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ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 2003—FY 2007

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PREFACE

The Fiscal Year (FY) 2003-2007 Institutional Plan describes the strategic directions and key issues that Lawrence Berkeley National Laboratory management must address with the Department of Energy (DOE) in charting its future as a multiprogram national laboratory. The Plan provides an overview of the Laboratory's 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. The Plan facilitates the Department of Energy's ongoing efforts to strengthen the Integrated Laboratory System.

Preparation and review of the Institutional Plan is one element of the Department of Energy's strategic management planning activities, implemented through an annual planning process. The Plan supports the President's Management Agenda and the Government Performance and Results Act of 1993. The Plan complements the current performance-based contract between the Department of Energy and the Regents of the University of California, and summarizes Best Management Practices for a potential future results-based contract as a basis for achieving DOE goals and the Laboratory's scientific and operations objectives. 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 and DOE comments on prior years' plans.

The Laboratory Mission 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 activities in support of DOE Office of Science and other sponsors; support for DOE goals; and the Laboratory Scientific Vision and operations goals. 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; site and cyber security; workforce diversity; communications and trust; integrated safety management; and technology transfer activities. 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.

CONTENTS

I. DIRECTOR'S STATEMENT

The powerful research capabilities of the Department of Energy deliver science and technology programs of vital national interest. Following the events of September 11, 2001, it has become even more crucial that the Office of Science National Laboratories focus their capabilities on delivering scientific results. We must concentrate our planning and management efforts in support of this research mission, expending critical resources on the most necessary activities.

Lawrence Berkeley National Laboratory (Berkeley Lab), working in partnership with DOE leadership and the University of California (UC) Office of the President, has completed a Best Practices Pilot Study that defines the principles for operating the Laboratory for mission results. The Laboratory's strategic planning and management efforts are directed toward implementing these Best Practices and delivering results for the Department of Energy (DOE).

Focus on Results

Our management principles stem from the Administration placing high value on results, as expressed by President Bush: "*What matters in the end is completion. Performance. Results. Not just making promises, but making good on promises.*" To this end, the Laboratory is working with DOE towards framing results-based management arrangements based on these Best Practices principles:

- **Line Management Accountability.** Focus on mission success by integrating administrative requirements into mission priorities, and establishing line accountability in program and contractor organizations.
- **National Standards.** Build efficient support systems by establishing performance criteria based on applicable national standards instead of agency-specific requirements.
- **Assurance Reviews by External Experts.** Enhance assurance and stewardship credibility by using national experts for administrative reviews and compliance audits.
- **Bilateral Decision Process.** Tailor implementation of agency directives by taking site-specific conditions into account through a bilateral management decision process.
- **Oversight and Incentives Based on Certified Systems Metrics.** Replace transactional oversight with validation of certified systems.

A final principle is to embody these best management practices in a results-based management contract, defining the roles and responsibilities of DOE and contractor personnel, behaviors, and expectations. A results-based contract offers the prospect of effectively and efficiently delivering on the strategic goals of the Department of Energy.

Science Vision

The Berkeley Lab Fiscal Year (FY) 2003-2007 Institutional Plan addresses the strategic goals of DOE and key scientific thrusts of the nation. Our multidisciplinary capability in the physical and biological sciences opens new opportunities to design and fabricate the smallest and most efficient nanodevices. Our research to understand the properties of the universe is yielding new insights on the nature of matter and energy. We are bringing together biology, physics, computing, and engineering for a new era of genomic science and quantitative biology. Our computational science resources are focused on serving DOE programs and investigators, in areas such as global climate change, combustion, fusion, and fundamental physics. In addition, we are developing accelerators as critical tools to understand plasmas and harness fusion energy for a nation committed to secure, reliable energy supplies, and control of greenhouse gas emissions.

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 energy efficiency and reliability, and providing the computational capabilities and expertise that address Department of Energy scientific needs.

