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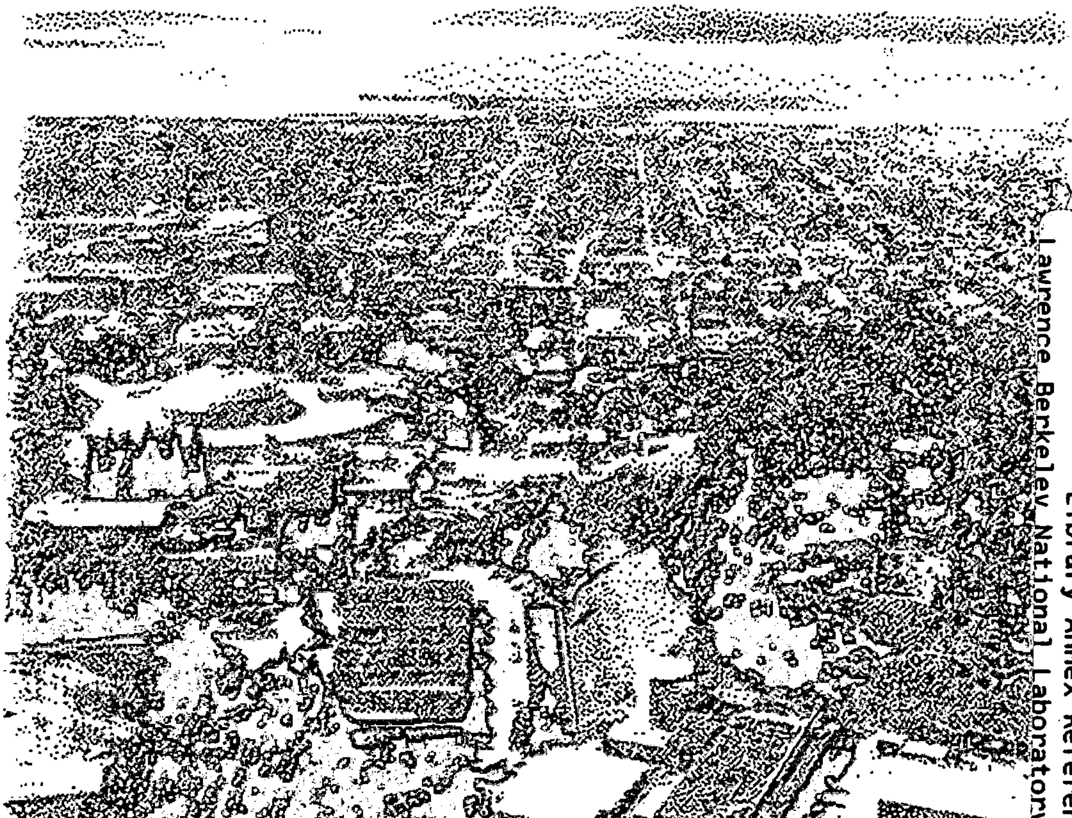
Ernest Orlando Lawrence Berkeley National Laboratory

Institutional Plan

FY 2002–FY 2006

October 2001



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ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 2002—FY 2006

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

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PREFACE

The Fiscal Year (FY) 2002-2006 Institutional Plan provides an overview of the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab, the Laboratory, LBNL) 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 national energy policy and research needs and the Department of Energy's program planning initiatives. Preparation of the Plan is coordinated by the Planning and Strategic Development Office from information contributed by Berkeley Lab's scientific and support divisions.

The Berkeley Lab FY 2002-2006 Institutional Plan reflects and complements the Department of Energy's *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 Mission and Core Competencies section identifies the specific strengths of Berkeley Lab that contribute to the mission 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; workforce diversity; communications and trust; worker, public, environmental, and asset protection programs; and management practices. The Infrastructure Strategic Planning section describes Berkeley Lab's facilities planning process and our site and facility needs. The Summary of Major Issues section provides context for discussions at the Institutional Planning On-Site Review. The Resource Projections are estimates of required budgetary authority for Berkeley Lab's research programs. Concise information about the Laboratory, as requested by the Office of Science, is included in the Laboratory Profile.

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I. DIRECTOR'S STATEMENT

As we move forward into the 21st century, the Ernest Orlando Lawrence Berkeley National Laboratory advances a program of research that addresses the strategic goals of the Department of Energy's Office of Science. Our multidisciplinary capability in the physical and biological sciences opens new opportunities to design and fabricate the smallest and most efficient nanodevices. We are bringing together biology, physics, computing, and engineering for a new era of genomic science and structural biology. Our computational science resources are focused on serving Office of Science programs and investigators, in areas such as global climate change, combustion, fusion, and fundamental physics. Our research to understand the properties of the universe is yielding new insights on the nature of matter and energy. In addition, we are developing accelerators as critical tools to understand plasmas and harness fusion energy for a nation committed to reliable electricity supplies and control of greenhouse gas emissions. These Office of Science efforts underpin many of the programs in other federal science and technology agencies, including those in medical, environmental, and space research. The Laboratory also supports the strategic goals of other Offices in the Department of Energy (DOE), including the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy. These two offices have strategic commitments to developing advanced energy technologies with reduced adverse environmental impacts.

Breakthrough Science

Already, Berkeley Lab, working with other scientific institutions, has made breakthrough advancements in many of these crucial Department of Energy research areas. *Science* magazine's "Breakthrough of the Year" for 2000 was "Sequenced Genomes," a joint effort among several national laboratories and other agencies that was initiated by the Office of Science. A number of the "Runners-up Breakthroughs" for 2000 depended on Berkeley Lab capabilities including x-ray crystallography that revealed the structure of the ribosome (the cell unit that builds proteins), and the detector fabrication and computation that led to the discovery that the universe has a flat geometry. In 1999, two of *Science* magazine's top ten breakthroughs were in biosciences on sequencing the *Drosophila* genome and earlier work on the ribosome. In 1998, *Science* magazine's "Breakthrough of the Year" was for discovering that the universe is expanding at an accelerating rate and pointing to an unseen dark energy in the universe, based on the Laboratory's studies of distant supernovae. In May 2001, the cover of *Science* featured Berkeley Lab's work on the crystal structure of the ribosome at 5.5-angstrom resolution. These scientific breakthroughs complement those at other national laboratories and highlight the quality and impact of the Office of Science programs.

Science Vision 2010

To sustain its record of science leadership, Berkeley Lab is committed to working with the Department of Energy and its Laboratories to focus its resources on research areas that make a difference for the nation. We are strategically directing our resources to five key foci: advancing nanoscience, understanding the properties of matter and energy in the universe, developing the new science of quantitative biology, improving the reliability of electricity supplies while sequestering carbon dioxide, and providing national user facilities that address Department of Energy research needs.

- Berkeley Lab is proposing a Molecular Foundry to advance the Office of Science role in the National Nanotechnology Initiative. This science research center will focus on the conjunction of soft and hard nanostructure building blocks and their fabrication into functional multicomponent assemblies. The Foundry will have an internal research program, a collaborative research facility for visiting scientists, a training program for students and postdoctoral fellows, and portals to major user facilities including the Advanced Light Source, the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center.

- Excited-state dynamics of molecules and atoms provides the scientific basis for understanding and manipulating chemical reactions at their most fundamental level, from laser-driven solid-solid phase transitions to photochemistry in biological systems. However, lifetimes of such states are extremely short, on a timescale of about 100 femtoseconds or less. The Laboratory is proposing to host a workshop on x-ray ultrafast science and explore the design of a user facility for femtosecond structural dynamics, complementing existing proposals for high-flux, free electron laser based sources. The Laboratory is looking forward to working with the Office of Science and the scientific community to explore the scientific promise of a short-pulse x-ray source
- Berkeley Lab is undertaking a research and planning effort for an astrophysics satellite program that will define the fundamental properties of the universe through the observations of supernovae. The effort stems from mounting supernova evidence that the expansion of the universe is accelerating, perhaps driven by an unseen dark energy. 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 this newly discovered dark energy. The international collaboration for this satellite mission will require resources for planning and experimental development during the next several years, in advance of project implementation.
- In the era that follows the sequencing of the human genome, a new biology program for the Office of Science is directed at developing a more predictive and quantitative understanding and control of biological systems. This includes developing the tools to understand the molecular machinery of microbes, rapid and high-throughput determination of macromolecular structure, and quantitative modeling of cellular dynamics. These advances in the biological sciences during the next decade—understanding from genomes to life—will be leveraged through investments in complementary studies in the physical and computing sciences.
- The National Energy Research Scientific Computing Center (NERSC) provides high-performance computational resources that are highly valued by its Office of Science user community. NERSC applies capabilities in computational science-of-scale to address national challenges for climate prediction, combustion modeling, subsurface transport, functional genomics, accelerator physics, nanoscience, and other research areas. NERSC emphasizes comprehensive scientific support, leveraging the Office of Science initiative on Scientific Discovery through Advanced Computation, and providing a unified environment that integrates computing with experimental science.
- Berkeley Lab has a distinguished record of research that improves the energy security of the nation while reducing environmental impacts. Successes include low-emissivity windows, high-frequency ballasts for fluorescent lamps, and efficient fixtures for compact fluorescent lamps. The "Berkeley Lamp" is achieving widespread attention as a means of further reducing energy demands in offices and residences. The Laboratory is working to establish a Energy Efficiency and Electric Reliability Laboratory that will enable programs in DOE's Office of Energy Efficiency and Renewable Energy to further develop the most advanced energy efficiency and reliability technologies and to partner with industry so that these can be introduced into the marketplace. The Laboratory is working with the State of California to reduce energy demand and improve electricity distribution reliability through modeling and improved technology. The Laboratory also proposes to develop the next generation of energy-efficient technologies for carbon dioxide emissions reduction.

Office of Science National Laboratories

The Laboratory's human and physical capabilities are being called upon to serve the Office of Science and all the national laboratories in an integrated way. Berkeley Lab works in close partnership with Oak Ridge and other laboratories for the design and fabrication of the Spallation Neutron Source. Our partnerships in High Energy and Nuclear Physics are advancing the research program at the Relativistic Heavy Ion Collider at Brookhaven, the D-Zero and CDF Detectors at Fermilab, and the Asymmetric B Factory at the Stanford Linear Accelerator Center. The efforts of the Joint Genome Institute have successfully sequenced human chromosomes 5, 16, and 19 and we are moving ahead with sequencing other organisms relevant to DOE's mission.

The Laboratory's geoscience capabilities are being deployed with Lawrence Livermore National Laboratory to address the fundamental science needed to understand, and the potential for, ocean 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. The Office of Science Laboratories have jointly developed white papers that address key needs in infrastructure, communications, and other areas of management importance.

Infrastructure Strategic Planning

To sustain the Laboratory's scientific efforts, the nation needs to invest in the science infrastructure that underpins our discoveries and, ultimately, the economic prosperity and the health of our citizens. The Laboratory 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.

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 Oakland Scientific Facility 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 as well as other facility needs. The Molecular Foundry will be a key resource for the National Nanotechnology Initiative. Other buildings are also required to fully address the Laboratory's need for modern laboratories and offices. Working with the Office of Energy Efficiency and Renewable Energy, we are exploring the concept of a facility that would combine offices and laboratories to investigate, test, monitor, and demonstrate new energy-efficiency technologies and design processes.

Operations Strategic Planning

Meeting these future challenges requires effective management of human resources; environment, health, and safety efforts integrated with operations; and constructive relationships with the surrounding community. All divisions of the Laboratory have developed Diversity Plans to enhance the quality of the working environment and to aid in recruitment of a diverse workforce. 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 collegs 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 worked with a community task force to evaluate and contribute to a new program for environmental monitoring. 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 cybersecurity 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. 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 multiprogram national research facility operated by the University of California for the Department of Energy (DOE). 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 computing sciences, physical sciences, energy sciences, biosciences, and general 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 (UC) 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 National Laboratory and Idaho National Engineering and Environmental Laboratory. 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 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; radiofrequency (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:** Nanoscience and nanotechnology; advanced spectroscopies and microscopies based on photons, electrons, and scanning probes; ceramics; alloys; heterostructures; superconducting, magnetic, and atomically structured materials; biomolecular materials.
- **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, secure, 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 physical sciences, energy sciences, biosciences, and general sciences divisions.

Computing Sciences

- **National Energy Research Scientific Computing Center (NERSC):** Unsurpassed high-end computing services to the Office of Science user community as well as a wide range of other university, government, and industry users; access to five state-of-the-art supercomputers, including an IBM RS/6000 SP, a Cray T3E-900 and three Cray SV1s; archival data storage; collaboration and support for users and computational scientists for modeling, software implementation, and system architecture; scientific imaging and visualization tools, as well as science-of-scale projects; scientific data management.
- **Energy Sciences Network (ESnet):** International high-speed computer-data-communications network serving thousands of DOE scientists and collaborators at laboratories and universities worldwide by providing high-bandwidth, reliable connections.
- **Mathematics Department:** Development of numerical and analytical methods and their application; problems in physics and engineering; vortex and particle methods; solid mechanics and fracture; interface techniques; turbulence theory; dynamics of polymeric systems; parallel implementation of codes for large-scale scientific computing; fast algorithms.
- **Center for Computational Sciences and Engineering and Applied Numerical Algorithms Group:** High-resolution numerical methods for partial differential equations; adaptive methodologies; computational fluid dynamics; algorithms for parallel architectures; scientific visualizations.
- **Information Technologies and Services:** Information technology infrastructure and services, including cybersecurity, business applications, desktop computer support, electronic mail, networking and telecommunications, and technical information.

Physical 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, 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.
- **Materials Sciences:** Advanced ceramic, metallic, polymeric, magnetic, biological, and semi- and superconducting materials for catalytic, electronic, optical, magnetic, structural, and specialty applications; studies of nanoscience, nanodevices, 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.

- **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 Berkeley Center for Structural Biology at the ALS.

Energy Sciences

- **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; 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.

Biosciences

- **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.
- **Life Sciences:** Integration of experimental and theoretical connections between genes and proteins, their function, and their organization within cells and tissues; investigation of the basic mechanisms of human disease including the biology of breast cancer, DNA repair and genomic stability, mechanisms of aging, metabolic studies of neurological diseases, coronary artery disease, and disorders of red blood cell formation; structural biology of molecular machines; experimental, theoretical and computational modeling approaches to understanding the health effects of low level ionizing radiation; microarray technology; development of human disease models in mice; nuclear chemistry; diagnostic and functional imaging.

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 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.

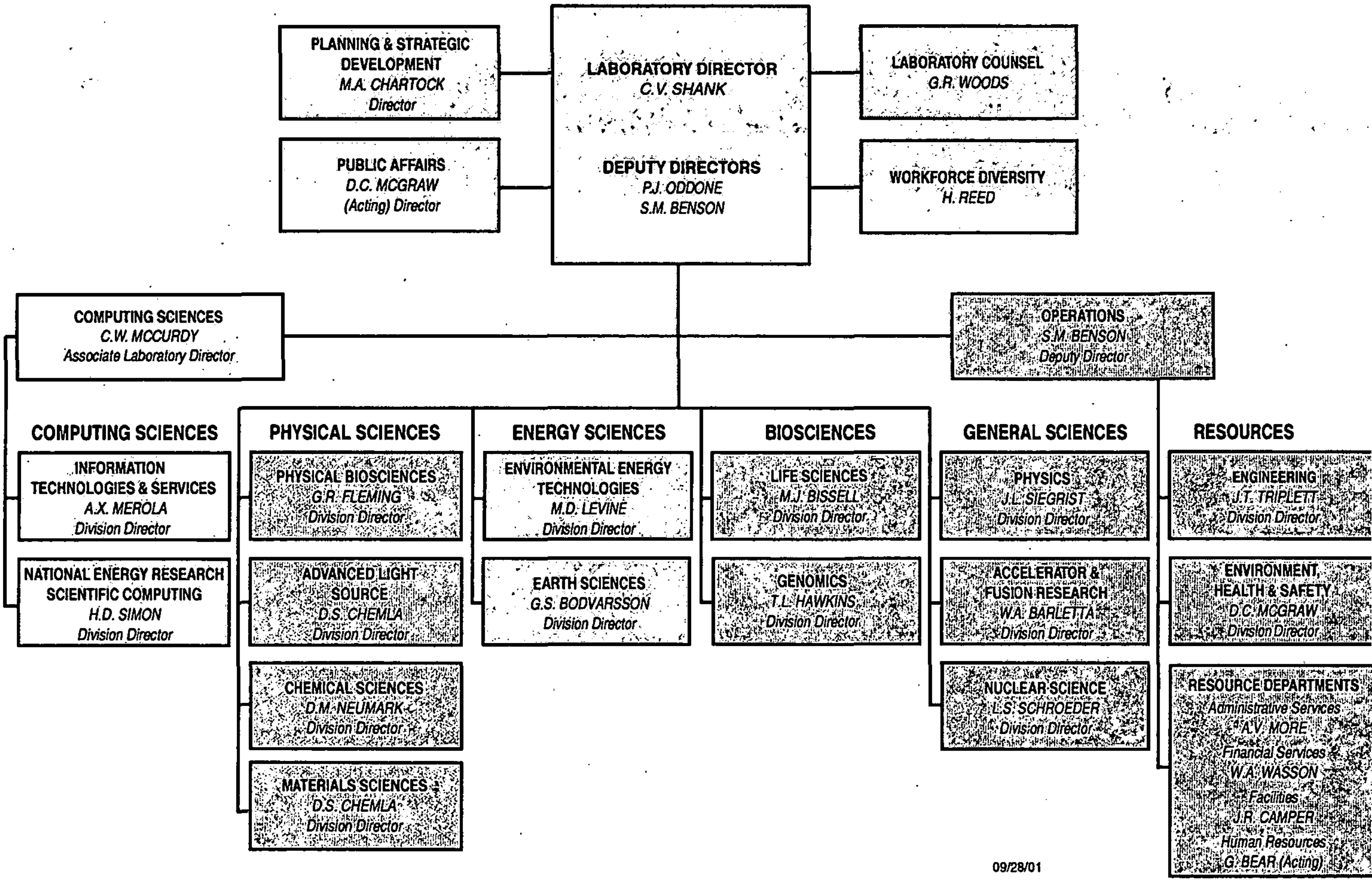


Figure II (1) Ernest Orlando Lawrence Berkeley National Laboratory Organization Chart

III. LABORATORY STRATEGIC PLAN

BERKELEY LAB'S VISION 2010

Berkeley Lab's Vision 2010 identifies key scientific directions that support the mission of the Office of Science and our other research sponsors, as well as the Laboratory's national role within the Department of Energy (DOE) system of laboratories. Five key areas provide the long-term outlook for Vision 2010: understanding the universe, nanoscience, quantitative biology, new energy sources and solutions, and advanced computing for Office of Science research programs.

- **Nanoscience.** 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. Berkeley Lab is proposing a Molecular Foundry to advance the Office of Science role in the National Nanotechnology Initiative. This nanoscience research center will focus on the conjunction of soft and hard nanostructure building blocks and their fabrication into functional multicomponent assemblies. The Foundry will have an internal research program, a collaborative research facility for visiting scientists, a training program for students and postdoctoral fellows, and portals to major user facilities. The Advanced Light Source, the National Energy Research Scientific Computing Center, and the National Center for Electron Microscopy play leading roles both in our exploration of complexity and in contributing to the national nanoscience and nanotechnology effort. The Laboratory is also advancing ultrafast science through the development of a femtosecond x-ray source.
- **Matter and Energy in the Universe.** High energy and nuclear physics are at the core of the Laboratory. The programs are 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 are taking data at high rates. Data collection at the Sudbury Neutrino Observatory has resulted in the observation of flavor oscillations in solar neutrinos. 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 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. Completion of genome sequences for many organisms, including, human, Fugu, and many bacteria has been so dramatic that the Joint Genome Institute (JGI) serves as a central resource for DOE'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. Biology, mostly an observational science in the last century, is on its way to becoming a predictive quantitative science in the 21st century. The Laboratory's new Genomics Division and the Physical Biosciences Division exploit the tools of physics, chemistry, engineering, mathematics, and computing to solve problems in biology.
- **New Energy Sources and Solutions.** Three pivotal energy issues are appropriate subjects for Berkeley Lab research for Vision 2010: How can the nation provide reliable supplies of electricity and other forms of energy? How might technology be applied to reduce public energy consumption? What are the long-term global consequences of energy use and how can potential problems be mitigated? 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. 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. The Laboratory stands 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.

- **Advanced Computing for Office of Science Research.** Our vision for the National Energy Research Scientific Computing Center (NERSC) is to make available high-performance computing for all Office of Science 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 provides NERSC with 4-teraflop capability, the most powerful civilian scientific computing capacity in the world. The commitment for improved computing infrastructure has resulted in the establishment of Berkeley Lab's Oakland Scientific Facility, which houses the new supercomputing acquisitions. NERSC serves as a comprehensive resource for DOE's new initiative in Scientific Discovery through Advanced Computing (SciDAC).

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 Office of Science and the program goals of our sponsoring offices and other key customers.

SITUATION ANALYSIS: KEY CUSTOMERS

Within the fabric of American science, Berkeley Lab serves as a multiprogram science laboratory whose primary role is fundamental science with important further contributions in energy resource and environmental research. The following discussion presents a synopsis of Berkeley Lab's efforts for our major Laboratory research sponsor—the Office of Science—and for other DOE Offices and government agencies. Berkeley Lab's efforts for all customers are unclassified.

Office of Science

The Office of Science is the primary customer for Berkeley Lab's fundamental science mission. The Office of Science is the third-largest government sponsor of basic research in the United States and the largest government supporter of the physical sciences. Berkeley Lab's research and facilities support, in particular, the following research offices: Advanced Scientific and Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics. The level of funding provided by these offices is indicated in Section VIII: Resource Projections and Tables.

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 in support of the Office of Advanced Scientific Computing Research are:

- **National Energy Research Scientific Computing Center (NERSC):** an extremely powerful computing environment incorporating high-performance computing capability, capacity, and storage resources. NERSC includes 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.

- **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.

To provide the large-scale resources needed by the scientific applications NERSC is now upgraded to a 4-teraflops IBM system. 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. 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 Basic Energy Sciences

Basic Energy Sciences programs focus on advanced materials and nanoscience, physical chemistry, and geosciences. The Advanced Light Source—which provides the world's brightest beams of ultraviolet and soft x-ray radiation and is now 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, with more than 1,000 users. 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. A core capability is in the area of nanotechnology building blocks and assemblies of both soft (e.g. carbon) and hard (e.g. silicon) based nanomaterials. The Laboratory is also 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. A new thrust in this area is an environmental nanoscience research program to conduct laboratory experiments and numerical simulations to learn how nanosized materials, such as iron oxides and zinc sulfate, grow and aggregate into larger crystalline forms under inorganic and unusual organic conditions. Earth sciences researchers at Berkeley Lab are also among the leading experts in the areas of subsurface imaging of the structure and dynamics of the earth's crust, experimental investigation of the mechanisms by which lithospheric processes influence energy resources, and numerical modeling of geochemical and hydromechanical processes occurring in heterogeneous fractured rock formations.

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. It also pursues the conjunction of biology and materials science in the biomolecular materials program. New directions in research in photosynthesis cut across specialties to address two major scientific issues: the delineation and application of nature's design rules to create new functions in photosynthesis, and the obstacles toward progress in the harnessing of sunlight and its conversion to alternative fuels. This 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.

Office of Biological and Environmental Research

Research at DOE's Joint Genome Institute (JGI) successfully delivered on the national goal of a rough draft of the human genome sequence in March 2000; has completed the draft sequence of the puffer fish for comparative genomics; and has sequenced many key bacterial genomes. 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 transgenic mice developed by researchers at Berkeley Lab, and by comparisons with other organisms. Related programs include studies in gene expression within mammary-gland and blood-forming systems, and hematopoietic research.

