computational science and engineering. The Energy Sciences Network (ESnet) is the backbone of DOE's research network, providing access to the NERSC computing environment—and to other research, experimental, and computational facilities—for scientists across the nation and by international collaboration. In order to meet the immediate needs for computing infrastructure, the Laboratory has leased the Oakland Science Facility with a planned occupancy during the summer of 2000.

Computational Sciences Research Facility

To meet the multiprogram needs in computational sciences research, a centralized computational and mathematical sciences research facility is planned that will enable the joint development of algorithms and protocols for solving complex problems of scale. These algorithms include systems of equations for physical, chemical, and biological processes and for petabyte data analysis and visualization of complex systems and peta-scale experiments. The problems to be addressed include forthcoming peta-scale efforts at the frontiers of high energy and nuclear physics; problems of global environmental data analysis and modeling; problems of molecular design and materials simulation; and data problems and analysis for structural biology, genomics, microbial cell simulation, and plasma science. The 50,000 gsf office building has an estimated cost of $25M.

Computing Infrastructure Building

The computing resources at Berkeley Lab are expected to continue to experience increased programmatic demands in response to the transformation of scientific disciplines to highly predictive quantitative enterprises that analyze petabyte scales of data with teraflop (and eventually petaflop) processing capacity. This transformation is being mediated by the development of tera- to petaflop computing. The concomitant transformations in software and scientific services supported by NERSC will greatly strengthen scientific understanding and prediction in all areas supported by the Office of Science. The effort will require new computing facilities, offices, and electronic communication and networking systems.

A 27,000 gsf building for computing is now leased in Oakland—the Oakland Science Facility. This facility should provide adequate floor capacity for high-performance computing equipment for the foreseeable future, perhaps through 2010. At that time, a 150,000 gsf facility for computing infrastructure is planned for operation at the main site. This facility should meet the significantly increased computational capability that will be required in the future. The estimated total cost is $100M (not including computers).

Fusion Energy Science

DOE's fusion energy research at Berkeley Lab focuses on accelerator systems that support the nation's inertial-confinement energy science programs. This heavy-ion fusion accelerator research advances the physics of induction acceleration as the means for producing high-current, heavy-ion beams as drivers for inertial-confinement fusion systems. Critical areas of study now 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 range of experiments in beam physics, beam-target interaction physics, fusion target physics, and physics of the reactor chamber. The potential Integrated Research Experiment accelerator test system is now being assessed for proceeding to a CD-0 stage. This step is needed by the nation to understand the feasibility of accelerators as drivers of inertial-confinement fusion. The experimental systems are a next step beyond the single-beam and multiple-beam transport experiments already completed at Berkeley Lab. The specific cost, scope, and location will be determined at the conceptual design stage. The work also includes studies of plasma heating by various methods, and support for networking and computing for fusion energy science.

Fusion High Bay Addition

The existing component testing, assembly, and research in the Building 58 area lacks adequate floor space, crane coverage, and high bay area to efficiently implement the current program. In order to more efficiently advance the current experimental program and to further examine the accelerator components for injection, focusing, and the behavior of space-charge-dominated beams undergoing current amplification, a $3M addition to the Building 58A high bay is proposed.

DOE Missions in Energy and the Environment

Berkeley Lab conducts essential research for the nation's programs in Energy Efficiency and Renewable Energy. These comprise a 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 programs advance the overall goal of providing energy efficiency systems that reduce greenhouse gases and dependence on foreign oil and enhance the reliability of electricity systems. Key elements of the program are building technologies research on residential and commercial buildings and geothermal energy resources, and increasing the reliability of the utility grid. Advances from Berkeley Lab technologies now in the market place save the nation several billion dollars annually in energy costs.

Berkeley Lab conducts a multidisciplinary program of 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 sponsored by the geosciences program in the Office of Basic Energy Sciences and the Office of Health and Environmental Research, Berkeley Lab is contributing to technology and applied development research at DOE's Yucca Mountain Project, at DOE site restoration locations nationwide, and for DOE research on carbon sequestration.

Earth and Environmental Sciences Research Facility

In order to address the global and national environmental challenges of the next decade, office and laboratory facilities are needed to conduct advanced research in carbon sequestration, global change, radioactive waste management, and other vital areas. The laboratory facilities must also address new research in engineered remediation of metals and radionuclides using biological methods such as immobilization of contaminants *in situ*. The facilities must also provide offices and laboratories for geological engineering research for the storage of high-level nuclear wastes. This research includes characterizing geologic formation and understanding the processes occurring in rock formations, such as hydrologic and chemical transport mechanisms.

Two components of the Earth and Environmental Sciences Facility are planned: one a research office area, and the second a laboratory, field staging area, and office complex. The research offices will house programs closely coupled to computationally intensive research, including global climate modeling, carbon sequestration modeling, computational seismology, and the development of computational models for complex transport in heterogeneous media. These offices are located in close proximity to the proposed Computational Sciences Research Facility.

The second laboratory/office complex includes staging areas for field research, including staging for specialized large mobile instrumentation in seismology, geology, and geochemistry, and for ocean science carbon sequestration studies. This component of the facility is in closer proximity to the Advanced Light Source, where important earth and environmental sciences characterization studies are conducted. The combined area of the facility is approximately 80,000 gsf with an estimated cost of $80M.