- **Nanoscience.** 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.
- **Astrophysics**. 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.
- **Genomes to Life**. 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 microbiological systems. This includes characterizing the regulatory networks of microorganisms and creating data-driven, validated models of biological responses in environments of critical importance to DOE. Berkeley Lab's efforts are directed towards an integrated program of environmental microbiology, functional genomic measurement, and computational analysis and modeling to understand the basic biology of microbial systems and to restore contaminated environments.
- **Energy Efficiency and Security**. 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 Laboratory is working to establish E-Lab, an energy efficiency and electricity 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 and to work toward advancing research in potential long-term solutions using inertial confinement fusion.
- **Scientific Computation**. The National Energy Research Scientific Computing (NERSC) Center provides high-performance computational resources that are highly valued by its DOE user community. NERSC Center and the Computational Research Division apply 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 Center and the Computational Research Division also emphasize comprehensive scientific support, leveraging the Office of Science initiative on Scientific Discovery through Advanced Computing, and providing a unified environment that integrates computing with experimental science.

National Partnerships

The Laboratory's capabilities are being called upon to serve the DOE 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 essential to DOE's missions.

Our geosciences leadership is 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 Laboratory's geoscience capabilities are also being deployed with Lawrence Livermore National Laboratory to address the fundamental science needed to understand the potential for ocean carbon sequestration.

Research Infrastructure

To sustain the Laboratory's scientific efforts, the nation needs to invest in the science infrastructure that underpins our discoveries and, ultimately, the security, economic prosperity, and 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 Manhattan Project and Atomic Energy Commission-era 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 constructing additions to the 88 Inch Cyclotron and National Center for Electron Microscopy. 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. Working with the Office of Energy Efficiency and Renewable Energy, we are exploring the concept of E-Lab as a "living laboratory" facility that would combine offices and laboratories to investigate, test, monitor, and demonstrate new energy-efficiency technologies and design processes. In addition, the Office of Science must sustain its support for dismantling the Bevatron following its illustrious career in high energy physics, heavy ion nuclear physics, and nuclear medicine.

Investing in People

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 colleges to bring new students to the Laboratory in planned programs that offer improved prospects for career employment. New educational partnerships with community colleges and secondary schools promise local and national benefits linked to DOE technology and scientific resources. 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 university-based scientific and management skills of our staff, and close working relationships with campuses, government, and industry. The priority needs for delivering results for the Department of Energy and fulfilling our scientific vision are reflected in this Institutional Plan.

Charles V. Shank

Director

II. LABORATORY MISSION

Berkeley Lab is a multiprogram national scientific 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 conducts key elements of DOE's security missions in science, energy, and the environment. In support of these missions Berkeley Lab:

- Performs 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 environmental protection.
- Develops and operates unique national experimental facilities for qualified investigators.
- Educates and trains future generations of scientists and engineers to promote national science and education goals.
- Transfers knowledge and technological innovations and fosters productive relationships among Berkeley Lab's research programs, universities, and industry.

The Laboratory's results-based management efforts are directed towards advancing DOE overall strategic interests and to the Office of Science goals to advance the frontiers of the physical sciences and areas of the biological, environmental and computational sciences that deliver the scientific knowledge and discoveries for DOE's missions. The Laboratory's activities address the Department of Energy's goal to provide world-class research facilities and essential scientific human capital to the nation's overall science enterprise.

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 efficient energy use, the earth's structure and energy reservoirs, fusion, and combustion of fuels. The Laboratory is extensively involved in environmental research, including Yucca Mountain site characterization, 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, and Biomedical Isotope 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 planning 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 successfully 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 now conducting charge-parity measurements in the b-meson system at the Stanford Linear Accelerator Center (SLAC). Berkeley Lab's ion source efforts for 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. 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 Genomics Facility, which is 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. The core competencies also enable Berkeley Lab to respond to changing national needs and new research problems.

- **Advanced Detector Systems.** Major detectors for astrophysics, high energy physics, and nuclear science; scientific conception and project leadership; advances in particle and photon detection; implementation of new concepts in detector technology.
- **Advanced Technologies for Energy Supply and Energy Efficiency.** Building technologies; energy analysis; electrochemistry; fossil fuel technologies; subsurface resources and processes.
- **Bioscience and Biotechnology.** Structural biology; genomics and proteomics; bioinstrumentation; biological and medical imaging; molecular, cell and tissue biology of carcinogenesis, aging and other 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.
- **Chemical Dynamics, Atomic Physics, Catalysis, and Surface Science.** Reaction dynamics; photochemistry of molecules and free radicals; dynamics of atomic and molecular photoionization; surface structures and functions; heterogeneous, homogeneous, and enzymatic catalysis.
- **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.
- **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.
- **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.