Since January 1999, the JGI has increased its production rates by more than twenty-fold to approximately 25 million raw bases per day. 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 addressed. Leveraging this productivity, the JGI 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.

The research focus of Berkeley Lab's Physical Biosciences Division 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.

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. Within this group, PBD has two "home" facilities: the Berkeley Center for Structural Biology (BCSB) and BioSpec. The BCSB is a national facility for the study and advancement of protein crystallography. Since its began operations in 1997, the BCSB 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 Basic Energy Sciences Advisory Committee (BESAC) subpanel review of the ALS commended the protein crystallography program of the BCSB as "outstanding." 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.

In another area of focus, 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. Research efforts at Berkeley Lab aim 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.

Research in nuclear medicine includes new studies in molecular biology, and continuing studies of improved radiopharmaceuticals and advanced instrumentation for applications to medical science. The Department of 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. This effort includes 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 purpose of this research is to apply new technologies to the study of atherosclerosis, heart disease, aging, neurological and psychiatric diseases, and cancer.

Recent experimental measurements and computational modeling of scintillation mechanisms have lead to the discovery of a new class of inorganic scintillators able to detect gamma rays with the efficiency and energy resolution of the best scintillators but with a hundred-fold improvement in response time. When developed, these new inorganic scintillators will allow major advances in instrumentation for a variety of fields (nuclear medicine, nuclear physics, high energy physics, and astrophysics). Of particular interest in nuclear medicine is the development of a low-cost positron emission tomograph able to use time-of-flight information to reconstruct the distribution of tracer molecules in the human head with a two-fold improvement in spatial resolution and a four-fold improvement in sensitivity over conventional PET.

Berkeley Lab is engaged in several other critical areas related to the Office of Biological and Environmental Research (OBER) mission. These include 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. Further studies entail interspecies extrapolation and risk assessment in carcinogenesis; quantitative three-dimensional image analysis; interactions of genome and cellular microenvironment; protein annotation using machine learning methods; and structural genomics.

Life Sciences Division investigators have ongoing and newly initiated research to increase the understanding of radiation effects at very low doses that can be used to inform the current models of risk estimation. The radiation biology program encompasses molecular, cellular, and multicellular responses to low-dose radiation exposure. One goal is the identification of genes involved in the response to DNA damage and the genetic, molecular, and biochemical characterization of these as they relate to determining susceptibility to pathology. Theoretical studies that incorporate experimental results form the basis for models necessary for extrapolation to environmental exposures.

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 coordinates a program office for the Natural and Accelerated Bioremediation (NABIR) Program Office for the Office of Science. This long-term research program, conducted by performers throughout the DOE system, 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 carbon dioxide 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 addresses 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 Laboratory conducts an advanced program in astrophysics that is directed toward understanding the origins and fate of matter and energy in the universe. Key areas address supernova cosmology, cosmic background radiation, and neutrino studies. The Laboratory is working with DOE, the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) to develop a

SuperNova/Acceleration Probe satellite to define the fundamental parameters of the universe, including the possible "dark energy," (see Section IV, Initiatives).

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, as well as waste management operations. The Stewardship Committee brings together program representatives and Laboratory managers to address the operational and infrastructure needs of 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. Ongoing technology development efforts contribute to significant advances in nuclear instrumentation that allow progress in cutting-edge science. 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 will begin its second year of operations 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, performed beyond all expectations during the first RHIC running in 2000. Exciting first physics results were presented at Quark Matter 2001. The STAR Parallel Distributed Systems Facility (PDSF) computing facility at Berkeley Lab (which complements the RHIC Computing Facility at Brookhaven) is now in production mode; 75% of the usage so far this year is by STAR collaborators outside Berkeley Lab. Looking to the future, Berkeley Lab scientists are designing a next generation, high-resolution vertex detector for STAR to enable the measurement of the very short-lived D mesons.

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 2002. VENUS will provide the nuclear science community with an enhanced capability of heavier projectiles at increased intensities.

The Gammasphere has returned to Berkeley in its third campaign 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 the Berkeley Gas-Filled Separator (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 ^{14}O-beams from the IRIS (Ion source for Radioactive ISotopes) ion source.

DOE Nuclear Physics is moving forward with planning for an advanced radioactive beam facility, the Rare Isotope Accelerator (RIA), as recommended in both the 1996 and 2001 Long Range Plans. The nuclear physics identified covers a broad range of topics, including nuclear structure, nuclear astrophysics, exotic nuclei, and heavy elements, requiring both stable and radioactive beams. Berkeley researchers expect to play a strong role in both the science and the technology of RIA and are currently participating in the RIA research and development activities. GRETA could be one of the major detectors to address RIA physics and we expect that VENUS will serve as a prototype for the RIA driver. We also envision a need for a premier stable beam facility to complement the planned RIA facility and are working to ensure that the facility of choice will be at Berkeley Lab. As one option, we are identifying and evaluating potential improvements and added capabilities to make the 88-Inch Cyclotron the premier stable beam facility. Another option being considered is construction of a different accelerator.

Berkeley Lab is actively involved in a coordinated neutrino research program. Berkeley Lab scientists played a major role in the construction of the Sudbury Neutrino Observatory (SNO), an experiment to detect neutrinos from the sun and from supernovae. SNO is now taking data in its "laboratory" in Canada, 6800 feet underground; first physics results provide evidence for neutrino oscillations as well as neutrino mass. 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; commissioning is expected in late 2001. Lab scientists are also participating in the Cryogenic Underground Observatory for Rare Events (CUORE/Cuoricino), 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. Next-generation experiments and detectors in neutrino science and double-beta decay are being developed for deployment in a new underground laboratory (see Section IV, Initiatives) and to exploit the unique opportunities afforded by detection of high-energy neutrinos.

Science Education for DOE

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

All Berkeley Lab education 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 ten-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 ten-week research experience. The preservice teacher program offers undergraduate students from California colleges and universities who are planning to obtain a secondary, single-subject teaching credential in science, mathematics, or computer technology with a ten-week summer research participation 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 Laboratory staff, and coordinates its efforts with the Office of Workforce Diversity and Community Outreach.

Laboratory Directed Research and Development (LDRD)

The Berkeley Lab LDRD program is a critical tool for directing the Laboratory's forefront scientific research capabilities towards vital, excellent, and emerging scientific challenges. The program provides the resources for Berkeley Lab scientists to make rapid and significant contributions to critical national science and technology problems. LDRD also advances the Laboratory's core scientific capability and permits exploration of exciting new opportunities.

Within the last year, LDRD funds were allocated to Berkeley Lab's Energy Sciences research area in, as examples, ultrafast x-ray spectroscopy via optical gating, phase- and amplitude-contrast tomography using intermediate energy x-rays, study of radionuclide-bacterial interaction mechanisms, ocean particulate carbon dynamics, ion-beam thin-film texturing, and atomically resolved spin-polarized imaging using superconducting Scanning Tunneling Microscopy (STM) tips. Research efforts in the General Sciences included dynamics of low-emittance electron rings with applications to high energy physics colliders, gamma ray studies using an 8-pi spectrometer, and solutions to data handling constraints for large High Energy and Nuclear Physics experiments. Efforts in the Biosciences areas included DNA microarray analysis of metabolic regulatory genes in the mouse, cryo-electron microscopy studies of eukaryotic transcriptional basal factor TFIID, and identification of novel functional RNA genes in genomic DNA sequences. Research in the Computing Sciences areas included numerical methods for time-dependent viscoelastic flows, electron collision processes above the ionization threshold, feature extraction from observed and simulated data, and linear algebra and statistical algorithms for text classification in large databases.

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 activities have been organized into building, power, industrial, and transportation technologies. Berkeley Lab has had a leadership role in the inter-laboratory studies on carbon management 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 and for understanding the energy use of home and office electronic equipment. Work extends beyond individual buildings to the regional issue of urban heat islands and measures such as light surfaces that could mitigate the effect.

The work in Power Technologies includes a geothermal energy resources program that consists of delineation and evaluation of geothermal systems, definition of reservoir processes, modeling of reservoir dynamics and exploitation effects, and analysis of field-management practices. Fluid production and injection technologies are also being studied to optimize reservoir management. In addition, Berkeley Lab undertakes a variety of analysis activities on issues and opportunities that may impact renewable and distributed energy technologies, including the restructuring of the electric utility industry, energy demand and energy technologies in developing countries, and specific renewable technologies for the U.S. including high temperature superconductors for electric power transmission. Berkeley Lab manages the multi-institution Consortium for Electric Reliability Technology Solutions (CERTS)—a joint effort between DOE and the State of California

Industrial 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 and furnaces. 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 Batteries for Advanced Transportation Technologies (BATT) Program, which seeks to advance the development of high-energy rechargeable batteries for use in electric vehicles. In the new Advanced Technology Development (ATD) program, Berkeley Lab is working with other DOE multiprogram laboratories 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.

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 carbon dioxide and the simultaneous catalytic reduction of nitrogen dioxide and sulfur dioxide from flue gas.

Berkeley Lab participates in a number of oil and gas projects through the Natural Gas and Oil Technology Partnership Program. The goal of this Partnership program is to bring advanced technologies developed at the Laboratories to the stage where independent producers can use them to increase production or to decrease the uncertainties and costs for drilling 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 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 in order to help 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 laboratories, 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.

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 DARHT, which takes advantage of developments originating in the Office of Science Fusion Energy Sciences Program.

Office of Nonproliferation and National Security

DOE has an important 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 agents released 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 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 Bechtel SAIC Company (BSC) 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 and materials sciences, and in 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 mission areas, and the levels of funding provided by these agencies is indicated in Section VIII: Resource Projections and Tables.

The proportion of support from non-DOE sources is expected to remain approximately level (18 to 23 percent of the total Laboratory budget). The actual projections for FY 2002 in the resource tables indicate best estimates of about 20 percent. The Laboratory's DOE mission areas that hold the strongest interest for collaboration by other organizations include Biological and Environmental Research, Basic Energy Sciences, Energy Efficiency and Renewable Energy, 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 over 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 beamline development and beamline operation.
- Other sponsors of sequencing, functional genomics, and computational biology are interested in the Office of Biological and Environmental Research capabilities associated with the genome program at Berkeley Lab and the DOE Joint Genome Institute, and the modeling capabilities of the Physical Biosciences Division. The primary sources of interest are the National Institutes of Health and the Defense Advanced Research Projects Agency (DARPA).
- The Laboratory's internationally recognized programs in cell and molecular biology are attracting support from the National Institutes of Health as well as the Department of Defense (for breast cancer, prostate cancer, and DNA repair studies) and biotechnology companies.
- Research in materials science that takes advantage of the capabilities at the Advanced Light Source, the National Center for Electron Microscopy, and the Center for X-Ray Optics is being sponsored by other agencies. 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.
- The Environmental Protection Agency (EPA) and the State of California are sponsoring research that builds upon Berkeley Lab's expertise and experimental facilities in the buildings and electricity reliability areas.
- 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 (NIGMS), 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. NIGMS is sponsoring a new protein structure effort at Berkeley Lab, which couples to the Laboratory's Advanced Light Source and instrumentation engineering capabilities, led by investigators in the Structural Biology Department of the Physical Biosciences Division.
- For the National Heart, Lung and Blood Institute (NHLBI), the Life Sciences Division is conducting research in cardiovascular flow and metabolism. Another area of funded research entails studies on lipoproteins and atherogenesis in transgenic animals. In addition, NHLBI is sponsoring, under the Programs for Genomic Applications, a multi-investigator initiative using a comparative genomic approach to identify and determine the function of elements regulating the expression of genes affecting the cardiovascular system.
- 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 the National Cancer Institute, the Life Sciences Division is conducting research in breast cancer and DNA repair.
- For the National Institute on Aging, the Life Sciences Division is conducting research to determine the causes and consequences of cellular senescence, the function of RecQ-like helicases and other DNA repair proteins in cellular and organismal aging phenotypes, and the regulation and function of telomeres in genomic stability, cancer, and aging.
- Important initiatives now underway in collaborations between Office of Science/OBER and NIH are described below under Structural Cell Biology of DNA Repair Mechanisms and Genomes to Life: Computational Capabilities (see Section IV, Initiatives).

In addition, 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. NIH also supports 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 NIH: 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 (DOD). 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 toxic 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 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 Defense Advanced Research Projects Agency (DARPA), 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.
- Also for DARPA (through Lawrence Livermore National Laboratory), the Environmental Energy Technologies Division conducts research on chemical transport in buildings.
- An important biological modeling initiative now underway in collaborations between Office of Science/OBER and DARPA is described below under Genomes to Life: Computational Capabilities (see Section IV, Initiatives).

National Aeronautics and Space Administration (NASA)

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. Laboratory 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.

Research in the Earth Sciences Division is carried out under NASA's Regional Earth Sciences Applications Center, discussed in more detail under the Carbon Science Initiative (See Section IV, Initiatives), as well as studies in an autonomous profiler for carbon systems and biology.

Environmental Protection Agency

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, and the analysis of real-world automobile emissions based on state data.

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

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.

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

In the energy area, for many years funding from the State of California has complemented that provided by DOE, particularly for building technologies. Much of the results of the research have been incorporated in products available in the market and in the State's building codes and standards. 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 new 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 now underway address high-performance commercial building systems and electric system reliability. The latter involves co-sponsorship with DOE of the Consortium for Electric Reliability Technology Solutions (CERTS).

Utility funding for some projects, such as research on natural gas burners with low nitrogen oxide emissions, reflective roofs, 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. The California Air Resources Board is funding (through the University of California) an analysis of the effectiveness of the California Smog Check II program on reducing emissions from motor vehicles. A study just getting underway for the California EPA is addressing the relationship between childhood asthma and school children's exposure to vehicle exhaust emissions.

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:

- A beamline for biological crystallography is now operational at the ALS, managed through the Physical Biosciences Division under sponsorship of the Genomics Institute of the Novartis Foundation. This beamline features advances in robotics and high-throughput automation.
- The Howard Hughes Medical Institute has made a major investment in funding two superbend beamlines at the ALS also supporting research in protein crystallography.
- Research being conducted by the Environmental Energy Technologies Division includes sustainable energy in China under sponsorship from the Energy Foundation, Shell International, and international appliance standards under sponsorship of the Alliance to Save Energy.
- 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, atherosclerosis, and obesity.
- 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.

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, science issues of social significance, 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 including 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 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.
- Research on aging will integrate the efforts of UC Berkeley and Laboratory 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. The Center for Research and Education in Aging, lead by a UC Berkeley professor, 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 30 projects currently underway are in many fields, including efficient building systems, physics, chemistry, materials science, geosciences, and biology. Some larger CRADAs (above $200K) are:

- **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. The effort is conducted in partnership with Sandia and Livermore National Laboratories
- **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.
- **Thin Film High Temperature Superconductors.** This research in the Environmental Energy Technologies Division is using Berkeley Lab-developed novel thin film coating techniques for the purpose of developing practical tapes for transmitting electricity.

CRADAs typically 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 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.

Program Strategic Directions

- **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, design, and synthesize systems with nanoscale dimensions.** This effort will integrate capabilities in materials science, condensed matter physics, synthetic chemistry, structural biology, molecular 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.
- **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 scientific capabilities for 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 the multiteraflop power of the National Energy Research Scientific Computing Center.
- **Berkeley Lab provides world leadership in particle physics and astrophysics.** Recent discoveries include 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. As part of 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.
- **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.
- **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 and function of cell systems.** Genomes-to-Life activities, including those characterizing the microbial cells and their components and integrated networks, are key to this effort (see Section IV, Initiatives). Important questions include how biological molecules work in assemblies as molecular machines. Understanding how the three-dimensional architecture of cells is developed from the one-dimensional code of DNA bases and amino acid sequence complements these efforts. 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. 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.

- **For Fusion Energy Sciences, Berkeley Lab applies its accelerator physics, 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.

Operations and Infrastructure Strategic Directions

- **Research Infrastructure.** Berkeley Lab's facilities planning 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 Berkeley Lab's planning are adequate space and facilities for users at the Laboratory's national user facilities, in order to meet program goals for the 21st century, and modernization through program line-item projects and the Multiprogram Energy Laboratory Facilities Support program. Because facilities planning is a critical element of the Laboratory's stewardship activities, it is included as Section VI 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.
- **Strengths of the Office of Science National Laboratories.** Berkeley Lab is part of the complex of Office of Science national laboratories and is applying its capabilities as part of coordinated inter-laboratory efforts. Key examples are the Joint Genome Institute, Spallation Neutron Source, 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 ALS and NERSC. Some current thrusts of these partnerships center on nanoscience and nanotechnology, ALS science partnerships, simulation and computational science-of-scale, and the advancement of the physical biosciences to fulfill the promise of the physical sciences for modern biology.

- **Effective 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, including its Integrated Laboratory System partnership projects such as the Front End for the Spallation Neutron Source, it has added project management oversight staff and is conducting senior management reviews to assure high performance and a continued reputation as location-of-choice for major science projects. This year, the Laboratory has formed a Project Integration and Management Board to assure that effective project management is included at early stages of development of scientific initiatives and projects.
- **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.
- **Waste Management, Pollution Prevention, and Waste Minimization.** 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 for "newly generated" waste to the Office of Science, continued funding is uncertain by Environmental Restoration and Waste Management.
- **Effective Community Relationships.** Berkeley Lab has established a new Public Affairs organization that fosters 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 of and participation in the Environmental Sampling Task Force. Community review of the sampling plan has been completed and sampling is underway. 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.
- **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 2001. However, continued efforts at travel cost savings cannot be sustained without 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.
- **Workforce Diversity and Recruitment.** Enhancing the diversity of our workforce is a vital part of our collective strength and success as a Laboratory. We are committed to building a community in which diversity is valued, cultural differences are respected and even celebrated, and individuals perceive fairness and equity across the board. The Laboratory's new results-oriented Diversity Plans reflect this commitment. They are organization, division, and department specific, and

provide strategies and actions to enhance the work environment for all employees, and methods of outreach and recruitment to promote equality of opportunity. Employees are encouraged to view these plans and participate in their own group's workforce diversity program. The overall success of achieving a diverse work environment rests with all Laboratory employees. Implementation accountability of the plans rests with the management of Berkeley Lab at all levels. 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 include the Division Diversity Plans—to improve the recruitment and retention of a diverse workforce.

- **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). An Integrated Safeguards and Security program has been developed and approved to serve as a management and compliance tool.

IV. INITIATIVES

INTRODUCTION

Berkeley Lab's role in the national laboratory system—charted by Laboratory management working in concert with DOE—is based on its 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. 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.

Office of Science

Office of Advanced Scientific Computing Research

- Scientific Discovery through Advanced Computing (SciDAC)
- National Energy Research Scientific Computing Center (NERSC) Strategic Plan

Office of Basic Energy Sciences

- Molecular Foundry (Nanoscience)
- Femtosecond Structural Dynamics User Facility
- Advanced Light Source (ALS) Science Strategic Plan
- Dynamic Atomic Resolution Microscopy at the National Center for Electron Microscopy (NCEM)
- Molecular Environmental Science

Office of Biological and Environmental Research

Genomes to Life

- Combinatorial Chemistry Applied to Functional Genomics
- Center for Single-Molecule Studies
- Structural Biology at the Advanced Light Source [(with Work for Others: National Institutes of Health (NIH)]
- Soft X-Ray High-Resolution Structure Determination

Other Office of Biological and Environmental Research Initiatives

- Carbon Science to Address Global Climate Change (with Fossil Energy and Work For Others)
- National 12-Tesla Whole-Body Magnetic Resonance Resource (with Work For Others: NIH)
- Structural Cell Biology of DNA Repair Mechanisms (with Work For Others: NIH)
- Three-Dimensional Cellular and Tissue Architecture
- Biological Effects of Low-Dose Ionizing Radiation

Office of Fusion Energy Sciences

- Heavy-Ion Fusion Integrated Research Experiments

Office of High Energy and Nuclear Physics

- Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP) [with Work for Others: National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA)]
- Accelerators for the High Energy Physics Frontier
- GRETA (Gamma-Ray Energy Tracking Array)
- Next-Generation Experiments at a National Underground Science Laboratory

Office of Energy Efficiency and Renewable Energy

- Electric Reliability Performance Systems
- Advanced Energy-Efficient and Healthy Buildings
- Energy Efficiency and Electricity Reliability Laboratory

Office of Fossil Energy

- Carbon Sequestration (with Office of Biological and Environmental Research and Work For Others)

Work for Others

- Genomes to Life: Computational Capabilities [Defense Advanced Research Projects Agency (DARPA) and NIH]
- Air Quality: Particulate Matter and Tropospheric Ozone [Environmental Protection Agency (EPA) with Offices of Biological and Environmental Research, Fossil Energy, and Energy Efficiency and Renewable Energy]
- Partnerships for Science Education (with Office of Science)

OFFICE OF SCIENCE

Office of Advanced Scientific Computing Research

Scientific Discovery through Advanced Computing (SciDAC)

The goal of Scientific Discovery through Advanced Computing is to enable the use of terascale computers to dramatically extend exploration of the fundamental processes of nature as well as advance the ability to predict the behavior of a broad range of complex natural and engineered systems. This will be achieved by creating a Scientific Computing Software Infrastructure to bridge the gap between the most advanced computing technologies available and the scientific research programs of the Office of Science.

SciDAC will include research in, and development of, computational modeling and simulation capabilities that take full advantage of the extraordinary computing capabilities provided by terascale computers and advance, as no other approach can, the fundamental science programs of DOE:

- Understanding and predicting the energetics and dynamics of chemical reactions and the interactions between chemistry and fluid dynamics relevant to, but not limited to, combustion, environmental fate and transport, surface-mediated catalysis, and chemical processing.
- Understanding and predicting chemical reactivity unique to the nanoscale phenomena that drive such processes as catalysis and chemical vapor deposition.
- Predicting the earth's climate at both regional and global scales for decades to centuries, including levels of certainty and uncertainty.
- Understanding macroscopic stability and microscopic turbulence, including their effect on core and edge confinement, in magnetically confined plasmas. Understanding basic plasma science topics such as electromagnetic wave/particle interactions and magnetic reconnection.
- Understanding the physics required for inertial fusion energy applications, for example, that are associated with electromagnetic fields and beam dynamics in heavy ion accelerators.
- Predicting electromagnetic field and beam dynamics in particle accelerators, with particular attention to processes, such as beam halos, that impact the performance of current and proposed high-energy accelerators.
- Predicting the physical phenomena encompassed in the Standard Model of Particle Physics to determine whether additional theoretical concepts are needed to explain fundamental interactions at very high energies or short distances.
- Predicting the structure of nuclei, as well as nuclear processes, involved in energetic events such as stellar supernovae explosions.

SciDAC will also include research and development of software to accelerate the creation of scientific codes that take full advantage of terascale-and-beyond computers, protect the long-term investments in these codes, and enable a broad range of scientists to use simulation in their research:

- Basic mathematical methods, algorithms, and libraries that scale to thousands and tens–of-thousands of processors.
- Code development environments and tools to enable the development of complex, scientific simulation codes.
- Disciplinary problem-solving environments to enable the use of computational modeling and simulation by a broad range of scientists.

- Scientific data management and analysis (visualization) systems to enable the extraction of knowledge from the massive data sets (100s of terabytes to petabytes) produced by advanced scientific simulations.
- Scalable operating system software and tools for management of terascale-and-beyond computer systems, including resource management, scheduling, and high-performance messaging.

In addition, SciDAC will engage in research and development of collaboratory and networking software to link geographically separated researchers, facilitate access to, and movement of, large (100s of terabytes to petabytes) data sets, and ensure that all qualified scientists can fully participate in the activities described above.

Scientific Discovery through Advanced Computing (SciDAC)
Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
Operating**	15.3	15.6	16.4	16.4	16.4	80.1

*Preliminary estimate of Berkeley Lab Budget Authority, including equipment (B&R Codes KJ, KC, KA, KB)
**Resource projections are per total submitted FWPs; actual funding decisions are under review by appropriate DOE program offices. Amount of FY01 funding also being reviewed.