Advanced Energy Efficiency Laboratory

The development of innovative energy-efficient building systems and other end-use technologies requires quality laboratory facilities, instrumentation, and building systems simulation capabilities. These elements of new research space enable the development of novel systems from conceptual studies, to benchtop experiments, through prototyping to small-scale evaluation and demonstration. In addition to this integrated science facility primarily for buildings research, offices and laboratories are required in proximity to the core of the Environmental Energy Technologies Division, and renovations and replacements are needed for those substandard trailer and temporary structures currently occupied. The 40,000 gsf building has an estimated cost of $40M.

MULTIPROGRAM ENERGY LABORATORY FACILITIES SUPPORT

In order to meet the needs of the Laboratory's scientific programs and to conduct operational and administrative support, general purpose facilities infrastructure is required. This includes the operations function; general engineering support; general computing support infrastructure; service needs for personnel, including environmental, health, and safety resources; property protection and emergency services; transportation services; cafeteria and conference services; and other infrastructure needs. The following buildings (and a summary of utility system needs) are important elements of the *Berkeley Lab Strategic Buildings Plan*.

Operations Building

An Operations Building is a high priority in this *Strategic Buildings Plan* and is vital for the continuity of facilities services and to address the inefficiencies in the existing distribution of facilities services. The building will enable the consolidation of existing services and replace aged temporary trailers. The scope of important Laboratory support functions included in the building are: facilities management, administration, planning, architecture and engineering, inspection, project management, management information systems, estimating, site services, and other support activities.

The Operations Building will save annual operating costs through productivity gains, functional efficiency, energy conservation, reduced travel, and reduced maintenance costs. This building will result in a gain of needed shop space through relocation of administrative functions from shop areas to more efficient office space. The facility will relieve crowded conditions, especially in shop areas. The Laboratory's emergency preparedness will also be improved by relocating the Facility Department's Emergency Operations Center from the shops area to the new building. In addition, the appropriate space and physical safeguards will be provided for records management and storage. The location for this facility will be in the between Buildings 75 and 76. The 25,000 gsf facility has an estimated cost of $13M.

Administrative Services Building (Replace Building 29)

An Administrative Services Building will bring a variety of essential administrative support functions to a central area, where these services can be efficiently managed and easily accessed by all staff and guest researchers. This new building will house some of the current occupants of the Building 29 trailers and key Laboratory administrative functions that are now scattered across the site. These include the Laboratory's Education Center, the Technology Transfer and Patent Departments, the Technical and Electronic Information Department (TEID)—library, printing and copy center, and photography, audio-visual and publications services—as well as other general support services such as procurement.

Building 29 and its four associated trailers contain 15,600 gsf of office and dry lab space. Building 29 was constructed in the 1940s and has been condemned and vacated. This building is not structurally sound and is subject to collapse. The four trailers are also in very poor condition. This project will demolish the poor structures, and construct a 31,000 gsf building at this site. The estimated cost is $24.0M.

Utility Systems Upgrade Projects

Utility systems upgrades are essential for maintaining program operations without risk of interruptions and for providing a safe working environment with protections for the environment. Important utility system upgrades include the Sitewide Water Distribution System Upgrade, rehabilitation of mechanical utilities, and Seismic Safety and Building Rehabilitation Projects.

Sitewide Water Distribution Upgrade: Phase 1

This project will correct serious performance deficiencies in the high-pressure water system to assure an ample water supply under normal operating conditions as well as during fire and earthquake emergencies. Cast iron pipe will be replaced, cathodic protection installed, and pressure reducing and isolation valves replaced. This project includes construction of a 200,000 gallon-fire water storage tank on the eastern edge of the Laboratory. Under the Laboratory's Wildland Fire Risk Management Plan, the eastern edge of the Laboratory is maintained as a fuel-break protecting Laboratory assets from the periodic and dangerous Diablo wind-driven wildland fires which occur in the east bay hills. The service road to the tank site will be upgraded and fire hydrants installed in order that mutual-aid fire suppression forces can safely fight any flamefront approaching the Laboratory. The estimated cost is $8.3M.

Rehabilitation of Site Mechanical Utilities: Phase 2

This project will correct deteriorating conditions in the piping systems for natural gas, low conductivity water, compressed air, and storm drainage. The proposed corrective actions will ensure that these utilities provide safe and reliable services under normal operating conditions as well as during fire and earthquake emergencies. The estimated cost is $8.2M.

Other Multiprogram Energy Laboratory Facilities Support Buildings

Engineering Support Facility 77A

This project will construct a 19,000 gsf addition to Berkeley Lab's primary engineering support center. These engineering services are used by all research divisions. This addition will add dry laboratory, computer, and office space to Building 77A. The Building 77 complex contains the Laboratory's primary assembly and engineering research spaces. This addition will allow consolidation of all primary engineering functions at a single site, improving coordination, efficiency, and research support. The estimated cost is $14.5M.

Replace Building 25: Seismic Stability

Building 25 is actually an assembly of building additions surrounding a core building constructed during World War II. This 28,000 gsf dry lab and office building does not meet seismic safety standards and would not be usable after a significant earthquake. This building is located at the very center of the Laboratory and continues to be central to much of the research work performed at the Laboratory. This project will demolish the existing building and construct a new 25,000 gsf office and support services building at this site. This building will allow approximately half of the Operations personnel who are currently housed in off-site leased space to return to the Laboratory. This building will improve overall service quality while also reducing lease costs. The estimated cost is $19.0M.