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 deliver results for DOE programs within scope, schedule, and budget 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 division personnel, with computational, engineering, and technical services integrated in research teams across the physical sciences, energy sciences, biosciences, and general sciences divisions.

Computing Sciences

- **National Energy Research Scientific Computing (NERSC) Center Division**. Unsurpassed high-end computing services to the Department of Energy 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.
- **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.
- **Computational Research Division.** Leadership of four SciDAC projects—the DOE Science Grid, the Performance Evaluation Research Center, the Scientific Data Management Center, and the Applied Partial Differential Equations Center—as well as collaboration in another seven projects in this nationwide DOE program to create a new generation of scientific simulation codes.
- **Information Technologies and Services Division (ITSD).** Information technology infrastructure and services, including cybersecurity, business applications, desktop computer support, electronic mail, networking and telecommunications, and technical information. ITSD includes the Energy Sciences Network (ESnet), an 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.

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; health effects of low-level ionizing radiation; functional genomics and microarray technology; development of human disease models in mice; nuclear chemistry; biological and functional imaging at molecular, cellular and human scales.

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, and for other advanced detection 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; astrophysics; particle database for the high energy physics community; 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.

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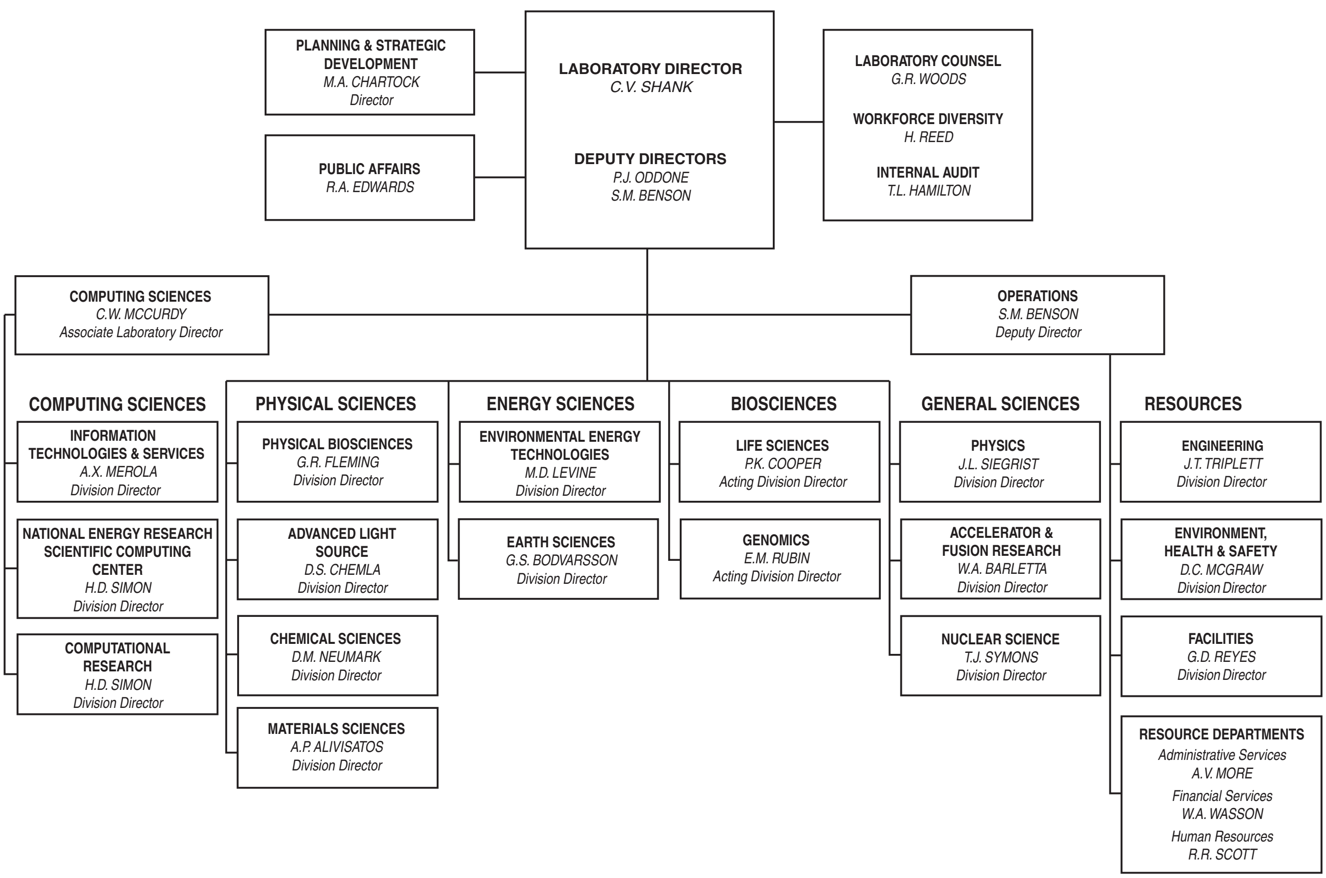