National Energy Research Scientific Computing Center (NERSC) Strategic Plan

NERSC is DOE's premier scientific computing facility for unclassified research. Over the last five years, NERSC has built an outstanding reputation for providing both high-end computer systems and comprehensive scientific client services. At the same time, NERSC has successfully managed the transition for its users from a vector-parallel to a massively parallel computing environment. Building on a foundation of past successes, this strategic plan presents NERSC's vision for its activities and new directions over the next five years. NERSC's continuing commitment to providing high-end systems and comprehensive scientific support for its users will be enhanced, and these activities will be augmented by two new strategic thrusts.

The first new component of NERSC will be the provision of intensive support for Scientific Challenge Teams funded by the new DOE Office of Science program called Scientific Discovery through Advanced Computing (SciDAC). DOE envisions that these large-scale teams will be formed to develop and deploy advanced modeling and simulation codes, as well as new mathematical models and computational methods that take full advantage of the new generation of terascale computers. These teams are representative of a shift from the single-principal-investigator model for high-end computing to a collaborative model aimed at producing "community codes" whose development is shared by entire scientific research communities.

A second new component of the NERSC strategy addresses another change in the practice of scientific computing. In recent years, rapid increases in available networking bandwidth, combined with continuing increases in computer performance, are making possible an unprecedented simultaneous integration of computational simulation with theory and experiment. This change will have a fundamental impact on areas of science that have not yet made much use of high-end computing. By deploying critical parts of a Unified Science Environment (USE), NERSC anticipates playing a key role in the emergence of a new paradigm in computational science.

NERSC proposes a strategy consisting of four components. The two continuing components are:

- **High-End Systems.** NERSC will continue to focus on balanced introduction of the best new technologies for complete computational and storage systems, coupled with the advanced development activities necessary to wisely incorporate these new technologies.
- **Comprehensive Scientific Support.** NERSC will continue to provide the entire range of support activities, from high-quality operations and client services to direct collaborative scientific support, to enable a broad range of scientists to effectively use the NERSC systems in their research.

The new components are:

- **Support for Scientific Challenge Teams.** NERSC will concentrate its resources on supporting these teams, with the goal of bridging the software gap between currently achievable and peak performance on the new terascale platforms. This goal is explicitly stated in the SciDAC plan.
- **Unified Science Environment (USE).** NERSC will enhance its architecture and systems as required to make NERSC the most powerful computational resource on DOE's Science Grid. Over the next five years, NERSC will use Grid technology to deploy a capability designed to meet the needs of an integrated science environment, combining experiment, simulation, and theory by facilitating access to computing and data resources, as well as to large DOE experimental instruments.

Finally, NERSC will expand its collaborations with other institutions, especially with the other DOE Office of Science laboratories, to systematically integrate into its offerings the products of their efforts in computational science. With this strategy NERSC will enhance its successful role as a center that bridges the gap between advanced development in computer science and mathematics on one hand, and scientific research in the physical, chemical, biological, and earth sciences on the other. Implementing this strategy will position NERSC to continue to enhance the scientific productivity of the DOE Office of Science community, and to be an indispensable tool for scientific discovery.

National Energy Research Scientific Computing Center (NERSC)
Strategic Plan Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
Operating	32.5	35.7	41.2	44.9	48.7	203.0

*Preliminary estimate of Berkeley Lab Budget Authority, including equipment (B&R Code KJ). Some resources are current base funding, details being reviewed with DOE program offices.

Office of Basic Energy Sciences

Molecular Foundry (Nanoscience)

The Molecular Foundry is proposed as an Office of Basic Energy Sciences Nanoscale Science Research Center, advancing the Department of Energy's role in the National Nanotechnology Initiative and consistent with Department guidance and its two reports: *Nanoscale Science, Engineering and Technology Research Directions*, and *Complex Systems: Science for the 21st Century*.

The Molecular Foundry will be a major basic research center in nanoscience, stressing the conjunction of both "soft" and "hard" nanostructures and the fabrication of multi-component functional systems made up of these two types of building blocks. Its centerpiece will be a broad array of unique, state-of-the-art facilities in the design, synthesis, and characterization of nanostructures. These facilities, along with an associated scientific and technical staff, will be available for use by collaborators from academic, governmental, and industrial laboratories. Most collaborators will be from Western U.S. institutions, but many of the facilities will be unique nationally and will attract a national constituency. The Molecular Foundry will also serve to educate and train hundreds of undergraduate and graduate students and postdoctoral fellows from educational institutions throughout the West. Finally, it will serve as a "portal" to the Berkeley Lab user programs of the Advanced Light Source, the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center, all of which have strong programs to support research in nanostructures.

The Foundry will have a substantial internal research program, a component that will be essential to the viability of a productive, useful, and continually updated external collaborative program. The internal research activity will exploit the breadth of interests and experience of investigators now at Berkeley, or to be recruited. It will have two primary foci. The first will be studies not only of conventional "hard" nanocrystals, tubes, and lithographically patterned structures, but also of nanometer-sized "soft" materials, such as polymers, dendrimers, DNA, proteins, and even whole cells. (Cells are, of course, of micron dimensions, but their functions are based on systems whose components function at nanometer dimensions.) The second research focus will be the design, fabrication, and study of multi-component, complex, functional assemblies of these hard and soft nanostructures.

The Molecular Foundry will be housed in a new state-of-the-art building adjacent to the Advanced Light Source and near the Berkeley Lab Advanced Materials Laboratory. It will be designed to support multidisciplinary research in fields including materials science, physics, chemistry, biology, and engineering. It will also house the collaborative research facility, and provide space for visitors and collaborators.

Working at the nanometer scale is not simply doing "micron-level" work with smaller objects. Nanoscience phenomena, synthetic approaches, and characterization techniques are far more sophisticated, and innovative research is a far greater challenge. Through the facilities of the Foundry, and the availability of its trained scientific staff for collaboration and teaching, this challenge can be made tractable to a far broader section of the scientific community.

Molecular Foundry (Nanoscience) Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	3.0	3.0	3.0	3.0	13.0	18.0	43.0
Construction and equipment	0.0	1.5	13.0	61.3	5.3	3.9	85.0

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

Femtosecond Structural Dynamics User Facility

The use of femtosecond optical lasers has revolutionized the study of many phenomena in solid-state physics, chemistry, and biology in the last 30 years. For example, invention of the mode-locked, continuous wave (cw) dye laser in 1971 enabled the direct observation of extremely short-lived transition states—intermediate conformations between reactant and product species that have, in some cases, a lifetime on a timescale of a vibrational period, 100 femtoseconds, or less. The scientific significance of transition-state chemistry was recognized with the award of the 1999 Nobel Prize in Chemistry to A.H. Zewail. Many other examples of the importance of femtosecond optical studies exist—from laser-driven, solid-solid phase transitions to the study of photochemistry in biological systems—and clearly this area has grown into one of the most dynamic in modern science.

Although great progress has been made with optical spectroscopy, which probes extended electronic states, the information most needed is the motion of atoms. This is where x-ray techniques excel. X-ray diffraction provides direct three-dimensional information, and x-ray absorption provides a radial distribution function of atomic positions. Combining both techniques with a 100-femtosecond x-ray source will revolutionize many of the fields in which ultrafast optical techniques are used. Since 1993, Berkeley Lab has worked toward becoming the leading center worldwide in structural dynamics using x-rays. Several sources have been built at the ALS based on Thompson scattering and on the interaction of an intense laser beam with the ALS electron beam. These sources have been used to study a variety of dynamics, in particular the dynamics of ultrafast melting. While these studies have been successful in understanding solid-state dynamics in perfect single crystals, the U. S. scientific community will require a much more powerful x-ray source in order to address the wide range of science currently studied using optical techniques.

We propose to build a Femtosecond Structural Dynamics User Facility that will provide an increase in flux of more than 10^6 compared to our present ALS beamline, and, in addition, will provide for up to eight simultaneously operating experimental stations. The proposed facility is based on several robust new technologies: (1) a high-brightness photo-gun to produce intense, short pulses of electrons, (2) a superconducting linac to boost electrons to high energy, (3) a recirculator to direct electrons several times through the same linac structure, (4) radiofrequency 'crab' cavities to kick the electron beam to produce a longitudinal tilting of the beam, and (5) optical pulse compression. All of these technologies are well understood. For example, the superconducting linac is based on technology built for the Tera Electron Volt Energy Superconducting Linear Accelerator (TESLA) high energy physics program in Hamburg, Germany, and is commercially available. The radiofrequency photo-gun is available from a number of sources developing free electron lasers (FELs). By using an assembly of these technologies, we can provide an ultrafast x-ray facility with unprecedented performance, in the environment of a national user facility.

Together with the Stanford Synchrotron Radiation Laboratory (SSRL) and two European light sources (BESSY, in Berlin, and the Swiss Light Source) Berkeley Lab is sponsoring a workshop in the April to May 2002 timeframe that will bring together the existing ultrafast optical community and the emerging ultrafast x-ray community. The time regime from 50 picoseconds to a few 10's of femtoseconds will be the core focus area for this workshop, which is intended to define scientific highlights and directions for the use of the x-ray techniques, to promote cross fertilization of ideas between the two communities, and to define the source characteristics required for particular classes of experiment. This workshop will provide a survey of the compelling scientific opportunities and an understanding of how the many possible x-ray sources (laser-based systems, slicing at synchrotrons, FELs, ultrafast linacs, energy-recirculating linacs, etc.) best enable that science.

For example, ultrafast linac sources such as the facility we are proposing to build at Berkeley Lab and x-ray FELs such as the Linear Coherent Light Source at SSRL complement one another. On the one hand, the linac source is guaranteed to work using proven technology and will provide outstanding performance compared to presently available sources. Flux will not be an issue for many years, and, indeed, such a user facility is a logical stepping-stone on the way to sources of still higher performance, such as the x-ray FEL. The linac-based source also has the advantage of absolute synchronization of laser pump and x-ray probe, and a relatively short pulse length of 50 femtoseconds. X-ray FELs, on the other hand, will provide the ultimate in average and single pulse flux—some 1000 times higher still than the Berkeley Lab proposal. However, FELs are at the leading edge of accelerator technology and therefore unlikely to be the basis of a user facility until technical issues are resolved. Consequently, a sound national program would address the needs of this emerging field with a linac-based national user facility while continuing the development of x-ray FELs in parallel to provide the route to even higher performance in the future.

Berkeley Lab's Accelerator and Fusion Research, Materials Sciences, Physical Biosciences, and Advanced Light Source Divisions have joined forces to produce a pre-conceptual design report for submission to the Office of Basic Energy Sciences in June 2002 following the workshop. Written justification outlining the science and the machine is being prepared, and facility cost is currently being estimated.

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 the 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, which 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 over 1000 and—just with the completion of currently funded beamlines—is expected to increase to over 2000 users by FY 2004. By the end of the decade, the ALS will serve about 2500 users. An upgraded user facility supports the main recommendation of the BESAC 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 research in disciplines in addition to the nanoscience area.

Offices will be needed for ALS scientists and for ALS experimental systems support, 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 ALS 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.

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 elsewhere in this 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 endstations 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 nanometers 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 femtoseconds). 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 next-generation of high-brightness femtosecond x-rays for time-resolved structural studies of solution reactions, surface processes, and protein dynamics. This research and development is directly relevant to a possible new national user facility for femtosecond structural 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 program will establish a suite of high-performance stations for protein crystallography around several superbend ports, 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.
- **Center for High Pressure.** A superbend beamline dedicated to high-pressure research will take advantage of the combination of high-pressure/high-temperature techniques and synchrotron radiation, which together provide a powerful means of studying condensed matter. The beamline will give excellent performance to over 40 keV. Density is one of the most fundamental characteristics of a solid, and many new phenomena (superconductivity, phase transitions, metal-insulator transformations) are observed as density is varied through the application of pressure. Condensed-matter theorists can now predict many-body properties as a function of the density, and critical tests of these emerging theories are needed. In solid-state chemistry, there is a huge unmet need for an improved understanding of how particular solids form, when a high-energy phase will be metastable, and what the mechanisms are for structural transformations. In geophysics, fundamental problems bearing on the dynamics of planetary interiors and the geological history of volatile species can be addressed using high-pressure/high-temperature techniques. This proposal brings together users from University of California campuses and national laboratories as the core of a research community of diverse users, all of whom share a common need for a synchrotron x-ray beamline in support of high-pressure science on the West Coast.

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.

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

Category	2001	2002	2003	2004	2005	2006	Total
Operating	31.5	33.4	36.5	38.5	40.5	42.7	223.1
Equipment	1.9	4.0	4.0	4.2	4.3	4.5	22.9
ARIM/AIP	2.1	4.0	4.0	4.2	4.3	4.5	23.1
WFO**	0.0	0.0	1.1	1.1	1.2	1.2	4.6

*Preliminary estimate of total DOE Budget Authority (B&R Code KC). Construction figures for some upgraded user offices and labs will be identified as part of the development of the Molecular Foundry.

Dynamic Atomic Resolution Microscopy at the National Center for Electron Microscopy (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 as many different orientations as necessary for three-dimensional 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:

- Nanocrystallography—atomic structure refinement from nanocrystals and defects.
- Real-time *in-situ* observation of atomic-level mechanisms and dynamics.
- Three-dimensional 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. A prominent example of the key role played by electron microscopy in materials science is the discovery of nanotubes that ignited the current explosion of research activity in this area. With its unique ability to observe individual nanotubes or nanocrystals at the atomic scale, high-resolution electron microscopy will continue to take an essential role in the characterization and scientific understanding of nanomaterials.

Two major approaches toward quantitative sub-angstrom imaging will be pursued in parallel, combining real-time atomic resolution imaging with fine-probe spectroscopy for analysis of structure, composition, and bonding:

- 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 0.5-angstrom 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, three-dimensional 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 "beamline," 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 collaborative 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 at NCEM
Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
Operating	1.0	1.0	2.0	2.0	2.0	8.0
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)

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 at the ALS with unique capabilities 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, which is already partially funded, the 75eV to 1500 eV beamline and endstations 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 emission, 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 keV to 4 keV beamline and endstations.

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 the entire 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	2006	Total
Operating DOE	0.3	0.3*	0.4*	0.6*	0.8*	0.8*	0.8*	4.0
Construction DOE	2.3**	1.8	2.0	2.0‡	2.0‡	2.0‡	0.0‡	12.1

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Codes KC03, KC02)
** Includes previous FY1999 amounts
‡ Estimated for proposed future Phase II activities

Office of Biological and Environmental Research

Genomes to Life Initiatives

During the past year, the Office of Biological and Environmental Research (OBER) launched its Genomes to Life initiative, which builds on the success of the Human Genome Project that OBER launched in 1986. DOE's proposed Genomes to Life program would make important contributions in the quest to venture beyond characterizing such individual life components as genes and other DNA sequences toward a more comprehensive, integrated view of biology at a whole-systems level. The program calls for the evolutionary development of existing technologies toward high-throughput capability and for the revolutionary development of technologies that incorporate new modes of robotics and automation as well as advanced information and computing technologies. Berkeley Lab plans to meet these technology needs through a variety of initiatives described below, covering the areas of high-throughput proteomics, molecular and subcellular imaging, and computation (including Work For Others).

Combinatorial Chemistry Applied to Functional Genomics

The technique of combinatorial small-molecule library synthesis, pioneered in the Department of Chemistry at UC Berkeley, has enabled the rapid generation of large compound libraries for screening against biological targets. The technique is now widely applied by pharmaceutical companies to drug discovery efforts. The Center for Combinatorial Chemistry Applied to Functional Genomics will 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.

The Center will have three central components: (1) design and synthesis of novel small-molecule libraries, (2) development of novel high-throughput biological assays, and (3) creation of inventive strategies for identifying function. A highly collaborative five-year pilot program will focus on functional deconvolution of proteins from major multi-gene families, including proteases, kinases, and sulfotransferases, all of which appear to participate in fundamental regulatory processes within cells. Proteases are key regulatory enzymes that participate in cell growth and in programmed cell death. Protein kinases are the central mediators of signal transduction pathways inside cells. They act on protein substrates, phosphorylating them and altering their behavior in cellular pathways. The kinases are crucial to many steps in cell growth and division, and in programmed cell death. Sulfotransferases are a recently identified multi-gene family that is rapidly gaining attention as key modulators of cell-cell communication.

The Center will feature both a central instrumentation facility, located at Berkeley Lab and an organizational infrastructure to facilitate collaborative work among chemists, biologists, and engineers with common interests in functional genomics. Funding will be largely allocated to instrumentation for combinatorial library synthesis, analysis and screening, and research personnel. Initial funding of the pilot program through DOE will provide the focus needed to make rapid progress and establish proof-of-concept for this novel paradigm. The chemical libraries, screening and analysis technology, and approaches developed throughout the course of this research will be generalizable to the functional analysis of any multi-gene family identified from genome sequencing efforts, including the microbial sequencing efforts so central to DOE's mission.

Combinatorial Chemistry Applied to Functional Genomics
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	0.8	1.0	1.0	1.0	1.2	5.0
Construction	0.0	2.0	1.5	0.5	0.5	0.5	5.0

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

Center for Single-Molecule Studies

Traditional approaches to study the structure of biomolecules use bulk measurements that provide structural details of an average conformation [Nuclear Magnetic Resonance (NMR) spectroscopy] or in those cases where the molecules can be crystallized, of a single frozen conformation (x-ray crystallography). However, biomolecules are not well described by either static or average conformations. To understand their function in living organisms we must understand their dynamic properties and their responses when exposed to different types of force fields.

Many new techniques can capture the multiple conformations of single molecules under conditions that closely imitate those found *in vivo*. By revealing novel and dynamic conformations, the new field of real-time single-molecule spectroscopy holds great promise for biology. A particularly novel perspective was opened by the recent development of force spectroscopy that has enabled the study of the mechanical properties of single biological polymers. The application of mechanical force to biological polymers produces conformations that are different from those that have been investigated by chemical or thermal denaturation, and are inaccessible to conventional methods of measurement such as NMR spectroscopy and x-ray crystallography. Furthermore, recent studies have shown that the relevant structural features of many enzymes and motors are those that appear under conditions of a mechanical load. The effect of mechanical forces in the conformation of biological molecules is largely unexplored.

The Center for Single-Molecule Studies will pioneer several complementary techniques for single-molecule spectroscopy, focusing on force probes [atomic force microscopy (AFM) and optical tweezers], single-molecule fluorescence, and computer simulations. The purpose of the Center is to become, at the national level, the driving force behind the development of single-molecule spectroscopy. Its three main objectives are:

- To research and develop novel and next-generation single-molecule methodologies and their applications.
- To offer investigators outside the Center access to "proven" and state-of -the-art methodologies.

- To focus research and academic interest in single-molecule spectroscopy at Berkeley Lab and UC Berkeley.

The Center will have five closely interrelated research units (laboratories):

- A common laboratory for protein and nucleic acid engineering and organic chemistry to engineer molecules that are compatible with the existing schemes of manipulation and detection of molecules by mechanical and fluorescent probes.
- A common laboratory for the development of single-molecule detection instruments and software. This laboratory will generate state-of-the-art single-molecule force probe designs and fluorescence and other optical spectroscopy instruments and make them readily available to Center users.
- A laboratory of single-molecule force spectroscopy by AFM. These probes excel in accurate measurements of length at relatively high forces (10 to 1000 pN). The aim is to develop the AFM as an analytical tool that requires minimal operator intervention and with "artificial intelligence" analysis protocols that can identify and characterize mechanical conformations.
- A laboratory of single-molecule force spectroscopy by optical tweezers. This laboratory will focus on the use of optical tweezers for the measurement of the effect of low forces (0.1 to 70 pN) in the conformation and function of single molecules. The aim is to further develop the optical tweezers technique to become a multi-mode technique that can incorporate force spectroscopy, fluorescence spectroscopy, and pulsed laser activation, in a single instrument.
- A laboratory of computer simulations to perform simulations and develop software that will focus on individual molecular trajectories as revealed by single-molecule Fluorescence Resonance Energy Transfer (FRET) and on the effect of a force on the conformations of a molecule.

Center for Single-Molecule Studies Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	0.6	1.0	1.0	1.0	1.0	4.6
Equipment	0.0	1.6	0.2	0.2	0.2	0.2	2.4

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

Structural Biology at the Advanced Light Source (ALS)

Already a world-class structural biology facility serving hundreds of users, the Berkeley Center for Structural Biology (BCSB), which began operation at the ALS in late 1997, is poised for further dramatic growth. Over the next two years, the number of protein crystallography beamlines at the ALS is planned to grow from three to eight or more as technological developments continue to enhance the capabilities and the capacity of the BCSB. For example, the ALS superbend project incorporates superconducting bend-magnet sources ("superbends") into the design of synchrotron beamlines to provide 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 UC Berkeley/UC San Francisco and the Howard Hughes Medical Institute and are expected to become operational in the summer of 2001.

Working with researchers from academia and industry, Berkeley Lab scientists and engineers are designing and building robots to perform the laborious and difficult work of protein purification, screening, crystallization, and data collection. NIH-supported development of hardware and software for automating the manipulation of single crystal protein samples at the BCSB is being done in three phases, each representing a higher level of automation. Our ultimate goal is to eventually construct an integrated "cyberhutch" system that is capable of loading, centering, optimally collecting, and processing data on crystals of biological molecules, with human intervention dramatically reduced over what is currently available. In a related effort for NIH, called PHENIX, Berkeley Lab is developing expert systems for automated structure determination to eliminate the computational bottlenecks that impede rapid structure solution and the errors that result from subjective interpretation of the data. See Genomes to Life: Computational Capabilities under Work for Others, below.

Structural Biology at the Advanced Light Source
Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
DOE Operating	1.0	1.0	1.0	1.0	1.0	5.0
WFO Operating	2.0	2.1	1.6	1.4	1.3	8.4

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

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 nanometers). 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. It is a 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 focused by a zone plate lens and the magnified image is recorded on an x-ray sensitive charge-coupled device (CCD) detector.

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 $\lambda = 2.4$ nanometers) 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 micrometers, 0.5 micrometers, and 50 nanometers, respectively. Thus, cellular structures can be clearly distinguished

This initiative is designed to address questions regarding structure-function relationships of proteins in a wide variety of cells and tissues. We recently demonstrated the ability to do tomographic reconstructions of whole cells using cryo x-ray tomography, which enables us to retrieve the three-dimensional information about the position of proteins in whole cells at approximately 30-nanometer resolution. The next step is to develop an automated cryo-tilt stage to enable rapid, efficient collection of large data sets. Once cryo x-ray tomography is automated, we will be in the unique position to investigate structure-function relationships of proteins in a wide variety of cells and tissues using a combination of live-cell light and high-resolution soft x-ray microscopy. The use of the cryo x-ray tomography will generate unique, high-resolution three-dimensional information about the subcellular localization of those proteins throughout the entire cell. The development of this methodology will provide a high-throughput method for structure-function analyses of proteins.

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

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.5	0.5	0.5	0.5	0.5	0.5	3.0

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

Other Office of Biological and Environmental Research (OBER) Initiatives

Carbon Science to Address Global Climate Change

Berkeley Lab scientists are investigating promising technologies and science-based strategies to reduce greenhouse gas concentrations and predict the feedbacks to climate change. 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 potential impacts, 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 global emissions of anthropogenic carbon into the atmosphere, advance our understanding of potential climate change due to such anthropogenic carbon emissions, and provide new information on potential impacts.

Science of Climate Change. Berkeley Lab researchers have shown that organic aerosols are as abundant as sulfate aerosols, and that both must be taken into account in climate models, which have recently begun to include these radiative cooling properties. The new Atmosphere and Oceans Group at Berkeley Lab has several centers that address both carbon sequestration and climate change phenomena. These centers include the DOE Center for Ocean Carbon Sequestration (DOC) and the NASA Regional Earth Sciences Applications Center (RESAC). Additionally, the UC Berkeley Center for Atmospheric Sciences is closely affiliated with activities with both of these Berkeley Lab centers.