Environment, Health, and Safety (EH&S) Support Facility

This project will consolidate most EH&S staff at a single location. These staff are currently located at a number of sites including Buildings 90, 75, and 85; some of which are a mile distance from each other. This project will demolish a modest 3,500 gsf trailer, which makes inefficient use of a prime building site, and will construct a 21,000 gsf office building that will make good use of this site. The estimated cost is $15.5M.

Training Center and Auditorium

This project will construct a multipurpose training facility to address a pressing need to ensure that staff are fully able to safely, securely, and efficiently meet their work responsibilities. This 14,000 gsf facility will accommodate training programs that include employee orientation; environmental, health, and safety training; Division and Department certification and training sessions; DOE teleconference training sessions; and will also serve as an employee education (degree and certificate) center. This facility will incorporate a large assembly hall (auditorium) capable of accommodating 450 persons, two moderate-scale training rooms capable of accommodating 100 and 150 persons, and four "break-out" rooms each accommodating 20 to 30 persons. The estimated cost is $16.0M.

Site Support Building

This project will construct a new light-frame building to house, service, and outfit all Facilities Department equipment and maintenance supplies as well as the associated staff. This project will also establish a common yard area, designed to ensure that regular facilities functions can be safely performed and efficiently managed. Staff located in Buildings 76 and 31 will be consolidated at this site. The estimated cost is $9.5M.

Replace Building 73

This project will demolish Building 73 and construct a new 19,000 gsf building designed to enhance the Laboratory's ability to better exploit the research opportunities inherent in the ongoing science of this site. Building 73 is a 4,200 gsf wood frame structure that was constructed in 1961 to shelter a specific instrument that met its scientific objectives and is no longer in use. The mission required that this building be constructed using nonferrous material; therefore, this building will not have a traditional service life and is not readily adaptable for other uses. Building 73 is sited in a unique location that is accessible both from the Laboratory's roads and the public road system. The new building will take advantage of this site by constructing a facility that provides approximately 13,000 gsf of office and laboratory space as well as 6,000 gsf of seminar space and short-term housing for graduate students and post-docs. This facility will both serve the current scientific mission and allow the Laboratory to build new and stronger relationships with the next generation of scientists. The estimated cost is $14.0M.

INTEGRATED PLANNING PRIORITIES

The Laboratory has established initial priorities for the *Berkeley Lab Strategic Buildings Plan*. These priorities are reflected in the proposed schedule of projects shown in the Construction Projects Table. See Table VI(1). The priorities are based on risk prioritization and management evaluation of relative impact for DOE missions, timing of demand and risk to mission performance, and potential for improving conditions and efficiencies. All the projects identified have high scientific and operational benefit to address significant risk, and very high efficiency gain. Their relative prioritization primarily reflects the immediacy of scientific and user demands.

All projects will be reviewed to support DOE's compliance with the National Environmental Policy Act (NEPA) and UC's compliance with the California Environmental Quality Act (CEQA). Construction projects and operations strive to: (1) prevent damage to the environment from R&D and construction activities; (2) attain beneficial uses of the Laboratory environment and site; and (3) reduce the risk of undesirable or unintended environmental consequences. The buildings included in this plan can be readily accommodated on the 200 acre Laboratory main site. See map, Figure VII(8). The replacement of single or two story buildings with multistory buildings improves site efficiency, access and circulation, environmental quality, and emergency response.