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III. LABORATORY STRATEGIC PLAN

The Berkeley Lab Strategic Plan is based on the Laboratory's interest in advancing DOE's mission and goals, the implementation of a Berkeley Lab Scientific Vision, and pursuing operating and administrative goals for effective and efficient implementation of research. The following sections summarize the Laboratory's support for DOE programs and goals. The Berkeley Lab Scientific Vision (see below, page 3-21) 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.

DOE PROGRAM FOCUS ON RESULTS

Within the fabric of American science, Berkeley Lab serves as a multiprogram science laboratory whose primary focus is fundamental science with important contributions in energy security and environmental research. Berkeley Lab's long-term strategy is to serve as a results-based scientific organization that delivers on the quality, relevance, and performance goals of the sponsoring DOE program offices. 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.

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:

- **Computational modeling and simulation.** Berkeley Lab's Computing Sciences organization, in particular the Computational Research Division, conducts research in the three essential elements of computational modeling: computer science, computational science, and applied mathematics. For the Office of Advanced Scientific Computing Research's initiative on Scientific Discovery through Advanced Computing (SciDAC), Berkeley Lab is the lead organization for three Integrated Software Infrastructure Centers: the Performance Evaluation Research Center, the Scientific Data Management Center, and the Applied Partial Differential Equations Center. In addition, Berkeley Lab's Chemical Sciences Division shares leadership of the SciDAC Advanced Methods for Electronic Structure project, and the Accelerator and Fusion Research Division shares leadership of the Advanced Computing for 21st Century Accelerator Science and Technology project. Berkeley Lab researchers are also collaborating on SciDAC projects to develop Scalable Systems Software, Terascale Optimal Partial Differential Equation Solvers, and the Terascale Community Climate System Model.

- **Collaboration and networking research.** Berkeley Lab's research and development of collaboration and networking technologies is focused on creating an integrated science environment, combining experiment, simulation, and theory by facilitating access to computing and data resources as well as large DOE experimental instruments. Berkeley Lab is the lead organization for the SciDAC DOE Science Grid collaboratory, and Lab researchers are also collaborating on the SciDAC Earth Systems Grid, National Fusion Collaboratory, and Particle Physics Data Grid projects.
- **High performance computing and networking facilities.** The National Energy Research Scientific Computing (NERSC) Center is the flagship general-purpose, high-end computing facility for the Office of Science research community, providing 5 teraflops of computing capability and 2.5 petabytes of storage. NERSC Center provides comprehensive scientific support for users and intensive support for Scientific Challenge Teams. By December 2002, Computing Sciences will begin deploying Grid technology to connect its computing and storage systems to the DOE Science Grid, a major step toward creating a Unified Science Environment. ESnet, the backbone of DOE's research network, provides access to NERSC Center and to other research, experimental, and computational facilities for scientists across the nation and by international collaboration.