RESAC's California Water Resources Research and Applications Center has continued to produce Regional Climate System Model (RCSM) short-term weather and stream flow predictions, seasonal climate and stream flow predictions, long-term climate variability and impact assessments, and model evaluation. It has performed water quality and sediment related research and applications, including agriculture impact assessments, real-time San Joaquin water quality monitoring, identification of runoff from abandoned mine sites, erosion modeling, sediment transport modeling, and assessments of related hazards. RESAC at Berkeley Lab has maintained a two-way flow of information with its users, has become a member of the Earth Science Information Partnership, and has contributed to the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Assessment.

The new DOE Water Cycle and Dynamics Prediction Initiative builds on our water resources research for RESAC. Its focus is on the water cycle at the regional scale, with intensive observation and modeling of the water cycle (atmosphere, land surface, and subsurface) and the interactions between them in order to obtain "closure" for the water cycle in a region. This initiative has successfully launched a multi-laboratory (with Argonne, Brookhaven, Los Alamos, Lawrence Livermore, and Oak Ridge National Laboratories) pilot study in the Walnut River Watershed at DOE's Atmospheric Radiation Measurement (ARM) Southern Great Plains site. The goal of the pilot study is to demonstrate methods for quantifying those mechanisms that cause hydroclimate variability. Berkeley Lab scientists will be implementing information from oxygen and hydrogen isotopic measurements into their climate and hydrology models.

The DOE Center for Ocean Carbon Sequestration (DOCS) is an essential element in the broad approach to carbon science. Future directions are elaborated below in the initiative on Carbon Sequestration.

Carbon Science. The Berkeley Lab programs on terrestrial carbon cycling and land-atmosphere carbon fluxes are addressing major challenges in climate change research, such as bridging plot scale measurements with regional and global scale models, and linking the fluxes of carbon, water, and energy. There are two main areas of research and programmatic development being pursued with national laboratory and university partnerships. First, the DOE Atmospheric Radiation Measurement (ARM) program is designing, building, and deploying a suite of instrumentation to measure concentrations and fluxes of carbon dioxide and water near the ground, in the boundary layer, and from aircraft above the boundary layer for ARM's Southern Great Plains site. Measurements are combined with dynamic ecosystem models and mesoscale models to address problems of scaling and land use change. A second main area of work is soil carbon cycling in temperate and tropical ecosystems, and factors promoting long-term stabilization of carbon in soil organic matter. There are currently projects on carbon impacts of elevated carbon dioxide, climate change, land use change, and plant allocation. Berkeley Lab's carbon research is building and utilizing strengths in isotope analysis, field experiments, and ecosystem and mesoscale modeling. In particular, advanced isotopic techniques are being used to study trace gas exchange, to test models, and to determine the capacity for long-term carbon storage in soils. In the future, there is strong potential for the Climate Change and Carbon programs to work together to build major initiatives within DOE for the water cycle and the linked carbon, nitrogen, and water cycles.

Low-Carbon Energy Sources. New sustainable energy sources will be needed for a more carbon-free energy economy. Berkeley Lab research will 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. First, however, 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. Geothermal resources represent an essentially zero carbon energy source. However, in order for geothermal to provide a greater percentage of the overall energy supply, it will be necessary to find new resources and to extend the life and enhance the productivity of known resources. Berkeley Lab's expertise in geochemistry and geophysics can contribute to the development of new geothermal exploration technology. Modeling and imaging capabilities provide the understanding needed to develop new, sustainable production strategies. Other Berkeley Lab programs could contribute to new science for fuel cells, hydrogen production, chemical light pumps (photochemistry), bioengineering photosynthetic systems, reactive membranes, genetic studies of novel biosystems, new catalytic processes, photovoltaics, and other energy conversion systems.

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

Category	2001	2002	2003	2004	2005	2006	Total
Operating	5.5	5.5	6.0	6.0	6.0	6.0	35.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Codes KP, AA) and Work For Others: NASA, NOAA

National 12-Tesla Whole-Body Magnetic Resonance Resource

The purpose of this project is to build a national resource capable of safely performing forefront magnetic resonance studies of the chemical composition and high-resolution anatomy of the living human body. The resource for medical science discoveries at 12-tesla magnetic field (120,000 gauss or 1/4 million times the earth's magnetic field) is beyond any other existing or proposed facility in the world. The engineering and medical science studies that underpin this proposal are complete. The proposal targets OBER-NIH interagency sponsorship to enable production of a second resource at NIH.

There are important medical science opportunities with this improved technology. The increase in signal strength relative to the background is directly related to the increase in field. This increase in signal allows one to image at a much higher resolution than is possible with currently available magnets. Among the advances that can be enabled with this improved resolution is the identification of patterns of Alzheimer's plaques that have diameters as small as 40 micrometers. Another target is the architecture of the cortex, which is believed to be disturbed in disorders such as dyslexia and possibly in other syndromes associated with behavior disorders. The improved resolution has promise to reveal distorted nerve fiber tracts thought to underlie some forms of schizophrenia. To realize the resolution of 50 micrometers, motion compensation is needed, and this is an area of associated research already underway with collaborators at Brookhaven National Laboratory.

Major biomedical potentials of this resource include the opportunity to study the intra- and extracellular balance of sodium and potassium in brain, heart, and muscles. The high field enables studies of intracellular sodium, potassium, and chlorine heretofore not possible at lower fields. Thus, for the first time we will be able to study imbalances in intracellular and extracellular ion concentrations. This study will be particularly important for manic-depressive diseases and for studying remedies for congestive heart failure and skeletal muscle disorders.

Another equally important application of high-field magnetic resonance is detection of body chemistry in health and disease using carbon-13 nuclei. Carbon-13 is in all chemicals of the body, and though it is only about 1% as abundant as carbon-12 it is possible to use carbon-13 magnetic resonance spectroscopy to detect most of the important metabolites of the human body anywhere in the body. Thus, it is possible to determine, for example, changes in metabolites with various diets and disease states. This capability can open new horizons in medical science by allowing measurements of patterns associated with a wide breadth of medical problems ranging from the relationship of obesity and nutrition to that of aging and cancer. Our current evaluation of safety associated with radiofrequency (RF) power gives us confidence these potentials will be realized.

The limitations of commercially used wire made of niobium titanium material is mainly the maximum current density in amperes per mm^2 that can be used at a given field strength. Until recently, this wire was thought to be too brittle and too expensive for our application. However, in 1997, Berkeley Lab developed a record-setting accelerator-style dipole designed for 12 Tesla, and this magnet reached 13.5 Tesla. Currently a larger bore magnet is under construction for 14 Tesla using new methods for handling the Nb_3Sn wire. The important technical parameters that Berkeley Lab is addressing are: an achievable current density of 2600 A/mm^2, successful methods of forming the magnet coils, and challenges with tissue penetration for proton magnetic resonance. Berkeley Lab's unique capabilities will enable advances on all these fronts.

National 12-Tesla Whole-Body Magnetic Resonance Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
DOE Operating	0.5	1.4	1.2	1.5	3.0	7.6
DOE Construction	0.0	5.0	2.5	1.2	3.0	11.7
WFO Operating	0.0	0.4	0.4	0.4	0.4	1.6
WFO Construction	0.0	0.2	0.2	0.2	0.2	0.8

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

Structural Cell Biology of DNA Repair Mechanisms

A major challenge for the future is to integrate the molecular cell biology of complex cellular processes with structure at escalating levels of complexity from protein domains to large multi-protein molecular machines. Characterizing such dynamic assemblies is an extremely challenging problem. Major initiatives at Berkeley Lab through partnership between OBER and NIH are addressing this challenge by developing techniques and facilities to bridge the size and resolution gap between electron microscopy of biological assemblies and x-ray diffraction structures of separate proteins. This will advance the interpretative framework for molecular and cellular biology. Although these approaches will be widely applicable, the initial focus of these initiatives is on providing the framework to unite results from the genetics, biochemistry, and cell biology of DNA repair processes with structures of assemblies that coordinate DNA repair systems to maintain genomic integrity and stability in human cells. This effort builds upon major strengths of Berkeley Lab in Life Sciences, Physical Biosciences, the National Energy Research Scientific Computing Center and the Advanced Light Source Divisions and links them with major NIH-funded research efforts in DNA repair by academic collaborators from many universities.

As a joint effort of DOE and NIH, this initiative will provide the full application of a structural cell biology synchrotron beamline that has been purpose-designed for integrated studies of multi-protein complexes controlling genetic integrity. This tunable wavelength beamline, named SIBYLS for Structurally Integrated BiologY for Life Sciences, is under construction at the Advanced Light Source with funds provided in FY 2001 by OBER to support a major portion of the design and construction costs. Specialized instrumentation for SIBYLS and development of its versatile applications will be provided by the National Cancer Institute (NCI) as part of a multi-institution program project on Structural Cell Biology of DNA Repair Machines centered at Berkeley Lab.

SIBYLS is optimized for large unit cells, small crystals, and the collection of very low to very high resolution diffraction data that are key to solving large complexes. Furthermore, it will allow small angle x-ray scattering (SAXS) in solution to characterize conformational changes and to validate the crystallographically defined conformational states for DNA repair complexes. The technical challenge in solving structures of large, biologically important macromolecular complexes involves both merging a variety of traditionally independent experimental techniques and the collection of diffraction data at different beamline geometries. Thus, the SIBYLS beamline has been designed to allow a rapid conversion between a variety of beamline geometries that are required to cover the broad spectrum of data collection needs for large macromolecular complexes. SIBYLS will provide unique capability for structurally defining functionally important flexible regions of large protein complexes and the means to relate them to electron microscopy reconstructions. In addition, it will provide the technology to support experiments designed to allow docking crystal structures of component proteins into the electron density of the larger, multi-component biologically relevant states, some of which cannot be crystallized (such as some intermediate assembly states). It will thus provide detailed structural data for large complexes, including regions that undergo functionally important flexibility and conformational changes. 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 molecular machines that does not presently exist at any facility worldwide.

Structural Cell Biology of DNA Repair Mechanisms
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	4.0	4.4	4.1	3.4	3.6	19.5
Construction	0.0	2.5	0.0	0.0	0.0	0.0	2.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP). Resource Projections are for all participating institutions.

Three-Dimensional Cellular and Tissue Architecture

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 differential display and cDNA microarrays, 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, to study the dynamics of tissue formation and the reversion of the malignant phenotype.

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 angstrom) 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 amounts that three-dimensional crystallization becomes impractical.

Having solved the structure of tubulin at Berkeley Lab, 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 in 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, 300-keV electron microscope equipped with the field emission gun.

Three-Dimensional Cellular and Tissue Architecture
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
DOE Operating	0.0	2.5	2.5	2.5	3.0	3.0	13.5
WFO Operating	0.0	0.8	1.0	1.0	1.5	1.5	5.8

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

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. Mechanistic understanding of cellular and tissue responses to ionizing radiation is essential for development of meaningful models for assessing risk associated with exposure to low-level ionizing radiation (LLIR). 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. Overall estimates of radiation-induced cancer risks in humans cannot be based simply on empirical linear fits of available epidemiological data from relatively high dose exposures—even when adjustments are made for low dose and low dose rate exposures. Such an extrapolation can either over- or underestimate the risks. It is extremely difficult to directly measure small changes in most biological end points, particularly carcinogenesis. We hypothesize that experimentally determined molecular mechanisms operating at relatively high doses will also be applicable at low doses. Theoretical models are being developed for estimating risk at low doses and low dose rates. Our strategy is to extrapolate mechanisms taking into consideration those effects that are non-linear with dose.

A major research initiative will identify and characterize genes and gene products critical for repair of DNA damage from exposure of human cells to LLIR, investigate their inducibility by LLIR and their role in the adaptive response, and determine their role in susceptibility to LLIR in general and to the bystander effect in particular. An additional focus is on the possibility that apoptotic signal transduction is a susceptibility factor that modulates DNA repair and mutagenesis after exposure to LLIR. Concurrent with the mechanistic studies of DNA repair and damage signaling, recent advances in genomic and proteomic technologies coupled with development of transgenic mouse models are being exploited to correlate specific gene expression pattern(s) with relevant LLIR-induced biological consequences. Imaging bioinformatics is also being used to characterize changes in the irradiated microenvironment in mouse and human models of breast cancer in order to determine how tissue responses to LLIR contribute to mammary carcinogenesis.

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

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	2.5	3.0	3.0	3.0	2.5	14.0

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

Office of Fusion Energy Sciences

Heavy-Ion Fusion Integrated Research Experiments

The Heavy-Ion-Fusion (HIF) program's objective is to provide a comprehensive scientific knowledge base for inertial fusion energy (IFE) driven by high-brightness heavy-ion beams. The major part of the HIF program concerning intense ion beam science is located at Berkeley, Livermore, and Princeton Plasma Physics Laboratories, and coordinated through a Heavy-Ion-Fusion Virtual National Laboratory (HIF-VNL) headquartered at Berkeley Lab. The top-level scientific challenge for HIF is to produce sufficient beam power for both high-energy-density plasma science and for driving IFE targets, while retaining the well-established ability of accelerators to deliver well-focused beams, which are essential for achieving these objectives. The near-term effort by HIF-VNL addresses four key scientific questions derived from this top-level scientific challenge for HIF: (1) What dynamical phenomena affect the quality of space-charge-dominated beams undergoing transport and acceleration? (2) What role do non-linear processes and beam-plasma interactions play in beam chamber propagation and focusing onto a target? (3) How can we best apply and improve computational tools to provide the needed support for experiments, exploration of issues, and planning for the future? and (4) What physics determines beam brightness in heavy-ion sources and low energy transport? Together, these broad scientific questions are chosen to guide the development of the knowledge base needed for future follow-on, more-integrated beam experiment, e.g. for acceleration capability added to the present High Current Experiment (HCX), and for a high energy capability for an Integrated Research Experiment (IRE) for heavy-ion target physics. These questions are pursued by the following research elements within the VNL:

- **Comparisons of measured beam quality evolution in specialized high-current beam experiments.** The HCX Phase 1 will be configured primarily as a transport experiment through a combination of 40 electrostatic and four pulsed magnetic quadrupoles with various fill factors, quadrupole offsets, and beam centroid steering corrections. HCX Phase 2 will continue and extend the experiment with about 100 magnetic quadrupoles in order to be more sensitive to emittance growth, halo formation, electron effects, etc. These experiments will provide information that will enable the VNL to design a more cost effective IRE.
- **Transport and focusing of heavy-ion beams.** The VNL is designing and will construct an experiment to study the physics of beam neutralization and magnetic focusing of heavy-ion beams with currents of 100 mA to 1A. Issues to be addressed include, especially, the minimization of geometric and magnetic aberrations, and the disturbance of ion trajectories by fluctuating electric fields in the neutralizing plasma.
- **End-to-end numerical simulation codes of intense ion beams.** Accelerator science (largely the science of non-neutral plasmas) is synergistic with the laboratory-wide effort in numerical science inspired by capabilities of the National Energy Research Scientific Computing Center. We are developing a comprehensive three-dimensional source to the target numerical simulation

capability for existing and proposed accelerator systems, as an integral part of our long- and short-range scientific program.

- **Study of sources, injection, and low-energy matching section transport, at beam currents of 100 mA to 1A.** A new 500 kV test stand (STS500) will be commissioned for a series of critical experiments to study the beam brightness associated with new multi-beamlet plasma ion sources. We will continue to investigate the surface ionization source and develop practical ways of extending the source lifetime as well as reducing the alkaline metal vapor emission. Our goal is to evaluate, experimentally, the two types of ion source options to lead to a selection of the appropriate ion source for a new injector to be used in the HCX experiments.

Resource requirements (below) are the 2001 and anticipated future portions at Berkeley Lab. However, the four described research elements are carried out in a coordinated effort by the three VNL laboratories with $11.5M funding in 2001 and level funding guidance in 2002. The expansion beginning in 2003 (to $17M VNL total) enables the full HCX experimental program and a vigorous pursuit of the other three areas.

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

Category	2000	2001	2002	2003	2004	2005	2006	Total
Operating	4.0	4.0	4.0	5.7	5.9	6.0	6.2	35.8
Equipment	1.1	1.1	1.1	4.0	4.1	4.2	4.4	20.0

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

Office of High Energy and Nuclear Physics

Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP)

Recent studies of Type Ia supernovae, 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 were 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 supernovae 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 supernovae 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 1.8-meter 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. A detailed budget and schedule will be developed in coordination with DOE's Office of Science/High Energy and Nuclear Physics program. There are also ongoing discussions with the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) regarding collaboration on the project.

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

Category	2001	2002	2003	2004	2005	2006	2007	Total**
Operating	1.2	4.3	10.0	0.0	0.0	0.0	0.0	15.5
Equipment	0.0	0.0	0.0	87.5	87.5	87.5	87.5	350.0

*Preliminary estimate of Budget Authority (B&R Code KA) and Work for Others: NSF and NASA. Profile projected steady state for each partner FY04 to FY07 for launch. Full scope of science partners is under development.
**Contingency budgets not included in spending profiles.

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 all of its beam energy available 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 and at the Sudbury Neutrino Observatory have demonstrated 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 kilometers) 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 tool to complement 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 radiofrequency (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.

Accelerators for the High Energy Physics Frontier
Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
Operating**	1.9	2.5	3.0	3.5	4.0	14.9

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

**Resource projections are for planning activities, eventual funding subject to DOE decisions on CD-0 and CD-1 for the respective accelerators.

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 Rare Isotope Accelerator (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 FY 2003. Assuming its success, we would then expect to begin construction of the full GRETA array in FY 2004 (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	2006	Total
Operating	0.0	0.0	0.2	0.2	0.5	0.6	1.5
Construction	0.2	0.3	2.0	3.0	3.0	6.0	14.5

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

Next-Generation Experiments at a National Underground Science Laboratory

Significant interest has been expressed in the nuclear physics, high energy physics, astrophysics, and geoscience communities in the scientific advances that could be made by having access to a dedicated deep underground scientific facility. Consequently, the Institute for Nuclear Theory at the University of Washington, with the encouragement of federal funding agencies, convened a committee to explore the scientific case, technical requirements, and possible site for a dedicated National Underground Scientific Laboratory (NUSL). A 36-page document summarizes the scientific case in over twelve disciplines, and over 30 letters of interest in various experiments at NUSL were received. The Homestake Mine near Lead, South Dakota was recommended and a proposal is being submitted (from outside Berkeley Lab) to the NSF to begin the conversion of the mine into a dedicated scientific facility. The *U.S. 2001 Long Range Plan for Nuclear Science* strongly endorsed opportunities associated with deep underground laboratories—in particular, recommending interest in such a U.S. site. Berkeley Lab has a long-term interest in the science that can be carried out at such a facility.

Berkeley Lab played a pivotal role in the assessment of the science case for a national facility and in defining the characteristics and qualities required for the next generation of experiments. The Nuclear Science and Physics Divisions are currently involved in a coordinated forefront neutrino physics and double beta decay research program, utilizing the Sudbury Neutrino Observatory (SNO), KamLAND, CUORE/Cuorcino, and the Antarctic Muon And Neutrino Detector Array (AMANDA). The NUSL would allow them to pursue next-generation experiments in these areas. For the Earth Sciences Division, the heterogeneity of the rock, as well as the complexity and physical distribution of disrupted and non-disturbed rock, provides an unparalleled opportunity to examine large spatial configurations by long-term direct observation for both geochemistry and geomechanics processes. These experiments can be done in a facility that allows data collections over long time periods, beyond the test durations currently limited by other program missions in present underground facilities.

This facility presents Berkeley Lab and the entire scientific community the opportunity to create a world-class facility to address several of the most fundamental science questions as generally identified by the Nuclear Regulatory Commission's Committee on the Physics of the Universe. By building on its experience base and the present activities related to NUSL science, Berkeley Lab has an additional opportunity to maintain its world leadership in the areas of nuclear physics, high energy physics, and geoscience. The Nuclear Science and Physics Divisions are actively pursuing new detection and instrumentation technology to address next-generation, low-energy neutrino and double-beta decay experiments on a time scale commensurate with the development of NUSL, with the long-term goal of mounting major experiments. Geoscientific investigations will likely be some of the first deployed at NUSL. Long-term experiments testing heat transfer and hydrology are anticipated early in the facility development. Geoscientists will also assist with the design and development of the facility to ensure its quality.

Scientific emphasis would be placed on those areas where pre-existing Laboratory expertise brings the most to bear, including low-background counting, double-beta decay, solar neutrinos, long-baseline neutrinos, geoscience heating, hydrology, and chemical tracer migration. The first scientific experiments could be deployed within a year of starting a facilities project. The current goal is determining the most promising approaches and then proceeding through to a proof-of-principle underground deployment, as the necessary prerequisite to developing full-scale funding (as proposed here) for at least two experiments—one in nuclear/high energy physics and one in geoscience.

Next-Generation Experiments at a National Underground Science Laboratory Resource Requirements ($M)*

Category	2002	2003	2004	2005	2006	Total
Operating	0.0	0.0	0.2	0.0	0.2	0.4
Construction	0.0	0.0	0.0	2.0	5.0	7.0

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

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

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, and 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	2002	2003	2004	2005	2006	Total
Operating	8.0	15.0	20.0	25.0	25.0	93.0

*Preliminary estimate of Budget Authority (B&R Code EE) and Work for Others. 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.

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 and Healthy 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	2006	Total
Operating	3.0	5.0	5.0	5.0	5.0	5.0	28.0

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

Energy Efficiency and Electricity Reliability Laboratory

Within DOE, the Office of Energy Efficiency and Renewable Energy has as its mission to lead the nation in the research, development, and deployment of advanced energy efficiency and clean power technologies and practices, providing Americans with a stronger economy, healthier environment, and more secure future. To address this mission, Berkeley Lab is proposing an Energy Efficiency and Electricity Reliability Laboratory that will be a regional and national focus for research and development partnerships, and a model of the infrastructure needed to nationally advance the state of the art in energy efficient and renewable energy technologies and practices.

Representing a model of sustainable and energy-efficient design, a proposed new laboratory building will provide investigators offices and laboratories to develop, test, monitor, and demonstrate new building technologies and design processes in partnership with industry. The building will also demonstrate the procurement processes; design strategies; and technologies, systems, and operating practices that will foster environmentally responsive laboratories and office buildings throughout the DOE complex and in state and local government procurements.

Overall, the Energy Efficiency and Electricity Reliability Laboratory is planned to be a four-story structure of 26,000 to 29,000 gross square feet at an estimated cost of $19M. It will be built of braced steel frame construction, with retaining walls, grade beams on piles and slab on grade. It will include offices, laboratories, and high-bay space for the core research program, including a program for students and visiting investigators from industry and universities. Laboratories of the following types will potentially be included:

- Lighting systems laboratory
- Window systems laboratory
- Ventilation systems laboratory

- Air quality laboratory
- Building simulation laboratory
- Commissioning and diagnostics laboratory
- Appliance and component testing laboratories
- Indoor environmental conditions laboratory
- Battery and fuel cell laboratory
- Combustion laboratory
- Sensors and controls for industry
- Thin film deposition for large-scale coating applications laboratory

The laboratory building will showcase a variety of new environmentally responsive design practices and technologies that can be replicated widely throughout the DOE Laboratory system, and then adopted by other market segments. The building will include a range of proven design products and systems and will selectively utilize emerging technologies and prototypes that are not widely available. State-of-the-art energy simulation tools will be used to develop and implement a building design that uses less than half of the purchased energy of conventional buildings, with a large fraction of the remaining energy needs met with on-site renewable sources such as photovoltaics and generators such as fuel cells. The design will be tuned to take advantage of the local climate, with a special emphasis on daylighting and natural ventilation. Building materials will be selected using life-cycle assessment tools to minimize adverse impacts of materials production and use.