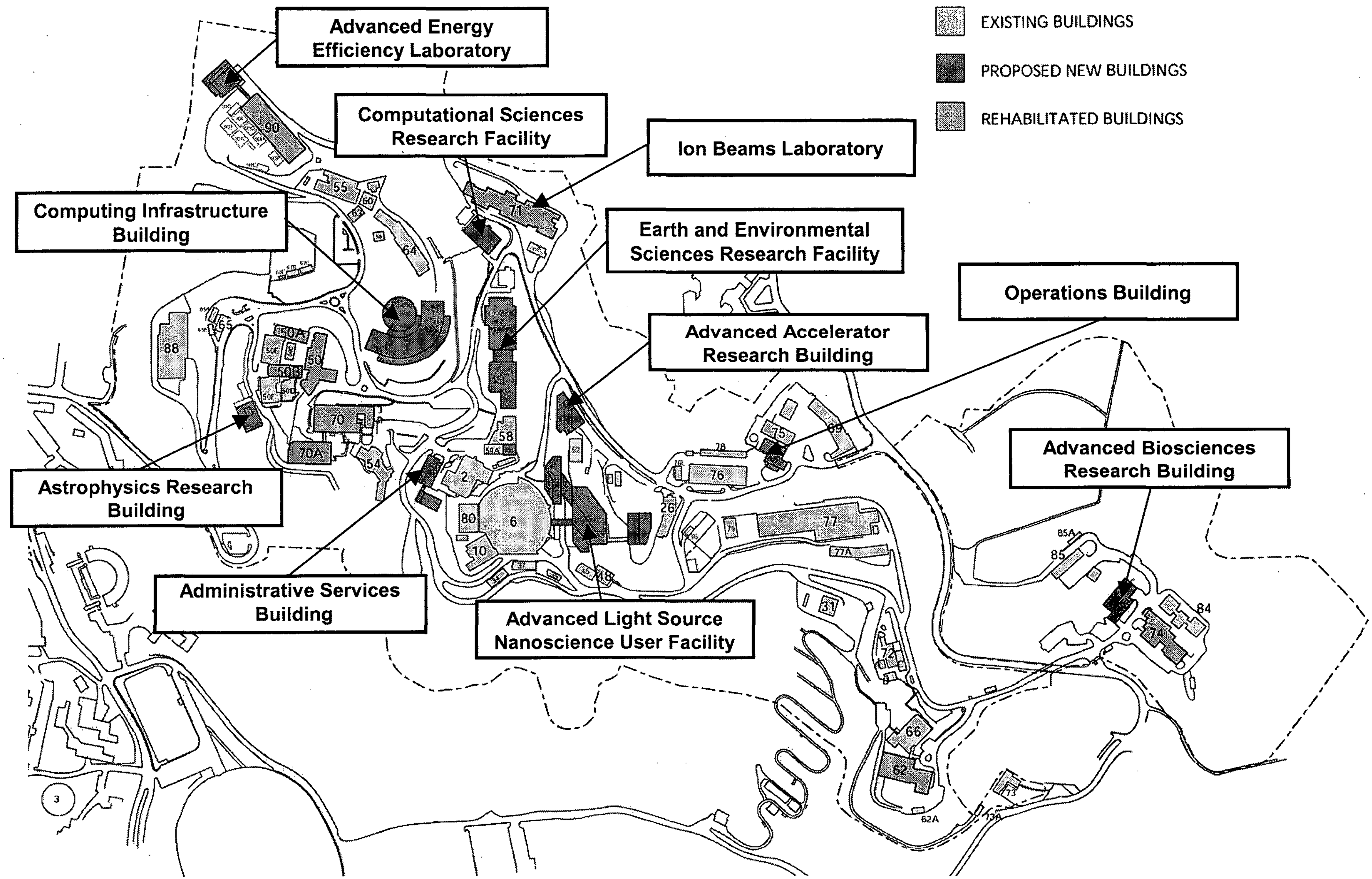

Figure VII(8) Map of Berkeley Lab strategic buildings 2000 to 2010 described in the *Berkeley Lab Strategic Buildings Plan* as Integrated Planning Priorities. The map shows existing buildings, proposed new priority buildings, and buildings to be rehabilitated. In addition, the *Strategic Buildings Plan* includes experimental accelerator facilities and other Multiprogram Energy Laboratory Facilities Support projects that are not shown above.

Table VI(1) Major Construction Projects (FY 2001-2010)

Major Construction Projects	TEC	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Funded Program Related Projects:											
None											
Funded MEL-FS Projects (KG):											
Building 77 Rehabilitation of Building Structure and Systems	8.0*	1.1									
Budgeted MEL-FS Projects (KG):											
Sitewide Water Distribution Upgrade, Phase 1	8.3	1.1	6.6	0.6							
Proposed Program-Related Projects:											
Advanced Light Source Nanoscience User Facility (BES)	**		5.7	7.9	**	**	**	**			
Advanced Biosciences Research Building (OBER)	45.0				9.0	33.8	2.2				
Astrophysics Research Building (HENP)	80.0					16.0	60.0	4.0			
Earth & Environmental Sciences Research Facilities (OBER ,EM, CRWM)	80.0						16.0	60.0	4.0		
Advanced Experimental Facilities (BES)	33.0						6.6	24.8	1.6		
Computing Infrastructure Building (ASCR)	100.0							20.0	75.0	5.0	
Advanced Accelerator Research Building (HENP)	25.0							5.0	18.8	1.2	
Advanced Energy Efficiency Laboratory (EE)	40.0								8.0	30.0	2.0
Proposed MEL-FS Projects:											
Operations Building	13.1		5.0	8.1							
Rehabilitation of Site Mechanical Utilities, Phase 2	8.2		1.2	6.5	0.5						
Replace Building 29: Administrative Services Building	24.0			4.8	18.0	1.2					
Engineering Building Addition (Bldg. 77A)	14.5				2.9	10.9	0.7				
Replace Bldg. 25 (Seismic Stability)	19.0					3.8	14.3	0.9			
EH&S Support Facility	15.5						3.1	11.6	0.8		
Training Center and Auditorium	16.0							3.2	12.0	0.8	
Site Support Building	9.5								1.9	7.1	0.5
Replace Bldg. 73	14.0*									2.8	10.5

* Includes out-year budgets

**Construction figures are for Project Engineering and Design of the ALS Nanoscience User Facility. Construction costs will be identified following completion of the preliminary design.

VII. 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 1999 budget authority and FY 2000 projected budget authority for comparison. These tables include:

- Resources by Major Program:

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

- Subcontracting and Procurement:

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

- Experimenters at Designated User Facilities (FY 1999), Table VII(6)
- University and Science Education, Table VII(7)

The FY 2000 estimate is based on FY 2000 DOE budget guidance, the President's Request, and assessments by Berkeley Laboratory Divisions. For fiscal years 2001 and beyond, operating cost projections are in FY 2000 dollars, and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 2001 to FY 2005, 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 VI.