The laboratory building will be operated and controlled with self-diagnosing environmental control systems that optimize energy performance while enhancing the quality of the indoor environment for occupants. An intelligent communications infrastructure extending to all experimental and office spaces will support intra-lab and inter-lab scientific collaboration, as well as partnerships with remote collaborators from the public and private sector. Advanced controls will facilitate intelligent management of building electric loads. This will be done in a manner that allows full building operation with lower peak demand during high-demand summer peak periods. It will also use an advanced interface with the California regional power grid to make the building responsive to price signals and emergency power curtailment requests from system operators. It is anticipated that the building will be in the top 1% of equivalent buildings in terms of energy efficiency and healthy, comfortable working environments.

Energy Efficiency and Electricity Reliability Laboratory
Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Construction	0.0	0.0	2.8	19.7	0.5	0.0	23.0

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

OFFICE OF FOSSIL ENERGY

Carbon Sequestration

Carbon sequestration, the long-term capture and storage of carbon, is one part of an overall strategy to reduce the buildup of carbon dioxide, 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 carbon dioxide 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 demand study.

Berkeley Lab, on behalf of DOE's Fossil Energy program, has 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 carbon dioxide in depleted oil and gas reservoirs, brine formations, and coalbeds. The current program is to conduct and manage a set of targeted, interrelated, applied research and development tasks that will:

- Lower the cost of sequestration by developing optimization methods for sequestration technologies with collateral economic benefits.
- Lower the cost of sequestration by optimizing trade-offs among the costs of carbon dioxide separation, compression, transportation, and geologic sequestration alternatives.
- Help developers to select sequestration sites by providing reliable information about the location and capacity of suitable geologic formations.
- Increase the effectiveness and safety of geologic sequestration by demonstrating cost-effective and innovative monitoring technologies.
- Enhance methods to predict and verify that long-term sequestration is safe and effective.
- Identify and pursue early opportunities to apply these technologies in pilot tests to facilitate near-term market penetration and commercial application.

The new DOE Center for Research on Ocean Carbon Sequestration (DOCS), a joint Berkeley Lab/Livermore Lab project supported through the DOE Office of Biological and Environmental Research, also pursues fundamental research on ocean sequestration including the assessment of the effectiveness and consequences of ocean fertilization and carbon dioxide 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. This Center also works closely with other aspects of Berkeley Lab's research in carbon science as noted above in the Carbon Science Initiative.

Berkeley Lab has special expertise in addressing the scientific questions related to terrestrial and geologic sequestration of carbon dioxide. Complementing our partnerships with the joint DOE Center on Terrestrial Carbon Sequestration (at Oak Ridge, Pacific Northwest, and Argonne National Laboratories), Berkeley Lab's program will focus on gaining a fundamental understanding of the carbon cycle, and management to enhance carbon removal storage in plant matter and agricultural soils. One of the main thrusts of the Laboratory's terrestrial carbon sequestration will be to use advanced isotopic and experimental techniques to determine the capacity for long-term storage of organic carbon in soils, and how storage capacity may be affected—increased or decreased—by agricultural and forestry practices, land use, and climate change.

For the study of geological sequestration, the Laboratory's earth science expertise will be important to address issues such as storage capacity, chemical reactions, and monitoring related to the storage of carbon dioxide—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	2006	Total
Operating	0.9	1.0	1.1	1.1	1.1	1.1	6.3

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Codes AA, KP) and Work For Others: NASA.

WORK FOR OTHERS

Genomes to Life: Computational Capabilities

The ambitious scope of the DOE/OBER Genomes to Life program establishes a research framework that encompasses Berkeley Lab initiatives that are directed toward the Genomes to Life program goals but are funded by other agencies. This is particularly true in the areas of computational biology and the development of advanced computational techniques for high-throughput structural determination. Opportunities will be sought to leverage developments in these National Institutes of Health (NIH)- and the Defense Advanced Research Projects Agency (DARPA)-funded research programs to address DOE mission needs in human susceptibility, bioremediation, biomass conversion, carbon sequestration, and chemical and biological nonproliferation.

For DARPA, Berkeley Lab has proposed the design and development of a Network Bioinformatics System of biological knowledge and software tools that together can be used to rapidly prototype and refine models of cellular systems. Biological knowledge will be delivered in the form of data and validated models. The software tools will be able to extract network information from data, create models at different resolutions and levels of abstraction, and perform model-to-data comparisons.

The Network Bioinformatics System will be driven by a suite of representative biological problems that (a) have significant relevance to DARPA interests, (b) span biological problems that are sufficiently wide-ranging to ensure that whatever model kernels are developed will be flexible enough to apply to any cellular system, and (c) are diverse with regard to the amount of information available about them so models applied to the problems will necessarily represent different levels of abstraction. Models for each biological problem, or target system, will be developed from the data collected and will be validated against follow-on experiments.

The collaborators on this proposal—from UC Berkeley, Stanford, Columbia, Harvard, Johns Hopkins, Caltech, NASA's Jet Propulsion Laboratory JPL, SRI, and CFDRD, Inc.—form a tightly integrated team of biologists, engineers, computer scientists, and mathematicians.

Genomes to Life: Computational Capabilities to Understand and Predict Complex Biological Systems Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	6.7	5.5	5.8	5.9	6.1	30.0

*Preliminary estimate of Berkeley Lab Budget Authority and Work for Others: DARPA

For NIH, Berkeley Lab is developing a new system for automated high-throughput crystallographic structure determination. For structural genomics to be successful, macromolecular structures will need to be solved at rates significantly faster than at present. The need for extensive manual intervention in macromolecular x-ray crystallography at present leads to two major problems: significant bottlenecks that impede rapid structure solution, and the introduction of errors due to subjective interpretation of the data. The new software system, named PHENIX (Python Hierarchical ENvironment for Integrated Xtallography), will permit all tasks required for the computation of phases, automated map interpretation, and model building and refinement, to be integrated with newly developed procedures for automated decision-making. Our ultimate goal is the creation of a system that will take x-ray diffraction data and rapidly produce minimally biased atomic coordinates with little or no human intervention.

The PHENIX system is being built on a strong foundation that can accommodate the current plans and future developments. A toolkit will be developed to provide an environment for integrating the implementation of crystallographic tasks and automated decision-making. The framework for the toolkit will be the Python system (Lutz & Ascher, 1999), which provides a powerful object-oriented scripting language. A fundamental feature of the toolkit is that the entire history of the structure solution, along with all the structural information generated, will be stored in an object-oriented database. This design allows the various tasks involved in the structure solution process to communicate information exclusively via the database. Complicated interfaces for the communication between tasks are avoided and new ideas can be rapidly implemented and tested. This approach will facilitate the incorporation and mutual exchange of new algorithms developed by different groups.

Berkeley Lab's PHENIX program includes collaborators at Los Alamos National Laboratory, Texas A&M University, and Cambridge University.

Genomes to Life: PHENIX Automated X-Ray Crystallography Structure Solution System Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	1.5	1.4	1.4	1.4	1.5	7.2

*Preliminary estimate of Berkeley Lab Budget Authority and Work for Others: NIH

Berkeley Lab has also proposed to develop computational technology for electron microscopy that will make it possible to determine high-resolution density maps, similar to those already obtained with two-dimensional crystals, but (1) to do so from electron microscopy images of large, macromolecular particles, and (2) to do so at a high rate of throughput. The advent of affordable, highly parallel computers and ever increasing processor speed brings the computational task into the realm of what can be done within a realistic amount of time. This research effort will develop versions of single-particle software that take full advantage of modern, highly parallel machine architectures.

In developing optimized software for this task, we plan to first implement pilot versions of desired code on multiprocessor clusters that are based on commodity PC hardware. This will establish the number of processor-element hours needed to routinely complete high-resolution reconstructions with very large data sets. We will also characterize the cost-benefit ratio involved in the choice between shared-memory vs. distributed-memory machine-architectures. This will provide an empirical baseline from which to project the ideal size of machine needed for high-throughput cryo-Electron Microscopy (EM) research. The ultimate goal is to develop the computational technology that will improve both resolution and throughput when calculations are run on machines that are affordable (a) for individual laboratories, (b) as shared instrumentation, or (c) as dedicated machines run for the community as multi-user facilities.

This research program does not attempt to solve all problems that currently exist regarding the computational technology needed for single-particle cryo-EM. Our main focus is to address the problems that we believe most limit the current speed and throughput with which high-resolution structures can be produced: the need for highly parallel computation, optimization of algorithms, automation of particle boxing, and optimal determination of particle-alignment parameters. Results of this effort will readily accommodate solutions to additional tasks that are produced by the field as a whole.

Genomes to Life: Parallel Computation for Single-Particle Electron Crystallography Resource Requirements ($M)*

Category	2001	2002	2003	2004	2005	2006	Total
Operating	0.0	1.6	1.4	1.5	1.5	1.5	7.5

*Preliminary estimate of Berkeley Lab Budget Authority and Work for Others: NIH

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 UC 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 currently of 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 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	2002	2003	2004	2005	2006	Total
Operating	2.5	3.0	3.5	3.5	3.5	16.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Codes KP, FE, EE) and Work for Others: EPA

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 Lab 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 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 Workforce Diversity will ensure awareness of career opportunities at the Laboratory. Greater numbers of ethnic minorities underrepresented in science and engineering careers will participate in the current undergraduate programs. Partnerships with California Community Colleges exist and will be expanded. The Department of Energy supports the Preservice Teacher Program for undergraduates planning to teach science, mathematics, and technology at the secondary level. Partnerships with state colleges and universities will be expanded to provide these students with research experience in areas related to their major. Partnerships with career academies in local school districts will provide high school and middle school students with enriched opportunities for after-school courses and tours to strengthen their preparation for college or technical careers. These education experiences will be models for quality science instruction by and for local science teachers. Berkeley Lab will expand its education outreach to adult public science literacy through a Friends of Science campaign.

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	2002	2003	2004	2005	2006	Total
Operating	0.5	0.7	0.7	0.8	0.8	3.5
Work for Others	0.5	0.5	0.5	0.5	0.5	2.5

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

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 Berkeley Lab's performance. These systems directly support DOE's Strategic Plans and operating objectives. The material in this section describes the management and administrative systems plans that support Berkeley Lab's programs and are key to successful operations management.

ENVIRONMENT, SAFETY, AND HEALTH

Integrated Safety Management

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 public, and the protection of the environment are integrated into all of the Laboratory's work. 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 support 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 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 Environment, Health, and Safety (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 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 requires a world class Environment, Health, and Safety organization that works as a partner with the Laboratory's research and development divisions to provide cost-effective, customer-focused services that enable the creation of world class science. EH&S staff must have the same dedication, professionalism, integrity, and intellectual curiosity as the researchers who establish Berkeley Lab's scientific performance.*

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 the Laboratory's 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'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 Management

Berkeley Lab sustains a strong waste management, pollution prevention, and waste minimization program in support of DOE goals and regulatory 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 now supported by the Office of High Energy Physics as part of the stewardship infrastructure support for the Office of Science.

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 Lab has established procedures to ensure that there will be no discharge of materials into the environment above established standards.

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, as well as waste management operations. The Stewardship Committee brought together program representatives and Laboratory managers to address the operational and infrastructure needs of the Laboratory. These include waste management, pollution prevention, and waste minimization in support of DOE goals and compliance regulatory 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.

COMMUNICATIONS AND TRUST

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.

Community Relations and Public Information

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 Laboratory's strategic planning. This emphasis parallels 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 that completed a sampling plan in FY 2001, 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 use 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 activities is to consider and respond to the interests of specific groups, including elected officials, opinion leaders, city staff, site neighbors, and employees. Activities have included briefings for elected officials, attendance at local community meetings, sponsorship of meetings with the public, speakers at local events and organizations, as well as Berkeley Lab tours. In addition, through the National Environmental Policy Act and California Environmental Quality Act (NEPA/CEQA), and other federal and state regulations requiring public involvement, Berkeley Lab works with these stakeholders to disseminate information and solicit public input. This includes input into the preparation of major NEPA and CEQA environmental documents. 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. The campaign especially includes those local charities that are dedicated to educational causes.

Berkeley Lab will continue to promote two-way interactions between management and the workforce through training for Berkeley Lab leadership, increased opportunities for employee development and feedback, improved communication mechanisms and programs, and employee annual evaluations that will include recognition for community outreach or significant involvement. 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.

MANAGEMENT PRIORITIES

Human Resources

Effective human resources development 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, which provide the infrastructure to support the Laboratory's programs and research efforts.

The objectives of the Human Resources Department are to help make Berkeley Lab the location of choice for employees and guests; and to help create and support an environment in which all employees view themselves as part of a team. 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, and responsive customer service and effective management relations with 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 Workforce Diversity Office to support and develop work/life programs and to expand our efforts to create a climate in which diversity in the workforce is valued.

Berkeley Lab'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 2000)

Full & Part Time Employees	Total		PhD		MS/MA		BS/BA		Other	
Scientists*	829	(23%)	747	(90%)	42	(5%)	33	(4%)	7	(1%)
Faculty	259	(7%)	252	(97%)	4	(2%)		0%	3	(1%)
Professional*	518	(14%)	79	(15%)	154	(30%)	190	(37%)	95	(18%)
Executive	7	(<1%)	7	(100%)	-	-	-	-	-	-
Administrative	564	(16%)	23	(4%)	94	(17%)	193	(34%)	254	(45%)
Technical	930	(26%)	18	(2%)	105	(11%)	219	(24%)	588	(63%)
All Other	506	(14%)	16	(3%)	89	(18%)	215	(42%)	186	(37%)
Grand Total	3613	(100%)	1142	(32%)	488	(14%)	850	(24%)	1133	(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.

Workforce Diversity

Berkeley Lab recognizes that 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 twofold: to attract qualified, diverse candidates, particularly those who have been historically underrepresented; and to sustain a vibrant, diverse culture and an equal employment environment for all.

Today, "workforce diversity" is recognized at Berkeley Lab to represent 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 workplace diversity program. These are commitments to:

- Leadership accountability
- Employee career growth
- Communication as a means of unifying our community
- Managing diversity through Laboratory processes, procedures, and policies
- Measuring our efforts using "best practices" as our standard

The Lab uses these diversity principles to shape a number of important initiatives and action plans. Berkeley Lab's Workforce Diversity Office (WFDO), in partnership with senior management and the Human Resources Department, has undertaken the following initiatives:

- Proactively create and sustain an internal climate of equal opportunity for all through workforce development initiatives such as job growth opportunities through mentoring, job shadowing, and training; tuition reimbursement; employee recognition;b and improved communication on relevant issues and activities.
- Provide specific resources to help managers and supervisors implement the Laboratory's workplace diversity initiatives to ensure a working atmosphere that is supportive and gives a sense of belonging to employees from all cultures.
- Strengthen Berkeley Lab's outreach in the recruitment marketplace to help develop viable, sustainable, and diverse pools of qualified candidates 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.

The updated Workforce Diversity Office web site http://www.lbl.gov/Workplace/WFDO/ now includes a comprehensive listing of valuable resources such as Laboratory-sponsored multicultural events, outreach programs, workplace diversity tools and resources, and links to diversity training and classes. More importantly, the WFDO web site will be updated whenever necessary.

In FY 2000, Berkeley Lab instituted the following measures, resources, and training for the advancement of workplace diversity:

- **Workforce Diversity Action Plans.** Berkeley Lab is committed to building a community in which diversity is valued, cultural differences are respected, and individuals perceive fairness and equity across the board. Berkeley Lab's Workforce Diversity Action Plans reflect this commitment. They are organization, division, and department specific, and provide strategies and action to enhance the work environment for all employees and methods of outreach and recruitment to promote equality of opportunity. In accordance with its commitment to collaborative leadership, Berkeley Lab involves each division in workplace diversity planning. Each division has appointed a person to act as its point of contact for its specific diversity plan. The plans are available on the web at the Workforce Diversity Action Plan Web site: http://www.lbl.gov/Workplace/WFDAP/.
- **Workforce Diversity Workshop.** The "Valuing Workforce Diversity: Awareness & Accountability" workshop was attended by EH&S line management, as well as other selected Laboratory employees. The prototype workshop provided participants with the opportunity to discuss issues concerning diversity at Berkeley Lab, and to understand how creating a diverse workplace requires personal awareness and accountability at all levels. Laboratory-wide diversity workshops are forthcoming throughout the fiscal year.
- **Performance and Assessment Measures.** Diversity Leadership and Awareness has been added as an annual Performance Measure for the Laboratory. It will appear this year in Appendix F to Contract 98. It reads as follows: "Evaluation of senior management's effectiveness in increasing the awareness of diversity in all divisions of the Laboratory. The assessment will focus on the development and implementation of diversity plans and their innovative actions to enhance the work environment for all employees and to engage in proactive methods of diversity outreach and recruitment designed to promote equality of opportunity." Last year, a measure was added to annual performance evaluations of senior management that will assess their effectiveness in increasing the awareness of diversity in all divisions of the Laboratory.

Berkeley Lab's initiatives and action plans represent significant steps the Laboratory has taken toward a workplace of diversity, accountability, and open communication. Its prominence in the scientific community, its partnership with DOE, and its commitment to being an employer of choice require Berkeley Lab's leadership in workplace diversity.

Table V (2) Equal Employment Opportunity (FY 2000)

Federal Occupational Category	Total		Caucasian		Minority Total		Black		Hispanic		Asian/Pac. Isl.		Nat. Am.	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
OFFICIALS & MANAGERS	106	42	86	39	20	3	5	1	7	0	8	1	0	1
	71.62%	28.38%	58.11%	26.35%	13.51%	2.03%	3.38%	0.68%	4.73%	0.00%	5.41%	0.68%	0.00%	0.68%
Total male and female	148		125		23		6		7		9		1	
	100%		84.46%		15.54%		4.05%		4.73%		6.08%		0.68%	
PROFESSIONALS														
Scientists/Engineers	912	248	703	177	209	71	21	8	18	7	168	55	2	1
	78.62%	21.38%	60.60%	15.26%	18.02%	6.12%	1.81%	0.69%	1.55%	0.60%	14.48%	4.74%	0.17%	0.09%
Total male and female	1160		880		280		29		25		223		3	
	100%		75.86%		24.14%		2.50%		2.16%		19.22%		0.26%	
Management/Administrative	49	159	39	113	10	46	1	12	2	11	7	22	0	1
	23.56%	76.44%	18.75%	54.33%	4.81%	22.12%	0.48%	5.77%	0.96%	5.29%	3.37%	10.58%	0.00%	4.80%
Total male and female	208		152		56		13		13		29		1	
	100%		73.08%		26.92%		6.25%		6.25%		13.94%		0.48%	
TECHNICIANS	310	67	238	41	72	26	19	5	20	4	33	16	0	1
	82.23%	17.77%	63.13%	10.88%	19.10%	6.90%	5.04%	1.33%	5.31%	1.06%	8.75%	4.24%	0.00%	0.27%
Total male and female	377		279		98		24		24		49		1	
	100%		74.01%		25.99%		6.37%		6.37%		13.00%		0.27%	
CLERICAL	44	200	25	100	19	100	8	62	4	17	5	21	2	0
	18.03%	81.97%	10.25%	40.98%	7.79%	40.98%	3.28%	25.41%	1.64%	6.97%	2.05%	8.61%	0.82%	0.00%
Total male and female	244		125		119		70		21		26		2	
	100%		51.23%		48.77%		28.69%		8.61%		10.66%		0.82%	
CRAFTSMEN/LABORERS	125	1	90	1	35	0	12	0	14	0	7	0	2	0
	99.21%	0.79%	71.43%	0.79%	27.78%	0.00%	9.52%	0.00%	11.11%	0.00%	5.56%	0.00%	1.59%	0.00%
Total male and female	126		91		35		12		14		7		2	
	100%		72.22%		27.78%		9.52%		11.11%		5.56%		1.59%	
SVC. WORKERS/APPRENTICES	64	24	27	12	37	12	18	6	15	3	4	3	0	0
	72.73%	27.27%	30.68%	13.64%	42.05%	13.64%	20.45%	6.82%	17.05%	3.41%	4.55%	3.41%	0.00%	0.00%
Total male and female	88		39		49		24		18		7		0	
	100%		44.32%		55.68%		27.27%		20.45%		7.95%		0.00%	
Total All Categories	**2351**		**1691**		**660**		**178**		**122**		**350**		**10**	
	100%		**71.93%**		**28.07%**		**7.57%**		**5.19%**		**14.89%**		**0.43%**	

Figures are based on end of fiscal year 2000.

Security, Intelligence, and Nonproliferation

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. Consistent with the Lab's approach to integrated management of support operations, Berkeley Lab developed an Integrated Safeguards and Security Management (ISSM) program. The approach ensures the integration and coordination of all elements of security including physical, cyber, export control, information management, and related aspects.

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 designated 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 Stanford Linear Accelerator Center 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.

The Laboratory cybersecurity posture is described in its Cyber Security Protection Plan (CSPP). 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 65 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.

Berkeley Lab's cybersecurity 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 cybersecurity software is a powerful system for detecting network intruders and has served as a model for other laboratories.

Intellectual Property Management

Intellectual property is created in the course of research at Berkeley Lab, and is managed for the benefit of the DOE and Laboratory missions, and for the U.S. public under the applicable technology transfer statutes. Intellectual property includes patentable inventions, copyrightable works (e.g., software), and tangible research products and biological materials. Intellectual property disclosures are made to the Patent Department, and evaluated and transferred to the private sector by the Technology Transfer Department—typically under license, option, bailment, or similar agreements. As with most other national laboratories and research universities, Berkeley Lab's technologies tend to be nascent and require substantial development by a private sector company before commercial products are likely to emerge; therefore, protection and management of intellectual property is a key factor to successful commercialization and the realization of the benefit to the consumer. In FY 2000, Berkeley Lab reported 83 new inventions, filed 31 new U.S. patent applications and had 36 patents issued. A total of 42 new licenses and options were executed. These numbers are generally typical of those reported since the late 1990s.

Berkeley Lab has enhanced U.S. economic competitiveness through its technology transfer program, in part by fostering the creation of new companies based on Laboratory intellectual property. Just since 1990, Berkeley Lab licensed technology that formed the basis of 15 start-ups, creating over 500 new jobs in those companies alone. An FY 2000 Berkeley Lab-licensed start-up, Syrrx, Inc., has already positioned itself as a leader in the emerging commercial field of structural proteomics. Berkeley Lab's nanocrystallization robotics enables high-throughput protein crystallization, even for many proteins that previously were not readily susceptible to x-ray crystallography. Thus, Syrrx is able to rapidly generate protein structures from genetic information and then use these protein structures to identify drug candidates. This process enables a unique "gene to drug" platform based on the ability to perform high-throughput, rational drug discovery. Since Berkeley Lab licensed the start-up in January 2000, Syrrx has expanded to 50 employees in its first year.

Table V (3) Intellectual Property Management

Category	FY 1999	FY 2000	FY 2001 (est.)	FY 2002 (est.)	FY 2003 (est.)
Number of New Licenses*	51	42	50	50	50
License Income ($K)**	672	933	1,150	1,200	1,350
Software Disclosures	16	27	22	25	25
Invention Disclosures	95	83	83	85	85
U.S. Patent Applications***	34	31	25	30	35
U.S. Patents Issued	31	36	30	30	30

*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 2000 saw income from licensing ($933 K) grow approximately 39% in comparison to the FY 1999 figures, continuing a trend of substantial increases. 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 97 and Prior Disclosure (%)	FY 98 and Subsequent Disclosure (%)
Inventor Payments	42.5	35
Research and Development	42.5	65
Education	0	0
Office of Research and Technology Applications Administration	15	0

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

VI. INFRASTRUCTURE STRATEGIC PLANNING

A key DOE objective is to "provide leading research facilities and instrumentation to expand the frontiers of the natural sciences." Accordingly, Berkeley Lab's infrastructure planning and management are directed towards sustaining the Office of Science mission and this strategic objective. Mission performance is inextricably linked to the assets that house and facilitate this research—buildings and infrastructure that are dedicated to and operated for science.

Berkeley Lab is unique among the national multiprogram laboratories in that it is located in the center of one of the nation's premier research and development hubs. The physical presence of an Office of Science facility in this internationally recognized economic region provides unparalleled opportunities for scientific interactions and economic stimulation. Berkeley Lab is located in a wooded setting, immediately adjacent to a preeminent research university—an environment that is particularly conducive to concentrated scientific focus.

Research at Berkeley Lab is directly tied to a proactive building and utility maintenance program. Building and utility assets are managed so that researchers are able to obtain the maximum possible level of service from these assets. Although many assets are older, all usable buildings are fully and productively committed to the scientific mission. Research-driven space requirements are coupled with knowledge of maintenance requirements and limitations to form the basis of Berkeley Lab's infrastructure strategic planning.

In some cases, mission requirements are difficult to achieve in buildings with infrastructure systems designed to support laboratory practices of the 1940s and 1950s. Modern standards for cleanliness and temperature control, and expectations of micro-scale tolerances are particularly challenging in older buildings, yet much of the work now being performed demands such quality space. Building system upgrades are required in some buildings. In addition, some of the small older structures are not cost-effective to upgrade and need to be replaced in order to better address mission needs. In some cases, there is an additional benefit as these small World War II-era structures occupy prime sites, sites that can efficiently accommodate four- and five-story buildings. Increasing the user density at these prime locations will also improve overall operating and scientific efficiencies. Berkeley Lab expects to develop the site to:

- Stimulate and foster a collaborative, world-class scientific work environment that attracts and retains highly qualified professionals.
- Accommodate flexible, state-of-the-art facilities and infrastructure appropriate to Berkeley Lab's research roles for DOE.
- Support the growing user community at the Laboratory's scientific facilities.
- Promote its unique setting and outdoor spaces to maximize opportunities.
- Welcome users, visitors, and neighbors in an enabling, efficient, safe, and attractive manner.

The scientific drivers and buildings identified in Berkeley Lab's infrastructure planning 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 Sciences. 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 programmatic drivers and research facility needs that must be incorporated into the planning for Berkeley Lab and for DOE managers are summarized in this section.

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 1.76 million gross square feet (mgsf). In 2001, there were 111 buildings of conventional construction and 87 trailers and other structures at the main site. Additional space on the UC Berkeley campus includes 82,000 net square feet (nsf); and 290,000 gsf are located in leased buildings in the cities of Berkeley, Oakland, and Walnut Creek.

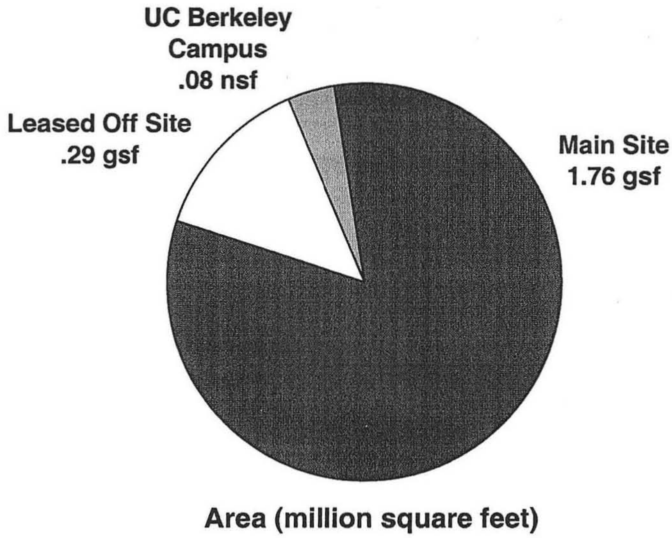


Figure VI (1) Laboratory Space Distribution

Berkeley Lab's scientific missions have changed since the first facilities were constructed on the current site for the 184-Inch Cyclotron and later 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's programs is shown below.

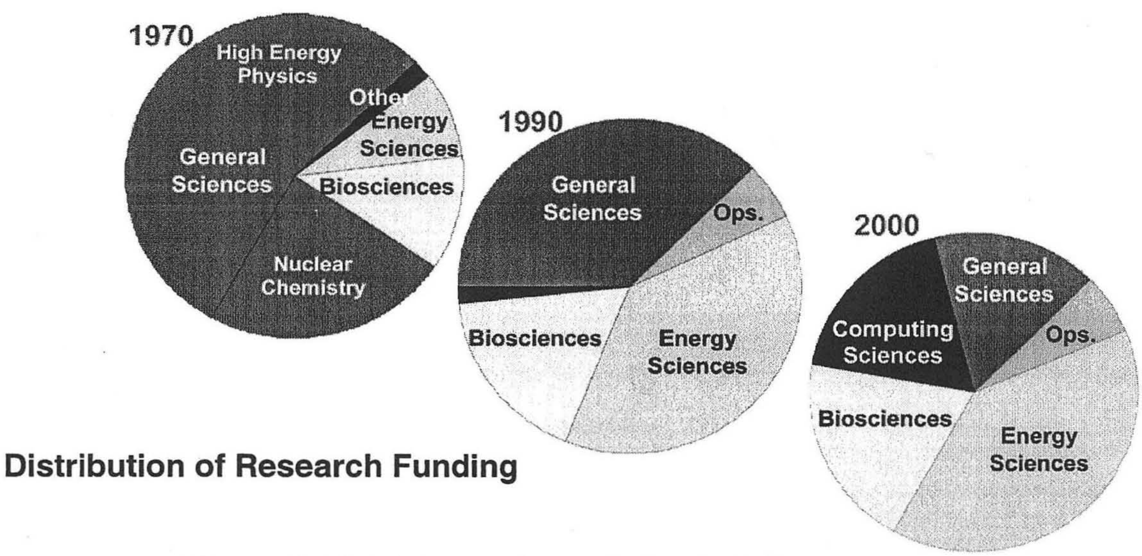


Figure VI (2) Change in Berkeley Lab Programmatic Areas

All usable space is fully committed to the scientific mission, and maintenance actions ensure that scientific needs are addressed. However, the World War II-era buildings are not matched to the current research programs. 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.

The Laboratory has four small buildings that are closed (condemned) pending demolition.

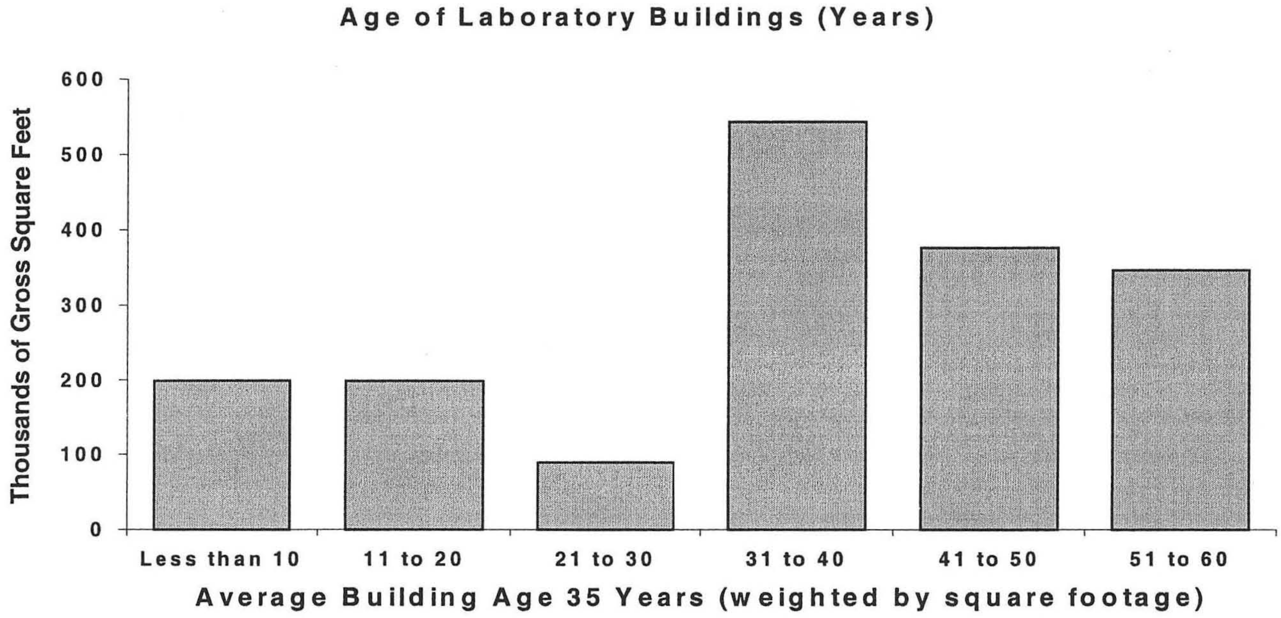


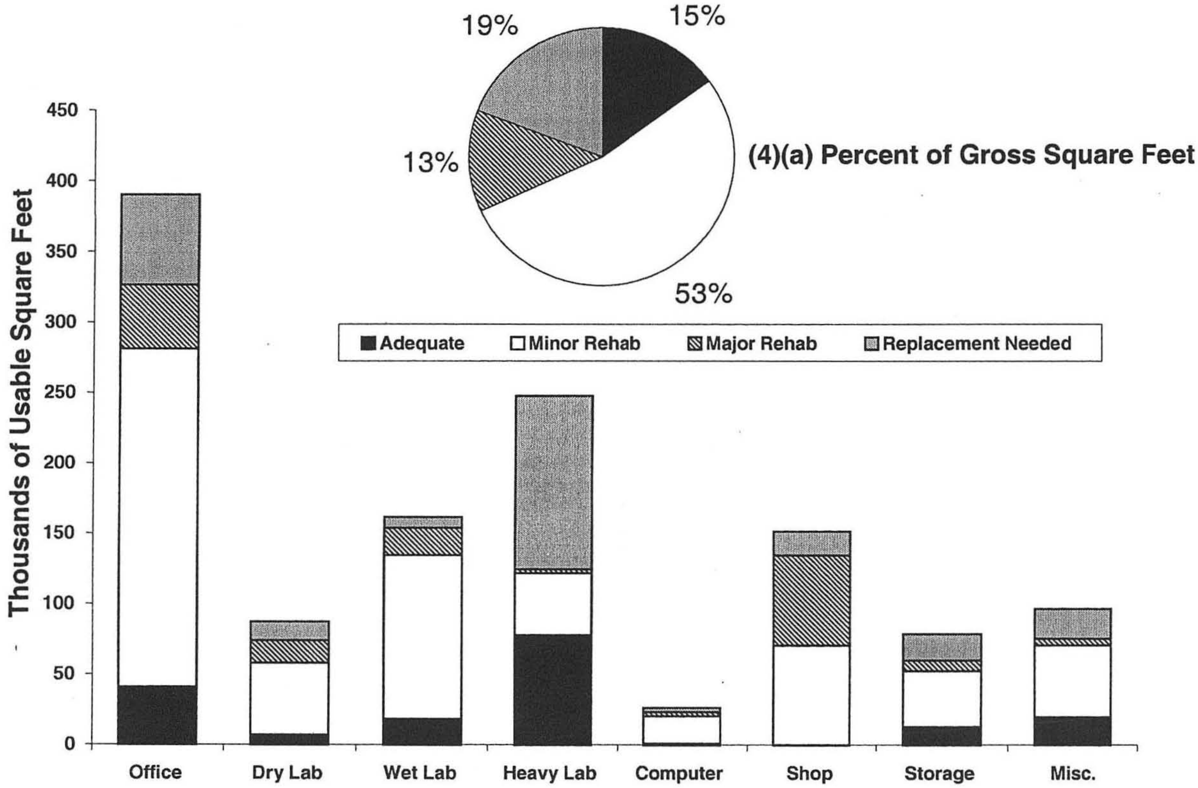
Figure VI (3) Age of Laboratory Buildings, Modulars, and Trailers

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 and the condemned buildings, all occupiable offices, laboratories, and support facilities at Berkeley Lab are 100 percent utilized.

The total replacement value of the facilities is $1091M, as reported in the Facilities Information Management System (FIMS), and the value of the equipment in the facilities is $480M. On an annual basis, the Laboratory invests $5M in non-capital projects in the buildings. The DOE Office of High Energy Physics has provided $3.5M for General Plant Projects. The Multiprogram Energy Laboratory Facilities Support (MELFS) Program 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).

Approximately 332,000 gross square feet (19%) of Berkeley Lab's space (at the main site) is substandard and in need of replacement. See Figure VI (4a). Existing research missions utilize much of this space, and much of it will remain 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. Evaluation of building condition and usability is based on categories utilized in the DOE Facilities Information Management Systems (FIMS) as of May 1, 2001.

Space is at a premium and capabilities must be increased in order to reduce overcrowding. Figure VI (4b), illustrates that 90% of computer space, 95% of wet lab space, and 85% of dry lab space are rated as functional (adequate, minor rehab needed, major rehab needed) in 2001. However, Berkeley Lab must continue to upgrade functional facilities that are not rated as adequate to ensure that they continue to meet researcher needs and all applicable health, safety, environmental, and performance standards.



(4) (b) Usable Square Feet

Figure VI (4) Use and Condition of Berkeley Lab Space

Guidelines for placing a facility into a particular category are as follows: Adequate = < 10% of Replacement Plant Value (RPV), Minor Rehab Needed = 10% to < 25% of RPV, Major Rehab Needed = 25% to <60% of RPV, Replacement Required = 60% or greater of RPV. Percentages are based on the total rehab and repair cost to a facility as a percentage of RPV. Normal operating/maintenance costs are not included.

BUILDINGS FOR DOE PROGRAMS (FY 2002-2006)

The critical scientific investments that advance the Laboratory's facilities stem from the value of the Laboratory's research to the DOE program offices. Berkeley Lab's facilities planning 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 planning 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 facilities planning. 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 programmatic building projects described below include only those that have received initial planning or project design and engineering funds.

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. The most immediate requirement is to meet the needs of advancing nanoscience, while addressing the needs of the ALS user community. To accomplish this, Berkeley Lab has proposed a Molecular Foundry.

Molecular Foundry

The Molecular Foundry is a Nanoscale Science Research Center (NSRC) under the Office of Basic Energy Sciences (BES), constituting a key resource for the Department of Energy's (DOE's) participation in the National Nanotechnology Initiative (NNI). The Molecular Foundry will conform with DOE guidance and address the research challenges described in the reports *Nanoscale Science, Engineering and Technology Research Directions* and *Complex Systems: Science for the 21st Century*. Its centerpiece will be a broad array of unique, state-of-the-art facilities in the design, synthesis, and characterization of nanostructures. These facilities, along with an associated scientific and technical staff, will be available for use by collaborators from academic, governmental, and industrial laboratories. Most collaborators will be from Western U.S. institutions, but many of the facilities will be unique nationally and will attract a national constituency. The Molecular Foundry will also serve to educate and train hundreds of undergraduate and graduate students and postdoctoral fellows from educational institutions throughout the West.

The Molecular Foundry's laboratories will be designed and constructed to facilitate collocation of research activities in a wide variety of fields as required for progress in this new area of science. It will support a broad research effort focusing primarily on the conjunction of "hard" (nanocrystals, tubes, and lithographically patterned structures) as well as "soft" nanometer-sized materials (polymers, dendrimers, DNA, proteins and whole cells). Its second major research focus will be the design, fabrication, and study of multicomponent, complex, functional assemblies of these hard and soft nanostructures.

By functioning as a portal to Berkeley Lab's established major user facilities, the Molecular Foundry will leverage existing nanoscience research capabilities at the Advanced Light Source, National Center for Electron Microscopy, and National Energy Research Scientific Computing Center. The research program will, as an additional benefit, provide significant educational and training opportunities for students and postdoctoral fellows of the first generation of nanoscientists. (See Section IV, Initiatives.)

High Energy and Nuclear Physics

Berkeley Lab works with the High Energy Physics Office as landlord and steward for the Laboratory's maintenance and scientific infrastructure. Among the most important needs is for more space through more effective utilization and for addressing the physical legacy of past programs. Of highest priority is to address the old Bevatron accelerator.

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 1993, the Bevatron has been largely abandoned by the Department of Energy, with no source of funds for its decontamination and demolition. A key element of the facilities planning is the demolition of the Bevatron facility so that the space can be utilized productively. 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.

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.

Energy Efficiency and Electricity Reliability Laboratory

The Energy Efficiency and Electricity Reliability Laboratory will feature an information technology infrastructure to support a variety of "research collaboratory" processes that will allow virtual project teams in geographically diverse locations to work together effectively. Active research partnerships will be developed with other national laboratories, with academic and state research and development groups, and with the private sector. By designating selected portions of the building as a "living laboratory" the researchers themselves will participate in testing, measuring, and helping our industry partners to refine emerging technologies that are not yet commercially available or in widespread use. While there is risk in such projects, there is also an enormous potential to speed the development and optimization of new technologies and systems by direct involvement of Berkeley Lab staff, in collaboration with teams of visiting or remotely based researchers. It is anticipated that the building will be a model and test-bed in terms of energy efficiency and healthy, comfortable working environments.

The Energy Efficiency and Electricity Reliability Laboratory will provide a regional and national center for research and development partnerships and the infrastructure needed to advance the state of the art in building science nationally. The facility will provide offices and laboratories to investigate, test, monitor, and demonstrate new building technologies and design processes in partnership with industry. (See Section IV, Initiatives.)

SCIENCE LAB INFRASTRUCTURE 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 are important elements of Berkeley Lab's plan.

Building 77—Rehabilitation of Building Structure and Systems, Phase 2

This project is the second phase of a two-phase project intended to fully rehabilitate Building 77 and 77A as high-precision fabrication, testing, and assembly facilities. Phase 1, funded in 1999, will correct structural deficiencies in Building 77. Phase 2 will rehabilitate mechanical, electrical, and architectural deficiencies in Buildings 77 and 77A. These two buildings are the center of the Laboratory's engineering support functions. These large structures contain 78,500 gsf of engineering high-bay. Specialized capabilities include numerically controlled precision machining, structural and precision welding of both common and exotic metals, sheet metal fabrication, metal sandblasting and painting, ultra-high-vacuum cleaning and testing, ceramics, machine tool repair, and large-apparatus precision assembly. These capabilities are in high demand within the DOE research and development community, and are not readily available from commercial vendors. Consequently, the buildings currently operate at capacity, and double shifts are necessary to handle the workload. Recent projects have served the needs of the Office of High Energy and Nuclear Physics, the Office of Health and Environmental Research, the National Institutes of Health, and the Office of Basic Energy Sciences. The estimated cost is $13.36M

Research Support Building

The Research Support 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. 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 in very poor condition; three have also been condemned and vacated. This project will demolish all five of these poor structures. 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. This 34,500 gsf building will house ~80 people from a variety of essential research support functions including Library Services, the Center for Science and Engineering Education, Technology Transfer, Internal Audit, the Patent Department, and the Technical and Electronic Information Department. Relocation of these functions from existing research buildings will free up ~ 20,000 gsf of research space and result in operational cost savings, efficient management, and improved access for staff and guest researchers. The estimated cost is $15.0M.

Building 74—Rehabilitation of Building Operating Systems

Building 74 is a major research laboratory facility that has safety and operational problems with its emergency egress, seismic stability, and mechanical and electrical systems. These deficiencies also limit research capabilities. This project will address the problems and update the 40-year old building operating systems to meet modern research laboratory standards.

Building 74 is a three-story structure originally constructed in 1960 as an animal holding facility. Since then it has undergone four additions and a series of modifications that together have converted 23,000 gsf of the original 35,000 gsf to research laboratories, and increased the total area to 43,430 gsf.

This project will provide modifications needed to rehabilitate Building 74's inadequate infrastructure systems, including mechanical, electrical, structural, and architectural systems. The building will be improved to withstand lateral forces that can reasonably be expected in an earthquake. In increasing the reliability and maintainability of building systems and improving their efficiency, these upgrades will extend the life of the structure by 40 years ensuring continued support of DOE's scientific mission for the foreseeable future and providing the flexibility to meet future programmatic challenges. The estimated cost is $9.0M

Building 62—Upgrade of Building Operating Systems

Building 62 is a key research laboratory facility with seismic stability problems and mechanical, low-conductivity water, electrical capacity and exiting deficiencies that restrict research. This project will upgrade the 40-year old building systems to comply with fire and building codes and to support modern research requirements.

Building 62 is a three-story (55,265 gsf) multipurpose laboratory building. This building was constructed in 1962. This major research facility contains laboratories used by researchers in the materials, chemical, energy, and life sciences. This project will address architectural deficiencies in the exit corridors, stairways, doors, and emergency lighting; install modern fume hoods and exhaust capabilities; and upgrade the low-conductivity water system, mechanical systems, control systems and electrical system to extend the productive life of this structure by 40 years. Moreover, the wet laboratories, clean rooms, and other research facilities will be upgraded such that they provide flexibility in use and can be readily adapted to meet the needs of researchers in a full range of disciplines. The estimated cost is $9.3M

Operations Building

An Operations Building is a high priority in this planning 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 for necessary 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 between Buildings 75 and 76. The 25,000 gsf facility has an estimated cost of $13.5M.

Engineering Support Facility

This project will construct a 19,000 gsf addition to Berkeley Lab's primary engineering support center at Buildings 77 and 77A. This engineering center provides engineering services 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 $15.3M.

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 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 $20.2M.

Environmental, Health, and Safety 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 $16.4M.

Third-Party Building Project

In conjunction with the University of California Office of the President, the Laboratory has recently participated in an assessment of third-party funding options for the construction of new buildings. For the last several decades, the Laboratory has experienced steady growth in its research programs. Despite federal investments by the Department of Energy—especially the Office of Basic Energy Sciences and the Office of Biological and Environmental Research—in modern laboratory and office facilities, the University continues to operate Berkeley Lab with considerable outdated and overcrowded research and office space. While the University's third-party project will not address the overall problem, it can relieve some of the pressures.

A possible building site has been selected, and an architectural program developed, for a 50,000 to 60,000 gsf office building. The proposed building site is an undeveloped slope located just inside the main entrance to the Laboratory. The expected useful life of the building is 40 years. All basic site utilities exist in proximity to the site. If plans move forward, following a University Ground Lease to a developer, it is anticipated that the developer will design, finance, construct and operate the administrative and research-related office space on the most cost-effective basis. It is projected that a Request for Qualifications of such a developer will be issued by the University in FY 2002. Pending identification of an actual name, this project is designated Building 50X.

Energy Utility Infrastructure Projects

The Laboratory continues to operate an aggressive program aimed at managing utility costs in a responsible manner. The Facilities Department has managed the investment of over $18 million dollars of Laboratory, utility, third-party and Federal Energy Management Program (FEMP) funds to achieve a high degree of energy efficiency. Moreover, this Facilities program works closely with DOE to identify lower cost energy providers and ensure reliable energy supply services. In FY 2001, the average cost of electricity to the researcher was 7.3 cents per kilowatt-hour at the main hill site—attractive relative to the regional and national averages. The Laboratory is currently investigating options, including photovoltaics and hybrid cogeneration, which might allow it to cost-effectively reduce peak electrical demand.

The Laboratory has also ensured that the researchers will not be subject to the rolling blackouts that some predict will hit California in calendar year 2002. The Laboratory has installed a two-megawatt standby generator in order to participate in the local utility's Optional Binding Mandatory Curtailment

(OBMC) program. Under the OBMC program, the Laboratory will operate this generator rather than curtailing power use during rolling blackouts.

The Laboratory will continue to seek opportunities to improve its physical plant and reduce operating costs while also providing reliable service to the research community.