Table VII(1)(a) Laboratory Funding Summary

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
DOE Effort	249.4	255.5	290.7	310.7	325.0	337.2	354.3
CRADA	7.0	7.8	6.3	5.5	5.8	5.5	5.3
WFO	69.6	80.8	81.3	84.0	88.3	88.3	89.8
TOTAL OPERATING	**325.9**	**344.1**	**378.3**	**400.3**	**419.1**	**430.9**	**449.3**
Capital Equipment	25.0	30.5	28.7	27.9	26.4	26.4	26.0
Program Construction	23.6	29.4	17.6	6.5	6.2	6.3	6.5
General Purpose Facilities	4.8	5.7	4.6	7.7	8.0	8.0	8.0
General Plant Projects	3.9	3.5	3.5	3.5	3.5	3.5	3.5
General Purpose Eqpmnt.	1.9	2.4	2.0	2.0	2.0	2.0	2.0
TOTAL LABORATORY FUNDING	**385.2**	**415.7**	**434.8**	**447.9**	**465.0**	**477.0**	**495.3**

Table VII(1)(b) Laboratory Personnel Summary

(Personnel in FTE)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
DIRECT							
DOE Effort	1,613	1,634	1,715	1,716	1,716	1,717	1,719
Work for Other than DOE	381	387	392	392	395	395	395
TOTAL DIRECT	1,994	2,021	2,107	2,108	2,111	2,112	2,114
TOTAL INDIRECT	706	713	720	731	740	740	740
TOTAL PERSONNEL	**2,700**	**2,734**	**2,827**	**2,839**	**2,851**	**2,852**	**2,854**

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

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
Office of Science (SC)							
Operating	188.4	193.0	226.2	241.1	253.8	266.2	279.8
Capital Equipment	24.2	30.2	28.0	28.1	26.5	26.6	26.3
Construction	10.7	10.9	14.7	15.2	15.7	15.8	16.0
Total	**223.3**	**234.2**	**268.9**	**284.4**	**295.9**	**308.7**	**322.1**
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Operating	22.7	22.4	25.8	28.1	30.0	31.2	32.5
Capital Equipment	0.2	0.3	0.3	0.4	0.5	0.5	0.5
Total	**22.8**	**22.7**	**26.1**	**28.5**	**30.5**	**31.7**	**33.0**
Assistant Secretary for Fossil Energy (FE)							
Operating	4.1	5.2	5.8	6.1	6.1	6.7	6.8
Total	**4.1**	**5.2**	**5.8**	**6.1**	**6.1**	**6.7**	**6.8**
Assistant Secretary for Environmental Restoration and Waste Management (EM)							
Operating	12.6	11.8	8.4	7.9	7.9	5.6	5.6
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total	**12.8**	**12.0**	**8.5**	**8.0**	**8.0**	**5.7**	**5.7**
Assistant Secretary for Defense Programs (DP)							
Construction	19.0	19.4	4.0	0.1	-	-	-
Total	**19.0**	**19.4**	**4.0**	**0.1**	**-**	**-**	**-**
Office of Nonproliferation and National Security (NN)							
Operating	3.8	3.6	4.2	5.0	5.3	5.2	5.3
Total	**3.8**	**3.6**	**4.2**	**5.0**	**5.3**	**5.2**	**5.3**
Assistant Secretary for Environment, Safety and Health (EH)							
Operating	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Total	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Office of Intelligence (IN)							
Operating	-	0.1	0.1	0.1	0.1	0.1	0.1
Total	**-**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Office of Security and Emergency Management (SO)							
Operating	-	-	3.7	4.2	4.1	4.3	4.5
Total	**-**	**-**	**3.7**	**4.2**	**4.1**	**4.3**	**4.5**
Work for Other DOE Contractors							
Operating	17.2	18.8	15.8	17.7	17.2	17.3	19.2
Capital Equipment	1.2	0.6	0.5	0.5	0.5	0.3	0.3
Construction	2.6	8.3	7.0	2.4	2.0	2.0	2.0
Total	**21.0**	**27.7**	**23.3**	**20.6**	**19.7**	**19.6**	**21.5**
Total DOE							
Operating	249.4	255.5	290.7	310.7	325.0	337.2	354.3
Capital Equipment	25.7	31.2	28.9	29.1	27.6	27.5	27.2
Construction	32.3	38.6	25.7	17.7	17.7	17.8	18.0
Total	**307.4**	**325.4**	**345.3**	**357.6**	**370.2**	**382.5**	**399.4**

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

(Personnel in FTE)		FY99	FY00	FY01	FY02	FY03	FY04	FY05
Office of Science (SC)								
	Direct FTE	1,230	1,252	1,360	1,380	1,393	1,400	1,407
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)								
	Direct FTE	128	130	143	150	155	154	152
Assistant Secretary for Fossil Energy (FE)								
	Direct FTE	20	24	26	26	25	27	26
Assistant Secretary for Environmental Restoration and Waste Management (EM)								
	Direct FTE	74	73	50	45	43	35	34
Assistant Secretary for Defense Programs (DP)								
	Direct FTE	36	35	7	-	-	-	-
Office of Nonproliferation and National Security (NN)								
	Direct FTE	16	16	18	21	21	20	19
Assistant Secretary for Environment, Safety & Health (EH)								
	Direct FTE	3	3	3	3	3	3	2
Office of Intelligence (IN)								
	Direct FTE	-	1	1	1	1	1	1
Office of Security and Emergency Management (SO)								
	Direct FTE	-	-	14	15	15	17	17
Work for Other DOE Contractors								
	Direct FTE	106	100	93	75	61	61	61
Total DOE								
	Direct FTE	**1,613**	**1,634**	**1,715**	**1,716**	**1,716**	**1,717**	**1,719**
Work for Others—Non-DOE								
	Direct FTE	381	387	392	392	395	395	395
	TOTAL LAB DIRECT	1,994	2,021	2,107	2,108	2,111	2,112	2,114
	TOTAL LAB INDIRECT	706	713	720	731	740	740	740
	TOTAL LAB PERSONNEL	2,700	2,734	2,827	2,839	2,851	2,852	2,854