INFORMATION TECHNOLOGIES INFRASTRUCTURE

The vision of network support for Berkeley Lab in the next ten years calls for substantially enhanced performance parameters and capabilities. Networking will move beyond "transport" to include a broad range of services. Increases in performance demand have been readily measured at 100% per year over the past several years, and over a ten-year extrapolation translates to a conservative growth factor of 1,000. Whereas Berkeley Lab is now deploying 100 megabytes-per-second to 1 gigabyte-per-second switched infrastructure today, growth to equivalent performance levels of 100 gigabytes-per-second to 1 terabyte-per-second over a ten-year timeframe can be anticipated. Additionally, it can be expected that the range of components and systems that will be "network smart" will increase dramatically, resulting in the need to attach end-systems numbering in the hundreds of thousands to millions for a laboratory facility such as Berkeley Lab.

Beyond simple extrapolation of performance and connectivity, it can be expected that network services capability will be greatly expanded. The network will become the research infrastructure backbone interconnecting scientific resources and researchers on a global basis. Researchers will work in a "virtual laboratory"—their geographic location will be largely irrelevant. Research activities will include remote interactions involving massive distributed computing resources, experimental facilities, support services, and communications systems. The impact on laboratory infrastructure will be significant. Substantial wireless technology will be necessary to support the anticipated conversion to that technology and the anticipated significant growth in end-systems connected to LBLnet. High-end performance networks will remain "wired" and will probably require significant upgrade of fiber-optic facilities. The computers, storage, and network equipment required to implement this Laboratory computing initiative is expected to cost in the neighborhood of $40M (General Purpose Equipment). Ongoing costs of $600K per year for network improvements are anticipated.

INTEGRATED PLANNING PRIORITIES

The Laboratory has established initial priorities for the identified projects. These priorities are reflected in the proposed schedule of projects shown in the Major 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 research and development 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 VI (5). The replacement of single or two story buildings with multistory buildings improves site efficiency, access and circulation, environmental quality, and emergency response.

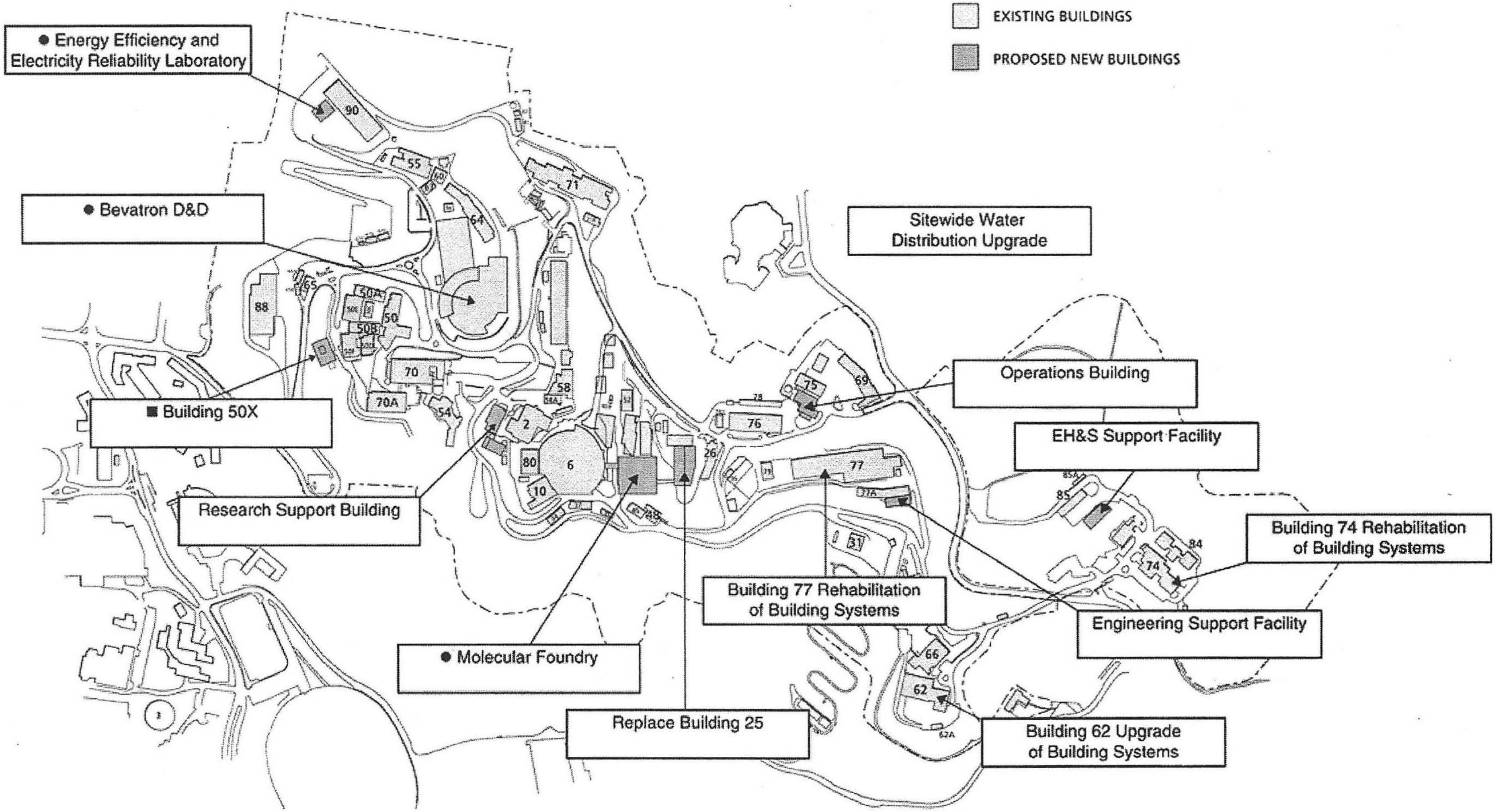


Figure VI (5) Map of Science Line Infrastructure (SLI) and Programmatic Line item construction projects, Bevatron D&D, as identified in Table VI (1). Programmatic projects are designated with a dot (•) in the title block. Note: This map shows the proposed site of a possible building to be financed and constructed by a "third party". This building, currently designated 50X pending the identification of an actual name, is designated with a (■) in the title block.

Table VI (1) Major Construction Projects (FY 2002-2006)

($ in M)	TEC	2002	2003	2004	2005	2006	2007	2008
Funded Program Related Projects								
None								
Funded Science Lab Infastructure (SLI) Projects (KG):								
Sitewide Water Distribution Upgrade, Phase 1 (FY 2001 start)	8.30	4.40	2.90					
Budgeted Science Lab Infastructure (SLI) Projects (KG)								
None								
Proposed Program -Related Projects *								
The Molecular Foundry (BES)	85.00	1.50	13.00	61.25	5.35	3.90		
Energy Efficiency and Electricity Reliability Laboratory (EE)	23.00		2.75	19.75	0.50			
Total Proposed Program-Related Projects	108.00	1.50	15.75	81.00	5.85	3.90	0.00	0.00
Proposed Science Lab Infastructure (SLI) Projects:								
Building 77- Rehabilitation of Building Structure & Systems, Phs 2	13.36		1.10	11.29	0.97			
Research Support Building **	15.00			2.00	12.50	0.50		
Building 74 - Rehabilitation of Building Operating Systems **	9.00			1.10	7.60	0.30		
Building 62 - Upgrade of Building Operating Systems **	9.30				1.10	7.40	0.80	
Operations Building	13.50				1.60	11.20	0.70	
Engineering Support Facility	15.30					1.50	1.70	11.40
Replace Building 25 (Seismic Stability)	20.20					1.50	1.70	15.80
Environmental, Health, and Safety Support Facility	16.40						1.50	1.70
Total Proposed SLI Projects	112.06	0.00	1.10	14.39	23.77	22.40	6.40	28.90
Proposed Operating Funding Needed for Removal of Retired Facilities:								
Bevatron Decontamination and Demolition ** ***	70.00	1.00	2.00	4.00	4.00	4.00	4.00	4.00
Total Proposed Special Operating Fund Projects	70.00	1.00	2.00	4.00	4.00	4.00	4.00	4.00

Footnotes:

Does not include "third-party" building projects that are being considered.

* *Includes only program-related buildings that have received DOE planning or construction funds.*

** *Project scope is being reviewed and TEC may change.*

*** *Berkeley Lab to provide matching funds ($1M in FY 2002 and $2M in FY 2003).*

VII. SUMMARY OF MAJOR ISSUES

This Summary of Major Issues Section is included in the Institutional Plan as background information on institutional issues addressed at the Berkeley Lab DOE Institutional Planning On-Site Review. Berkeley Lab issues are addressed regularly 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. However, a number of issues relate to DOE management activities that are being implemented outside of the Office of Science line management organization or the Oakland Operations Office, such as counterintelligence and aspects of safety management. Other issues arise from the difficulties in establishing priorities for a legacy of limited capital investment.

Issues not addressed in this section are the programmatic priorities for Berkeley Lab, which are described in Sections I through IV. Institutional issues that need to be addressed are discussed below.

BEVATRON DECONTAMINATION AND DEMOLITION

The Bevatron was constructed as a 6 GeV proton accelerator in 1954 and became a workhorse for the Office of Science during an illustrious scientific career. The Bevatron was the site for the discovery of the antiproton in 1956, for the particle reasonances in the early 1960s and, combined with the Super HILAC, for the founding of the fields of relativistic heavy ion physics and heavy ion radiotherapy in the 1970s and 1980s. Since its decommissioning in 1993, it has largely been abandoned by the Office of Science, sitting as a cement and steel sarcophagus. It is located in the most central part of Berkeley Lab on scientifically valuable property under the Office of Science jurisdiction. The accelerator is 180 feet in diameter, consisting of 20,000 tons of concrete shielding blocks and 11,000 tons of steel and nonferrous metals. The buildings make up about 10 percent of the total building space on the Berkeley Lab site.

The Laboratory has prepared analysis of the cost to decontaminate and demolish the Bevatron. Depending largely on materials disposal and site remediation assumptions, the total facility project cost is approximately 60 to 85 million dollars to restore a greenfield site. Last year, the Laboratory provided information to the Office of Science to advance towards a CD-zero decision. The issue of Bevatron decontamination and demolition (D&D) has been a critically important issue during past On-Site Reviews, for Landlord Activity Reviews, and for a number of stewardship and management meetings. The Laboratory believes it is time to establish and implement a viable D&D plan.

NEW BUILDINGS FOR DOE MISSIONS

The construction of new research and office buildings is critical to achieving the Laboratory's science mission. The buildings included in Berkeley Lab's strategic facilities planning are based on scientific drivers for DOE missions. In a number of instances, without new scientific investments that advance the research frontier, many of the existing unsatisfactory and decaying buildings threaten the scientific contributions to the program offices.

Several key proposed buildings highlight this need. The Molecular Foundry (described in Sections IV and VI) is a programmatic building that supports the national priorities in nanoscience and is being considered for construction on the basis of merit review within a framework of priorities established by the Office of Science and the Office of Basic Energy Sciences. Two critical buildings are being considered by the Multiprogram Energy Laboratories Facilities Support program—a Research Support Facility that replaces a condemned building, and an Operations Facility that consolidates and provides adequate space for Berkeley Lab's operations groups. An Energy Efficiency and Electric Reliability Laboratory is being considered by the Office of Energy Efficiency and Renewable Energy to house forefront programs in buildings, residential, and industrial efficiency research and in electric supply reliability, and is important to gain economic and national energy security. Berkeley Lab, with the University of California Office of the President, is also exploring third-party financing of office space. The Laboratory believes that a range of options must be pursued to address the need for new buildings, both to replace condemned buildings and to provide additional space.

ADEQUATE RESOURCES FOR MAINTAINING INFRASTRUCTURE

Infrastructure investments at Berkeley Lab are essential to maintain and rehabilitate buildings, utility systems, roads, and parking. At Berkeley Lab, more than 70% of the current government-owned space was constructed before 1970, when the Laboratory was a single-purpose Atomic Energy Commission facility. The average building age is 35 years, and of the 1.7 million square feet of existing building space, approximately 331,000 square feet of space is in need of replacement.

With Berkeley Lab's landlord—the High Energy and Nuclear Physics Program and Stewardship Committee—we are working to address the general infrastructure needs of the Laboratory. Central to this issue is securing the necessary infrastructure investments to sustain efficient, safe, and cost-effective operational requirements. General Plant Project funding, General Purpose Equipment, and Multiprogram Energy Laboratories Facility Support have been essential to address vital requirements, but the level of resources has been inadequate to meet existing needs. Increased support or new approaches to funding infrastructure are needed to meet critical needs, including replacement of existing abandoned structures, upgrading utilities, and rehabilitating building systems. Further information on this important topic is provided in Section VI, which addresses "Infrastructure Strategic Planning."

COUNTERINTELLIGENCE AND SECURITY FOR A TIER III LABORATORY

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 Office of Science mission and operational requirements. Berkeley Lab has been working with DOE's Office of Science and Berkeley Site Office to assure that effective and well-tailored security measures are provided for Tier III laboratories, all of which have no classified information and serve the nation's scientific community. The Laboratory has provided briefings and information on this topic to the germane Office of Science and DOE support offices, the Laboratory Operations Board, and the Commission on Science and Security, as examples. Berkeley Lab is fully committed to an effective security program that is commensurate and aligned with its Office of Science mission as a Tier III Laboratory. Berkeley Lab management seeks to reinforce effective line management and to be held accountable for security performance that is aligned with security risks. Further information on Berkeley Lab's security programs is included in Section V.

RECOMMITMENT TO INTEGRATED SAFETY MANAGEMENT

Berkeley Lab commits itself to perform all work safely, with the highest degree of protection for employees, participating guests, visitors, the public, and the environment. The Laboratory integrates safety practices with the conduct of all work to fully address the risks and scale of each activity. Every division has prepared and implements an Integrated Safety Management Plan.

Because the principles of Integrated Safety Management apply to all work, the specific implementation of safety practices can be tailored to the complexity of the work and the severity of the hazards and environmental risks. A recent DOE Environment, Safety, and Health Office (ES&H) "scoping visit," however, has framed an upcoming inspection in terms of compliance-based procedures, essentially returning to a system that is more costly, distracts from actual risks, and has no demonstrated performance benefits. A second ES&H thrust is that of requiring a "one size fits all" Environmental Management System (EMS) such as ISO 14000 to improve performance despite the fact that the Laboratory's environment, health, and safety record has improved greatly under the principles and practices of Integrated Safety Management as compared to the former compliance-based program. The Laboratory seeks to work with the Office of Science and the Environment, Safety, and Health Office for a recommitment to, and a sustained implementation of, Integrated Safety Management.

The Laboratory's Integrated Safety Management program and performance-based management have resulted in continuous improvement or sustained excellence in the quality of Environment, Health, and Safety efforts. The Laboratory has demonstrated further 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 continuous improvement in environmental control programs that will maintain environmental releases as low as reasonably achievable.

LABORATORY ENERGY SUPPLY AND COST

Berkeley Lab's main facilities are currently exempt from rotating outages in Pacific Gas and Electric Company (PG&E)'s electricity transmission and distribution system. However, the Laboratory's exemption may be lifted at any time. If the Laboratory becomes non-exempt, it intends to apply for an alternative PG&E program that will provide for continuous electricity delivery, but would require curtailment of up to 15% of the Laboratory electricity demand during every outage event. The Laboratory has received a Bay Area Air Quality Management District authority to construct and permit to operate a two-megawatt generator, which, combined with energy conservation measures, will effect the load reductions required. Documentation that the generator project complies with the California Environmental Quality Act and the National Environmental Policy Act has been approved. In addition, emergency preparedness plans are in place defining action steps to be implemented in the event of power outages for any reason, such as a grid failure.

Electrical power costs to the Laboratory are expected to increase in fiscal year 2002. However, the impact of the cost increases to programs located at the main site may be moderated because the current recharge rate has been set at a level to include funding for infrastructure reliability and energy conservation projects. The Grizzly Substation upgrade project will be completed this year, and Laboratory management may decide to defer other projects, so that next year's recharge rates can absorb some of the cost increases.

The Laboratory's natural gas is purchased through the Defense Energy Support Center and transported by PG&E. During winter peak-usage periods, there will be a threat to the reliable supply of natural gas to the Laboratory. If PG&E's supplies run short, they will be allowed to divert gas from non-core customers, such as Berkeley Lab, to their core customers, typically hospitals and residences. Costs have recently more than doubled, increasing the Laboratory bill from approximately $750K in FY 2000 to an estimated $2M for FY 2001.

These cost increases will impact the distribution of overhead funds and total indirect costs. The Laboratory is working with DOE to plan for the most cost-effective and environmentally sound solutions to these energy supply and cost issues.

VIII. RESOURCE PROJECTIONS AND TABLES

Resource projections for the Institutional Plan provide a description of the budget authority (BA) to implement the research programs. The resource tables also indicate actual fiscal year (FY) 2000 budget authority and FY 2001 projected budget authority for comparison. These tables include:

- Resources by Major Program:

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

- Subcontracting and Procurement:

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

- Experimenters at Designated User Facilities (FY 2000), Table VIII (6)
- University and Science Education, Table VIII (7)
- Laboratory Directed Research and Development, Table VIII (8)

The FY 2001 estimate is based on FY 2001 DOE budget guidance, the President's Request, and assessments by Berkeley Lab Divisions. For fiscal years 2002 and beyond, operating cost projections are in FY 2001 dollars, and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 2002 to FY 2006, 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. Some reporting summary levels may have slight differences in totals due to rounding. 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 VIII (1) (a) Laboratory Funding Summary ($ in Millions-BA)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
DOE Effort	264.0	286.1	310.2	327.7	321.5	323.1	345.1
CRADA	7.9	4.1	4.1	3.6	3.5	3.4	3.4
WFO	67.8	89.9	98.0	98.3	100.5	101.5	102.3
TOTAL OPERATING	**339.7**	**380.1**	**412.3**	**429.6**	**425.5**	**428.0**	**450.0**
Capital Equipment	29.2	35.3	46.9	49.2	30.9	31.5	33.9
Program Construction	36.1	16.3	12.0	24.4	30.6	18.7	5.9
General Purpose Facilities	6.1	2.1	5.6	5.1	8.0	8.0	8.0
General Plant Projects	3.0	3.5	3.5	3.5	3.5	3.5	3.5
General Purpose Equipment	1.2	1.5	2.0	2.0	2.0	2.0	2.0
TOTAL LABORATORY FUNDING	**415.3**	**438.8**	**482.3**	**513.8**	**500.5**	**491.7**	**503.3**

Table VIII (1) (b) Laboratory Personnel Summary (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
DIRECT							
DOE Effort	1,630	1,710	1,784	1,838	1,833	1,836	1,868
Work for Other than DOE	334	431	437	437	445	448	450
CRADA	37	19	18	16	16	15	15
TOTAL DIRECT	2,001	2,160	2,239	2,291	2,294	2,299	2,333
TOTAL INDIRECT	731	754	754	754	754	754	754
TOTAL PERSONNEL	**2,732**	**2,914**	**2,993**	**3,045**	**3,048**	**3,053**	**3,087**

Table VIII (2) (a) Funding by Secretarial Officer ($ in Millions-BA)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Office of Science (SC)							
Operating	202.9	219.9	240.8	259.5	256.3	258.7	280.1
Capital Equipment	28.8	35.6	48.9	51.1	32.9	33.5	35.9
Construction	11.3	8.0	17.5	33.0	42.1	30.2	17.4
Total	**243.0**	**263.5**	**307.2**	**343.6**	**331.3**	**322.4**	**333.4**
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Operating	24.8	25.4	28.8	28.6	28.6	28.1	28.1
Capital Equipment	0.1	-	0.1	0.1	-	-	-
Total	**24.9**	**25.4**	**28.9**	**28.7**	**28.6**	**28.1**	**28.1**
Assistant Secretary for Fossil Energy (FE)							
Operating	4.7	6.5	6.9	7.4	7.0	7.0	7.1
Total	**4.7**	**6.5**	**6.9**	**7.4**	**7.0**	**7.0**	**7.1**
Assistant Secretary for Environmental Restoration and Waste Management (EM)							
Operating	11.9	7.3	7.6	7.5	4.9	4.1	4.1
Capital Equipment	0.2	-	-	-	-	-	-
Total	**12.1**	**7.3**	**7.6**	**7.5**	**4.9**	**4.1**	**4.1**
Assistant Secretary for Defense Programs (DP)							
Construction	27.6	5.2	-	-	-	-	-
Total	**27.6**	**5.2**	-	-	-	-	-
Office of Nonproliferation and National Security (NN)							
Operating	3.0	4.7	3.9	3.6	3.6	3.6	3.6
Total	**3.0**	**4.7**	**3.9**	**3.6**	**3.6**	**3.6**	**3.6**
Assistant Secretary for Environment, Safety and Health (EH)							
Operating	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Total	**0.5**	**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	0.1
Total	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Work for Other DOE Contractors							
Operating	16.2	21.7	21.6	20.5	20.5	21.0	21.4
Capital Equipment	1.2	1.2	-	-	-	-	-
Construction	6.3	8.7	3.6	-	-	-	-
Total	**23.7**	**31.6**	**25.2**	**20.5**	**20.5**	**21.0**	**21.4**
Total DOE							
Operating	264.1	286.2	310.3	327.8	321.6	323.2	345.1
Capital Equipment	30.3	36.8	49.0	51.2	32.9	33.5	35.9
Construction	45.2	21.9	21.1	33.0	42.1	30.2	17.4
Total	**339.6**	**344.9**	**380.4**	**412.0**	**396.6**	**386.9**	**398.4**

Table VIII (2) (b) Personnel by Secretarial Officer (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Office of Science (SC)							
Direct FTE	1,264	1,349	1,446	1,520	1,526	1,528	1,558
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Direct FTE	129	129	144	144	144	144	144
Assistant Secretary for Fossil Energy (FE)							
Direct FTE	24	29	29	31	31	31	31
Assistant Secretary for Environmental Restoration and Waste Management (EM)							
Direct FTE	63	38	38	38	27	26	26
Assistant Secretary for Defense Programs (DP)							
Direct FTE	35	7	-	-	-	-	-
Office of Nonproliferation and National Security (NN)							
Direct FTE	13	21	18	17	17	17	17
Assistant Secretary for Environment, Safety & Health (EH)							
Direct FTE	3	3	3	3	3	3	3
Office of Intelligence (IN)							
Direct FTE	1	1	1	1	1	1	1
Work for Other DOE Contractors							
Direct FTE	98	133	105	84	84	86	88
Total DOE							
Direct FTE	**1,630**	**1,710**	**1,784**	**1,838**	**1,833**	**1,836**	**1,868**
Work for Others—Non-DOE							
Direct FTE	334	431	437	437	445	448	450
CRADA							
Direct FTE	37	19	18	16	16	15	15
TOTAL LAB DIRECT	2,001	2,160	2,239	2,291	2,294	2,299	2,333
TOTAL LAB INDIRECT	731	754	754	754	754	754	754
TOTAL LAB PERSONNEL	2,732	2,914	2,993	3,045	3,048	3,053	3,087

Table VIII (3) (a) Office of Science Funding ($ in Millions-BA) and Personnel (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
AT Fusion Energy Science							
Operating	5.0	4.0	4.1	5.8	6.0	6.1	6.3
Capital Equipment	0.6	1.1	1.1	4.0	4.1	4.2	4.4
Total	**5.6**	**5.1**	**5.2**	**9.8**	**10.1**	**10.3**	**10.7**
FS Field Security							
Operating	-	3.5	4.7	5.2	5.2	5.2	5.2
Total	**-**	**3.5**	**4.7**	**5.2**	**5.2**	**5.2**	**5.2**
KA High Energy Physics							
Operating	23.8	27.6	34.5	44.9	36.0	34.6	34.7
Capital Equipment	13.6	9.4	12.2	10.5	8.9	8.2	8.2
Construction	3.0	3.5	3.5	3.5	3.5	3.5	3.5
Total*	**40.4**	**40.5**	**50.2**	**58.9**	**48.4**	**46.3**	**46.4**
KB Nuclear Physics							
Operating	15.7	16.2	16.3	16.6	16.6	16.6	16.6
Capital Equipment	1.6	1.6	2.9	6.8	2.5	5.5	6.5
Construction	0.6	0.3	0.4	0.4	0.4	0.4	0.4
Total	**17.9**	**18.1**	**19.6**	**23.8**	**19.5**	**22.5**	**23.5**
KC02 Materials Sciences							
Operating	45.0	48.8	56.4	57.5	60.0	62.0	80.2
Capital Equipment	4.1	7.8	22.0	19.0	9.2	7.3	8.5
Construction	1.7	2.1	8.0	24.0	30.2	18.3	5.5
Total	**50.8**	**58.7**	**86.4**	**100.5**	**99.4**	**87.6**	**94.2**
KC03 Chemical Sciences							
Operating	9.5	11.0	11.5	11.7	11.9	12.0	12.1
Capital Equipment	1.9	2.8	3.0	3.1	0.7	0.7	0.7
Total	**11.4**	**13.8**	**14.5**	**14.8**	**12.6**	**12.7**	**12.8**
KC04 Engineering and Geosciences							
Operating	2.3	2.6	2.9	2.7	3.4	3.7	4.4
Capital Equipment	0.2	-	-	-	-	-	-
Total	**2.5**	**2.6**	**2.9**	**2.7**	**3.4**	**3.7**	**4.4**
KC06 Energy Biosciences							
Operating	0.8	0.4	0.4	0.5	0.5	0.6	0.6
Capital Equipment	0.1	-	-	-	-	-	-
Total	**0.9**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.6**
KG Multiprogram Energy Laboratories - Facilities Support							
Construction	6.1	2.1	5.6	5.1	8.0	8.0	8.0
Total	**6.1**	**2.1**	**5.6**	**5.1**	**8.0**	**8.0**	**8.0**

*Note for KA: figures do not include SNAP equipment for FY04 on.