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

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
AT Fusion Energy Science							
Operating	4.6	5.3	8.8	8.8	8.8	8.8	8.8
Capital Equipment	0.4	-	-	-	-	-	-
Total	**5.0**	**5.3**	**8.8**	**8.8**	**8.8**	**8.8**	**8.8**
KA High Energy Physics							
Operating	21.7	21.5	32.9	35.8	38.8	40.7	45.1
Capital Equipment	4.9	12.4	10.8	10.5	8.7	8.9	8.5
Construction	-	3.5	3.5	3.5	3.5	3.5	3.5
Total	**26.6**	**37.4**	**47.2**	**49.7**	**51.0**	**53.1**	**57.1**
KB Nuclear Physics							
Operating	16.0	15.9	18.5	20.9	21.8	22.8	23.8
Capital Equipment	3.1	3.0	3.0	3.0	3.0	3.0	3.0
Construction	3.9	-	-	-	-	-	-
Total	**23.0**	**18.9**	**21.5**	**23.9**	**24.8**	**25.8**	**26.8**
KC02 Materials Sciences							
Operating	45.3	46.3	50.7	53.6	56.5	59.5	62.7
Capital Equipment	6.0	5.0	5.0	5.0	5.0	5.0	5.0
Construction	1.7	1.7	2.1	4.0	4.2	4.3	4.5
Total	**53.0**	**53.0**	**57.8**	**62.6**	**65.7**	**68.8**	**72.2**
KC03 Chemical Sciences							
Operating	8.2	7.7	8.7	9.4	10.6	13.1	14.2
Capital Equipment	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	**9.3**	**8.7**	**9.8**	**10.5**	**11.6**	**14.1**	**15.2**
KC04 Engineering and Geosciences							
Operating	2.3	2.6	2.6	2.6	2.6	2.6	2.6
Capital Equipment	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	**2.5**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**
KC06 Energy Biosciences							
Operating	1.1	1.7	1.8	1.9	2.0	2.0	2.1
Capital Equipment	0.8	0.5	0.5	0.5	0.5	0.5	0.5
Total	**1.8**	**2.2**	**2.3**	**2.4**	**2.5**	**2.5**	**2.6**
KG Multiprogram Energy Laboratories - Facilities Support							
Construction	4.8	5.7	4.6	7.7	8.0	8.0	8.0
Total	**4.8**	**5.7**	**4.6**	**7.7**	**8.0**	**8.0**	**8.0**
KJ Computational and Technology Research							
Operating	52.3	50.7	53.6	55.4	57.4	59.4	61.5
Capital Equipment	5.5	5.0	5.0	5.0	5.0	5.0	5.0
Construction	0.1	-	-	-	-	-	-
Total	**57.9**	**55.7**	**58.6**	**60.4**	**62.4**	**64.4**	**66.5**

Table VII(3)(a) Office of Science Funding and Personnel --- *cont.*

KP Biological and Environmental Research							
Operating	36.6	40.9	47.5	51.2	53.7	55.7	57.5
Capital Equipment	2.3	3.1	2.4	2.9	3.0	3.0	3.0
Construction	0.2	-	4.5	-	-	-	-
Total	**39.1**	**44.0**	**54.4**	**54.1**	**56.7**	**58.7**	**60.5**
KX Program Directions							
Operating	0.2	0.5	1.2	1.5	1.5	1.6	1.6
Total	**0.2**	**0.5**	**1.2**	**1.5**	**1.5**	**1.6**	**1.6**
Total, Office of Science							
Operating	188.4	193.0	226.2	241.1	253.8	266.2	279.8
Capital Equipment	24.2	30.2	28.0	28.1	26.5	26.6	26.3
Construction	10.7	10.9	14.7	15.2	15.7	15.8	16.0
Total	**223.3**	**234.2**	**268.9**	**284.4**	**295.9**	**308.7**	**322.1**
Direct FTE	1,230	1,252	1,360	1,380	1,393	1,400	1,407

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

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
EB Solar and Renewable Resource Technologies							
Operating	2.1	1.7	3.6	5.1	5.4	5.7	5.9
Total	**2.1**	**1.7**	**3.6**	**5.1**	**5.4**	**5.7**	**5.9**
EC Building Technology, State and Community Sector							
Operating	12.3	12.2	13.0	13.6	14.5	15.1	15.7
Total	**12.3**	**12.2**	**13.0**	**13.6**	**14.5**	**15.1**	**15.7**
ED Industrial Sector							
Operating	2.0	2.3	2.5	2.3	2.5	2.5	2.6
Total	**2.0**	**2.3**	**2.5**	**2.3**	**2.5**	**2.5**	**2.6**
EE Transportation Sector							
Operating	4.0	3.8	4.2	4.6	5.0	5.1	5.4
Capital Equipment	0.2	0.3	0.3	0.4	0.5	0.5	0.5
Total	**4.2**	**4.1**	**4.5**	**5.0**	**5.5**	**5.6**	**5.9**
EL Federal Energy Management Program							
Operating	2.3	2.4	2.5	2.5	2.7	2.8	2.9
Total	**2.3**	**2.4**	**2.5**	**2.5**	**2.7**	**2.8**	**2.9**
Total, Assistant Secretary for Energy Efficiency and Renewable Energy							
Operating	22.7	22.4	25.8	28.1	30.0	31.2	32.5
Capital Equipment	0.2	0.3	0.3	0.4	0.5	0.5	0.5
Total	**22.8**	**22.7**	**26.1**	**28.5**	**30.5**	**31.7**	**33.0**
Direct FTE	128	130	143	150	155	154	152

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

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
AA Coal							
Operating	0.3	0.6	1.0	1.3	1.7	2.2	2.2
Total	**0.3**	**0.6**	**1.0**	**1.3**	**1.7**	**2.2**	**2.2**
AB Gas							
Operating	1.2	1.4	1.4	1.4	0.9	1.1	1.1
Total	**1.2**	**1.4**	**1.4**	**1.4**	**0.9**	**1.1**	**1.1**
AC Petroleum							
Operating	2.7	3.2	3.4	3.4	3.4	3.4	3.5
Total	**2.7**	**3.2**	**3.4**	**3.4**	**3.4**	**3.4**	**3.5**
Total, Assistant Secretary for Fossil Energy							
Operating	4.1	5.2	5.8	6.1	6.1	6.7	6.8
Total	**4.1**	**5.2**	**5.8**	**6.1**	**6.1**	**6.7**	**6.8**
Direct FTE	20	24	26	26	25	27	26
EW Environmental Restoration and Waste Management - Defense							
Operating	4.1	2.4	3.4	2.9	3.6	4.3	4.3
Capital Equipment	0.1	-	-	-	-	-	-
Total	**4.3**	**2.4**	**3.4**	**2.9**	**3.6**	**4.3**	**4.3**
EX Environmental Restoration and Waste Management - Non-Defense							
Operating	8.5	9.5	5.0	5.0	4.3	1.3	1.3
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**8.5**	**9.6**	**5.1**	**5.1**	**4.4**	**1.4**	**1.4**
Total, Assistant Secretary for Environmental Restoration and Waste Management							
Operating	12.6	11.8	8.4	7.9	7.9	5.6	5.6
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total	**12.8**	**12.0**	**8.5**	**8.0**	**8.0**	**5.7**	**5.7**
Direct FTE	74	73	50	45	43	35	34
DP Defense Programs Activities							
Construction	19.0	19.4	4.0	0.1	-	-	-
Total	**19.0**	**19.4**	**4.0**	**0.1**	**-**	**-**	**-**
Total, Assistant Secretary for Defense Programs							
Construction	19.0	19.4	4.0	0.1	-	-	-
Total	**19.0**	**19.4**	**4.0**	**0.1**	**-**	**-**	**-**
Direct FTE	36	35	7	-	-	-	-
GC Nonproliferation and National Security							
Operating	1.1	1.9	2.2	2.7	3.0	2.8	3.0
Total	**1.1**	**1.9**	**2.2**	**2.7**	**3.0**	**2.8**	**3.0**
GJ Arms Control and Nonproliferation							
Operating	2.7	1.7	2.0	2.3	2.3	2.3	2.3
Total	**2.7**	**1.7**	**2.0**	**2.3**	**2.3**	**2.3**	**2.3**

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

Total, Office of Nonproliferation and National Security							
Operating	3.8	3.6	4.2	5.0	5.3	5.2	5.3
Total	**3.8**	**3.6**	**4.2**	**5.0**	**5.3**	**5.2**	**5.3**
Direct FTE	16	16	18	21	21	20	19
HC Environment, Safety and Health (Non-Defense)							
Operating	-	0.6	0.6	0.6	0.6	0.6	0.6
Total	**-**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
HD Environment, Safety and Health (Defense)							
Operating	0.6	-	-	-	-	-	-
Total	**0.6**	**-**	**-**	**-**	**-**	**-**	**-**
Total, Assistant Secretary for Environment, Safety and Health							
Operating	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Total	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Direct FTE	3	3	3	3	3	3	2
IN Intelligence							
Operating	-	0.1	0.1	0.1	0.1	0.1	0.1
Total	**-**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Total, Office of Intelligence							
Operating	-	0.1	0.1	0.1	0.1	0.1	0.1
Total	**-**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Direct FTE	-	1	1	1	1	1	1
SO Security and Emergency Management							
Operating	-	-	3.7	4.2	4.1	4.3	4.5
Total	**-**	**-**	**3.7**	**4.2**	**4.1**	**4.3**	**4.5**
Total, Office of Security and Emergency Management							
Operating	-	-	3.7	4.2	4.1	4.3	4.5
Total	**-**	**-**	**3.7**	**4.2**	**4.1**	**4.3**	**4.5**
Direct FTE	-	-	14	15	15	17	17