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

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
KJ Advanced Scientific Computing Research							
Operating	54.9	58.6	57.8	60.1	62.1	63.8	65.8
Capital Equipment	2.7	4.0	3.0	3.0	3.0	3.0	3.0
Total	**57.6**	**62.6**	**60.8**	**63.1**	**65.1**	**66.8**	**68.8**
KP Biological and Environmental Research							
Operating	45.3	46.3	51.2	53.4	53.5	52.7	52.9
Capital Equipment	3.9	8.9	4.6	4.8	4.6	4.6	4.6
Total	**49.2**	**55.2**	**55.8**	**58.2**	**58.1**	**57.3**	**57.5**
KX Program Directions							
Operating	0.6	0.9	1.2	1.2	1.2	1.2	1.3
Total	**0.6**	**0.9**	**1.2**	**1.2**	**1.2**	**1.2**	**1.3**
Total, Office of Science							
Operating	202.9	219.9	241.0	259.6	256.4	258.5	280.1
Capital Equipment	28.7	35.6	48.8	51.2	33.0	33.5	35.9
Construction	11.4	8.0	17.5	33.0	42.1	30.2	17.4
Total	**243.0**	**263.5**	**307.3**	**343.8**	**331.5**	**322.2**	**333.4**
Direct FTE	1,264	1,349	1,446	1,520	1,527	1,528	1,557

Table VIII (3) (b) Energy Efficiency and Renewable Energy Funding ($ in Millions-BA) and Personnel (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
EB Solar and Renewable Resource Technologies							
Operating	2.4	4.1	5.4	5.4	5.8	5.9	5.9
Total	**2.4**	**4.1**	**5.4**	**5.4**	**5.8**	**5.9**	**5.9**
EC Building Technology, State and Community Sector							
Operating	13.1	12.2	12.8	12.3	12.3	12.3	12.3
Total	**13.1**	**12.2**	**12.8**	**12.3**	**12.3**	**12.3**	**12.3**
ED Industrial Sector							
Operating	1.8	2.4	2.8	2.8	2.8	2.5	2.5
Total	**1.8**	**2.4**	**2.8**	**2.8**	**2.8**	**2.5**	**2.5**
EE Transportation Sector							
Operating	4.9	4.0	5.3	5.4	5.0	4.7	4.7
Capital Equipment	0.1	-	0.1	0.1	-	-	-
Total	**5.0**	**4.0**	**5.4**	**5.5**	**5.0**	**4.7**	**4.7**
EH Policy and Management							
Operating	0.1	-	-	-	-	-	-
Total	**0.1**	-	-	-	-	-	-
EL Federal Energy Management Program							
Operating	2.5	2.7	2.6	2.6	2.6	2.6	2.6
Total	**2.5**	**2.7**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**
Total, Assistant Secretary for Energy Efficiency and Renewable Energy							
Operating	24.8	25.4	28.9	28.5	28.5	28.0	28.0
Capital Equipment	0.1	-	0.1	0.1	-	-	-
Total	**24.9**	**25.4**	**29.0**	**28.6**	**28.5**	**28.0**	**28.0**
Direct FTE	129	129	144	144	144	144	145

Table VIII (3) (c) Fossil Energy and Other DOE Program Funding ($ in Millions-BA) and Personnel (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
AA Coal							
Operating	0.5	1.1	1.4	1.8	1.8	1.8	1.8
Total	**0.5**	**1.1**	**1.4**	**1.8**	**1.8**	**1.8**	**1.8**
AB Gas							
Operating	0.9	1.4	1.8	1.8	1.3	1.3	1.3
Total	**0.9**	**1.4**	**1.8**	**1.8**	**1.3**	**1.3**	**1.3**
AC Petroleum							
Operating	3.2	4.0	3.8	3.8	3.8	3.9	3.9
Total	**3.2**	**4.0**	**3.8**	**3.8**	**3.8**	**3.9**	**3.9**
Total, Assistant Secretary for Fossil Energy							
Operating	4.6	6.5	7.0	7.4	6.9	7.0	7.0
Total	**4.6**	**6.5**	**7.0**	**7.4**	**6.9**	**7.0**	**7.0**
Direct FTE	24	29	29	32	32	32	32
EW Environmental Restoration and Waste Management - Defense							
Operating	2.2	3.0	3.4	3.5	3.5	2.9	2.9
Capital Equipment	0.1	-	-	-	-	-	-
Total	**2.3**	**3.0**	**3.4**	**3.5**	**3.5**	**2.9**	**2.9**
EX Environmental Restoration and Waste Management - Non-Defense							
Operating	9.7	4.3	4.2	4.0	1.5	1.2	1.1
Capital Equipment	0.1	-	-	-	-	-	-
Total	**9.8**	**4.3**	**4.2**	**4.0**	**1.5**	**1.2**	**1.1**
Total, Assistant Secretary for Environmental Restoration and Waste Management							
Operating	11.9	7.3	7.6	7.5	5.0	4.1	4.0
Capital Equipment	0.2	-	-	-	-	-	-
Total	**12.1**	**7.3**	**7.6**	**7.5**	**5.0**	**4.1**	**4.0**
Direct FTE	63	38	38	38	27	26	26
DP Defense Programs Activities							
Construction	27.6	5.2	-	-	-	-	-
Total	**27.6**	**5.2**	-	-	-	-	-
Total, Assistant Secretary for Defense Programs							
Construction	27.6	5.2	-	-	-	-	-
Total	**27.6**	**5.2**	-	-	-	-	-
Direct FTE	35	7	-	-	-	-	-

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

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
HD Environment, Safety and Health (Defense)							
Operating	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Total	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Total, Assistant Secretary for Environment, Safety and Health							
Operating	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Total	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Direct FTE	3	3	3	3	3	3	3
IN Intelligence							
Operating	0.1	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**	**0.1**
Total, Office of Intelligence							
Operating	0.1	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**	**0.1**
Direct FTE	1	1	1	1	1	1	1
NN Nonproliferation and Verification R&D							
Operating	3.0	4.7	3.9	3.6	3.6	3.6	3.6
Total	**3.0**	**4.7**	**3.9**	**3.6**	**3.6**	**3.6**	**3.6**
Total, Office of Nonproliferation and National Security							
Operating	3.0	4.7	3.9	3.6	3.6	3.6	3.6
Total	**3.0**	**4.7**	**3.9**	**3.6**	**3.6**	**3.6**	**3.6**
Direct FTE	13	21	18	17	17	17	17

Table VIII (4) Work for Others Funding ($ in Millions-BA) and Personnel (FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Work for Others—Federal Agencies							
Department of Commerce	-	0.6	0.6	0.6	0.6	0.6	0.6
Department of Defense	5.3	9.8	9.9	9.3	10.4	10.0	9.2
Enviromental Protection Agency	4.7	4.7	5.0	4.9	4.9	4.9	4.9
Department of Interior	0.1	0.3	0.4	0.4	0.4	0.4	0.4
NASA	4.0	5.2	5.7	5.8	5.6	5.6	5.7
National Institutes of Health	23.7	47.2	49.3	53.6	54.8	56.0	58.0
National Science Foundation	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Other Federal	0.2	0.7	1.0	0.8	0.8	0.8	0.8
Total Federal Operating	38.3	68.9	72.1	75.6	77.7	78.5	79.8
Total	**38.3**	**68.9**	**72.1**	**75.6**	**77.7**	**78.5**	**79.8**
Work for Others—Non-Federal Agencies							
Universities	14.6	12.0	10.0	7.1	7.1	7.1	6.6
State/Local Gov't/Non-Profit	8.0	4.0	10.3	9.9	9.9	9.9	9.9
Industry/Domestic	5.9	4.6	5.0	5.1	5.2	5.3	5.3
Other Non-Federal	1.0	0.4	0.6	0.6	0.6	0.7	0.7
Total Non-Federal Operating	29.5	21.0	25.9	22.7	22.8	23.0	22.5
Total	**29.5**	**21.0**	**25.9**	**22.7**	**22.8**	**23.0**	**22.5**
Total Work for Others—Non-DOE Contractors (no CRADA)							
Operating	67.8	89.8	98.0	98.3	100.5	101.5	102.3
Direct FTE	334	431	437	437	445	448	450
CRADA							
Operating	7.9	4.1	4.1	3.6	3.5	3.4	3.4
Direct FTE	37	19	18	16	16	15	15

Table VIII (5) (a) Subcontracting and Procurement ($ in Millions-Obligated)

	FY00	FY01	FY02	FY03
Subcontracting and Procurement from:				
Universities	9.9	10.1	10.3	10.5
All Others	155.0	158.1	161.3	164.5
Transfers to Other DOE Facilities	2.7	2.8	2.8	2.9
Total External Subcontracts and Procurement	**167.6**	**171.0**	**174.4**	**177.9**

Table VIII (5) (b) Small and Disadvantaged Business Procurement ($ in Millions-BA)

	FY00	FY01
Procurement from Small and Disadvantaged Business	71.5	66.52
Percent of Annual Procurement	56.8%	51.8%
Available Subcontracting Dollars	125.9	128.4

Table VIII (6) Experimenters at Designated User Facilities (FY 2000)

	Number of Experimenters	Number of Organizations	Percentage of Use
Advanced Light Source			
Laboratory	348	5	33%
Other DOE Laboratories	62	12	6%
Other U.S. Government	2	3	1%
University	371	85	36%
Industry	85	44	8%
Foreign Laboratory	29	24	2%
Foreign University	125	64	12%
Foreign Industry	5	3	1%
Other	9	3	1%
Total	**1036**	**243**	**100%**
National Energy Research Scientific Computing			
Laboratory	320	1	11%
Other DOE Laboratories	633	16	45%
Other U.S. Government	50	5	3%
University	741	78	36%
Industry	60	11	4%
Other (private labs)	45	5	1%
Total	**1849**	**116**	**100%**
88-Inch Cyclotron			
Laboratory	65	1	47%
Other DOE Laboratories	12	3	4%
Other U.S. Government	9	3	1%
University	63	18	15%
Industry	35	17	9%
Foreign Laboratory	9	9	1%
Foreign University	29	17	18%
Foreign Industry	15	7	5%
Total	**237**	**75**	**100%**

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

	Number of Experimenters	Number of Organizations	Percentage of Use
National Center for Electron Microscopy			
Laboratory	77	1	38%
Other DOE Laboratories	2	1	2%
Other U.S. Government	3	2	2%
University	75	20	37%
Industry	9	9	4%
Foreign Laboratory	7	3	3%
Foreign University	28	25	14%
Foreign Industry	--	--	--
Total	**201**	**61**	**100%**
National Tritium Labeling Facility+			
Laboratory	--	--	--
Other DOE Laboratories	--	--	--
Other U.S. Government	2	3	5%
University	2	2	5%
Industry	5	5	10%
Foreign Industry	1	1	2%
Total	**10**	**11**	**22%**
Grand Total			
Laboratory	**810**	**8**	**22%**
Other DOE Laboratories	**709**	**32**	**27%**
Non DOE U.S. Government	**66**	**16**	**2%**
University	**1252**	**203**	**34%**
Industry	**194**	**86**	**6%**
Foreign Laboratory	**45**	**36**	**1%**
Foreign University	**182**	**106**	**6%**
Foreign Industry	**21**	**11**	**1%**
Other	**54**	**8**	**1%**
Total	**3333**	**506**	**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 VIII (7) University and Science Education

	FY2000			FY2001*		
	Total	Minorities	Women	Total	Minorities	Women
PRE-COLLEGE PROGRAMS						
Student Programs	11	4	6	25	11	11
Teacher Programs	38	10	20	53	9	31
Special Programs	251	58	133	1103	409	602
UNDERGRADUATE PROGRAMS						
Student Programs	111	32	58	84	23	33
POSTGRADUATE PROGRAMS						
Postdoctoral Participating Guests	645**	106	144	625**	119	147
Faculty Participating Guests	468**	39	72	522**	43	91

*estimate

**Includes ethnic group unspecified

Table VIII (8) Laboratory Directed Research and Development Funding ($ in Millions-BA)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Budget	10.1	10.2	12.0	13.0	13.5	14.0	14.5

Ernest Orlando Lawrence Berkeley National Laboratory Mission Profile

Laboratory Information

Name:	Ernest Orlando Lawrence Berkeley National Laboratory
Location:	Berkeley, California
Full-Time Equivalent Employees:	2700
Scientific and Technical Degrees:	1450
Contractor:	University of California
Accountable Program Office:	Science
Field Office:	Oakland
Web Site:	www.lbl.gov

Funding Sources

Science: $243.0 million
Energy Efficiency and Renewable Energy: $24.9 million
Environmental Management: $12.1 million
Nonproliferation & National Security: $30.6 million
Fossil Energy: $4.7 million
Other DOE: $24.3 million
Non-DOE: $75.7 million

Total Funding: $415.3 million

Note: Budget data are for FY00

Description

Berkeley Lab is unique among the multiprogram laboratories with its close proximity to a major research university, the University of California at Berkeley. The Laboratory's principal role for DOE is fundamental science, including developing powerful experimental and computational systems for exploring properties of matter, deepening understanding of molecular interactions and synthesis, and gaining insights into biological molecules, cells, and tissues. Berkeley Lab is a major contributor of research on energy resources, including the earth's structure and energy reservoirs, fusion, combustion of fuels, and keys to efficient energy storage and use. The Laboratory is extensively involved in environmental research, including subsurface contaminant transport, bioremediation, and indoor air quality. User facilities include the Advanced Light Source, National Energy Research Scientific Computing Center, National Center for Electron Microscopy, 88-Inch Cyclotron, Biomedical Isotope Facility and National Tritium Labeling Facility. Our multidisciplinary research environment and unique location serve to strengthen partnerships with industry, universities, and government laboratories. Partnerships include the Joint Genome Institute and programs in advanced accelerator and detector systems, x-ray lithography, high-speed networking and computer architectures, building and lighting systems, and science education. The Laboratory was established in 1931 by Ernest Lawrence, the "father" of team science.

Distinctive Competencies and Major Facilities

MAJOR FACILITIES

Advanced Light Source: One of the world's brightest sources of ultraviolet light and soft x-rays and a powerful source of higher energy x-rays, serving as an excellent probe of the electronic properties of atoms, molecules, surfaces, and condensed matter, and a powerful tool for determining the structure of macromolecules. Over 1000 scientists are users on the ALS.

National Energy Research Scientific Computing Center and the Energy Sciences Network: Providing leading-edge computational resources, science and services; and national network for the scientific community. 1850 scientists are users at NERSC.

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

National Center for Electron Microscopy: One Angstrom, High-Voltage, Spin Polarized Low Energy, and Atomic Resolution Electron Microscopes. The facility hosts about 200 users annually.

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

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

DISTINCTIVE COMPETENCIES

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

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

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

Characterization, Synthesis, and Theory of Materials: Nanostructures; heterostructures; superconductors; alloys; magnetic materials.

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

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

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

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

Funding by Activity

(in $ millions)	FY 96	FY 97	FY 98	FY 99	FY 00
R&D and Operations	181.3	211.0	210.3	220.3	264.7
Construction	29.7	16.7	14.1	32.3	38.9
Capital	42.6	27.7	25.7	26.9	29.2
Non-DOE Funds	51.7	53.6	69.6	76.6	74.5
External Performers	17.2	22.7	26.4	29.1	8.0
Total	322.5	331.7	346.1	385.2	415.3

Funding by Mission Area

	R&D Funding by Mission Area	Total Funding by Mission Area
Total (in $ millions)	402.8	415.3
Science and Technology	77.6%	78.2%
Energy Resources	8.6%	8.4%
Environmental Quality	8.0%	7.8%
National Security	5.8%	5.6%
Total	100%	100%

Key Research and Development Activities

Science and Technology

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

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

Energy Resources

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

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

Environmental Quality

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

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

National Security

Berkeley Lab researchers perform unclassified research in support of nonproliferation and several analytical missions. This research encompasses:

- Accelerator for the Dual Axis Radiographic Hydrodynamic Test facility
- Detector development for portable, lightweight, gamma-ray spectrometers
- Laser fluorescence and nuclear detection capabilities for capillary electrophoresis
- Predictive tools to understand the dispersion of toxic agents in buildings

Significant Accomplishments

Crystallographic Studies of Protein Structures: Determination of more than 250 protein structures with rapid protein crystallography at the Advanced Light Source, including the entire ribosome and many enzymes and drug design targets. 1997-2001

Genome Sequencing: Completion of the draft sequence of chromosomes 15, 16, and 19 with LLNL and LANL at the Joint Genome Institute, and the sequencing of *Drosophila* with UC Berkeley. 1997-2001

Nanotechnology: Development and fabrication of nanotube circuits and single molecule transistors. 1996-2001

Neutrino Oscillation: Discovery of the existence of solar neutrino flavors through the Sudbury Neutrino Observatory. (SNO) 1996-2001

B-meson Physics: Conceptual foundations for the Asymmetric B Factory and the design and fabrication of the low energy B-Factory ring and the silicon vertex detector in BaBar. 1988-2000

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

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

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

Anisotropy of the Cosmic Background Radiation: The systematic observation (with COBE Satellite and BOOMERANG experiments) of ripples in the radiation afterglow of the primeval explosion that began the universe. These ripples are "hot" and "cold" regions in space, more than 1200 million light years across with temperature differences of a hundred-thousandth of a degree. They are the primordial seeds from which our present-day universe grew. 1975-1998

Billions of Dollars in Annual Energy Savings: Nationally significant energy savings through development of the most efficient window technology currently available, building energy analysis models now widely used, and transfer of advanced fluorescent lighting technology to industry. 1995-2000

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

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

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

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

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

Discovering Radon Exposure: Berkeley Lab was where the threat to American homes posed by radon was discovered. Exposure to radon gas in U.S. homes is thought to account for as many as 10,000 cases of lung cancer each year. 1985-1996

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

Predicting the Performance of Materials: Created one of the first-ever harder-than-diamond crystals and proved that computer models can play an effective role in the development of new materials. The new superhard crystal, a compound of carbon and nitrogen, was made from a recipe arrived at solely by theoretical calculations. These calculations showed that substituting carbon for silicon in the crystal structure of silicon-nitride would yield a super-hard carbon-nitride. 1980-1995

The Multicast Backbone (M-Bone): Developed by a team that included a Berkeley Lab computer scientist, M-Bone makes possible an electronic window through which users worldwide can not only see and talk to one another, but can work together on a shared "whiteboard." 1985-1995

"Stereotactic Radiosurgery": Pioneered the use of accelerated beams of ions as a scalpel on cancers and blood clots. 1970-1992

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

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

High Energy Physics and Nuclear Science: Discovery of the antiproton and the particle resonances. 1956-1965 Discovery of 13 elements, and numerous isotopes of medical and technological value. 1935-1974

Development of Particle Accelerators: Ernest Lawrence invented the cyclotron. Additional discoveries were the concept of phase stability and the synchrotron, the Alvarez linear accelerator, and induction linear accelerators for fusion. 1931-2000

Major Partnerships, Collaborations, and CRADAs		
Category/Mission	***Partner***	***Description***
Research partnerships with academia, government, and industry underlie many of Berkeley Lab's programs. We have more than 3000 scientists from throughout the world who are users at our national facilities (remotely and on site), more than 1600 participating guests working at the Berkeley Lab, with over 1000 guests from academia demonstrating our close relations with universities. Berkeley Lab has more than 100 Collaborative Research and Development Agreements, many in the energy, biotechnology, semiconductor, and computer-related industries.		
Science & Technology	UC Berkeley	Sequencing the *Drosophila* genome
	UC San Francisco	Transgenic mouse model of Sickle Cell Anemia
	Many universities	ATLAS detector for Large Hadron Collider (international collaboration)
	Many universities	BaBar detector system for B-meson decay (international collaboration)
	Many universities	Solenoidal detector for the Relativistic Heavy Ion Collider (RHIC) (international)
	National Cancer Institute/NIH	Chemical carcinogens; human mammary cell studies; progesterone receptors
	LLNL, LANL	Joint Genome Institute
	Fermilab	Silicon vertex detector upgrades for D-Zero and CDF experiments
	ORNL, BNL, LANL, ANL	Spallation Neutron Source
	Chiron	High-throughput assay for screening novel anti-cancer compounds
	Amgen, Inc.	Structure of the erythropoietin receptor
	Intel and IBM	X-ray photoemission microscopes at the Advanced Light Source
	CERN	NA-30 detector, magnets, ATLAS for Large Hadron Collider in Europe
	Ames	Heat capacity research, quasicrystals
	ORNL, ANL	DOE 2000 Collaboratory, interactive virtual labs
	Capintec, Inc.	Medical imaging scintillation camera
	Praxaire	Ionically conductive membranes for oxygen separation
Energy Resources	Several universities	Inertial fusion energy research
	U.S. AID	Energy efficiency in foreign countries
	Ford, Cummings Engine	Diesel Collaboratory--computation partnership
	State of California	Advanced building technology, electric reliability
	Scripps Institution of Oceanography	Subsurface imaging of salt domes with marine magnetotellurics
	Many companies	Crosshole and surface to borehole electromagnetic sensing
	Catalytica, Inc.	Catalyst optimization for heavy petroleum
	Several utilities	High-performance, energy-efficient lamps
Environmental Quality	U.S. EPA	Volatile organic emissions research, HVAC analysis, cool roofs, and efficient lighting
	PNNL	Environmental microbiology studies
	State of California	Sacramento River Delta environmental quality improvement
	Bechtel SAIC Co.	Yucca Mountain characterization studies
	Several universities	Bioremediation, Education, Science and Technology (BEST)
National Security	LANL	Accelerators for Dual Axis Radiographic Hydrodynamic Test facility

X. ACKNOWLEDGMENTS

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

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The Deputy Directors' Offices provided review and comments, and scientific program leaders contributed to specific sections of the Plan through division offices. Todd Hansen and Karin Levy provided overall editing and coordination of the Plan. In addition, elements of the document were developed in conjunction with the following responsible support program administrators and staff:

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Facilities Planning	Laura Chen, Richard McClure
Technology Transfer	Cheryl Fragiadakis
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Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098