Table VII(4) Work for Others Funding and Personnel

($ in Millions-BA)	FY99	FY00	FY01	FY02	FY03	FY04	FY05
Work for Others—Federal Agencies							
Department of Defense	12.3	8.6	7.8	9.6	9.2	9.4	9.5
Capital Equipment	-	1.7	1.8	0.7	0.7	0.8	0.8
Enviromental Protection Agency	5.5	4.2	4.6	5.8	6.0	6.2	6.5
Department of Interior	1.1	0.7	0.7	0.7	0.8	0.9	0.9
NASA	8.1	3.8	4.3	4.3	4.2	4.2	4.3
Nat. Institute of Health	20.7	25.6	30.0	30.0	30.0	30.0	30.0
National Science Foundation	0.1	0.6	1.4	2.7	5.7	2.7	2.6
Other Federal	0.7	2.3	3.6	4.0	4.4	4.7	4.9
Total Federal Operating	48.5	45.9	52.4	57.2	60.3	58.2	58.7
Capital Equipment	-	1.7	1.8	0.7	0.7	0.8	0.8
Total	**48.5**	**47.6**	**54.2**	**57.9**	**61.1**	**46.6**	**59.4**
Work for Others—Non-Federal Agencies							
Universities	15.2	16.5	9.7	8.9	8.9	9.0	9.1
State/Local Gov't/Non-Profit	1.5	5.0	6.0	6.0	7.0	7.0	7.0
Industry/Domestic	3.0	8.5	7.7	6.7	6.4	7.2	7.6
Other Non-Federal	1.4	4.9	5.5	5.3	5.5	6.9	7.4
Total Non-Federal Operating	21.1	34.9	28.9	26.9	27.9	30.1	31.1
Total	**21.1**	**34.9**	**28.9**	**26.9**	**27.9**	**46.6**	**31.1**
Total Work for Others—Non-DOE Contractors (no CRADA)							
Operating	69.6	80.8	81.3	84.0	88.3	88.3	89.8
Capital Equipment	-	1.7	1.8	0.7	0.7	0.8	0.8
Total	**69.6**	**82.5**	**83.1**	**84.7**	**89.0**	**89.0**	**90.6**
Work for Others—CRADA							
Operating	7.0	7.8	6.3	5.5	5.8	5.5	5.3
Total	**7.0**	**7.8**	**6.3**	**5.5**	**5.8**	**5.5**	**5.3**
Direct FTE	381	387	392	392	395	395	395

Table VII(5)(a) Subcontracting and Procurement

($ in Millions-Obligated)	FY99	FY00	FY01	FY02
Subcontracting and Procurement from:				
Universities	5.6	5.7	5.8	5.9
All Others	135.8	138.5	141.3	144.1
Transfers to Other DOE Facilities	3.1	3.2	3.2	3.3
Total External Subcontracts and Procurement	**144.5**	**147.4**	**150.3**	**153.3**

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

($ in Millions-B/A)	FY99	FY00
Procurement from Small and Disadvantaged Business	59.8	44.7
Percent of Annual Procurement	51.8%	38.0%
Available Subcontracting Dollars	115.4	117.7

Table VII(6) Experimenters at Designated User Facilities (FY 1999)

	Number of Experimenters	Number of Organizations	Percentage of Use
Advanced Light Source			
Laboratory	224	10	28%
Other DOE Laboratories	65	12	8%
Other U.S. Government	7	2	1%
University	266	62	33%
Industry	80	35	10%
Foreign Laboratory	35	25	4%
Foreign University	113	57	14%
Foreign Industry	5	4	1%
Other	8	7	1%
Total	**803**	**214**	**100%**
National Energy Research Scientific Computing*			
Laboratory	215	1	11%
Other DOE Laboratories	787	4	43%
Other U.S. Government	36	16	2%
University	735	80	39%
Industry	74	13	3%
Other	65	4	2%
Total	**1912**	**118**	**100%**
88-Inch Cyclotron			
Laboratory	67	1	40%
Other DOE Laboratories	14	3	5%
Other U.S. Government	13	3	9%
University	52	13	28%
Industry	30	8	2%
Foreign Laboratory	9	9	4%
Foreign University	18	8	12%
Foreign Industry	3	2	<1%
Total	**206**	**47**	**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 VII(6) Experimenters at Designated User Facilities—*cont.*

	Number of Experimenters	Number of Organizations	Percentage of Use
National Center for Electron Microscopy			
Laboratory	70	1	37%
Other DOE Laboratories	4	2	2%
Other U.S. Government	5	3	3%
University	69	13	37%
Industry	7	7	4%
Foreign Laboratory	2	1	1%
Foreign University	31	24	16%
Foreign Industry	0	0	0%
Other	0	0	0%
Total	**188**	**51**	**100%**
National Tritium Labeling Facility+			
Laboratory	0	0	0%
Other DOE Laboratories	0	0	0%
Other U.S. Government	5	2	7%
University	2	2	3%
Industry	8	5	10%
Foreign Industry	0	0	0%
Other	0	0	0%
Total	**15**	**9**	**20%**
Grand Total			
Laboratory	**576**	**13**	**19%**
Other DOE Laboratories	**870**	**21**	**29%**
Non DOE U.S. Government	**66**	**26**	**2%**
University	**1124**	**170**	**37%**
Industry	**199**	**68**	**5%**
Foreign Laboratory	**46**	**35**	**1%**
Foreign University	**162**	**89**	**5%**
Foreign Industry	**8**	**6**	**<1%**
Other	**73**	**11**	**2%**
Total	**3124**	**439**	**100%**

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

Table VII(7) University and Science Education

	FY1999			FY2000		
	Total	Minorities	Women	Total	Minorities	Women
PRE-COLLEGE PROGRAMS						
Student Programs	7	5	3	11	6	5
Teacher Programs	32	8	24	46	10	22
Special Programs	250	n/a	n/a	500	n/a	n/a
UNDERGRADUATE PROGRAMS						
Student Programs	98	53	46	120	60	60
POSTGRADUATE PROGRAMS						
Post Doctoral Programs	242	88	46	215	73	52
Faculty Programs	1	–	1	1	1	–

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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.

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