The Office of Advanced Scientific Computing Research also manages Technology Research programs, to which Berkeley Lab has made important scientific contributions. Examples include novel applications of pet imaging for evaluating genetic treatment of Parkinson's Disease and a new photoelectron emission microscope at the Advanced Light Source (ALS) for studying micromagnetic structures.

Office of Basic Energy Sciences

Basic Energy Sciences programs focus on advanced materials and nanoscience, physical chemistry, and geosciences. The DOE Materials Sciences Program supports the Advanced Light Source—which provides the world's brightest beams of ultraviolet and soft x-ray radiation and with new superbend magnets is now a powerful source of harder x-rays for structural studies. The ALS has substantially increased the delivery of beamline-hours and its science user base over the past year, with more than 1,300 users. The National Center for Electron Microscopy is also a powerful user facility for the Basic Energy Sciences program. Berkeley Lab research addresses 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 Molecular Foundry, a proposed user facility, is now proceeding with conceptual design leading towards authorization for Title I detailed design. The Laboratory delivered on its commitments to the multi-lab partnership for building the front end of the Spallation Neutron Source with the commissioning of the front end in the Spring of 2002.

Berkeley Lab supports DOE's Chemical Sciences Program in the areas of chemical physics, dynamics and mechanisms of chemical reactions and combustion processes, catalysis, actinide chemistry, and atomic physics. A range of studies are conducted, including electron spectroscopy, laser-material interactions, photochemistry, theoretical chemistry, actinide studies germane to environmental issues, and electrochemical processes and systems. In support of the DOE challenge to predict and control chemical reactivity, Berkeley Lab has a special focus on fundamental studies of chemical reaction dynamics ranging from laser-based coherent control schemes to the development of first-principles understanding of homogeneous and heterogeneous catalysis. These investigations are greatly facilitated by the Chemical Dynamics Beamline at the ALS, and the Laboratory is expanding this program and related studies in dynamics of molecular and atomic processes with new scientific staff and renovated laboratories. The Molecular Environmental Sciences beamline is scheduled to begin operation in the Fall of 2002, which will advance the fundamental understanding of the complex interactions of contaminants with their environment at the molecular level.

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 draft of the human genome sequence; 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, including a new effort on the *Ciona* genome. 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.

The JGI has increased its production rates by more than twenty-fold to more than 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 functionally important microbes, including those important to DOE missions in energy and the environment, 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 (PBD) 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 Laboratory recently created a consortium to coordinate protein crystallographic and spectroscopic research at the ALS. The Berkeley Center for Structural Biology (BCSB) has a range of capabilities, including the Macromolecular Crystallography Facility and BioSpec. The BCSB is a national resource for the study and advancement of protein crystallography, and its facilities and management have made the ALS fully competitive with protein crystallography facilities worldwide. 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, multidisciplinary efforts combining the strengths of PBD and the Life Sciences Division (LSD) are being brought to bear on understanding the complex molecular assemblies or central units consisting of numerous interacting components that behave as small, self-contained molecular machines and which carry out the central functions of the cell. Research efforts at Berkeley Lab aim to employ innovative microscopies to characterize the structural dynamics of molecular machines, the cell-cell interactions, and the tissue context. Single particle cryo-electron microscopy, atomic force microscopy, optical tweezers microscopy, and single-molecule fluorescence microscopy are the selected methodologies for studies at the molecular level. They are being applied synergistically with x-ray crystallographic and small angle x-ray scattering studies to coordinate structural information with ongoing functional studies using molecular cell biology and biochemical approaches to understand the molecular machines responsible for maintaining the integrity of the genome. At the cell and tissue level Berkeley Lab's specific expertise in electron microscope tomography, soft x-ray imaging and tomography, and a variety of fluorescence optical sectioning microscopies such as two-photon, deconvolution, and confocal microscopy will be employed. Together and coupled with advances in computational image analysis, these techniques span a range of spatial and temporal resolution that will provide a uniquely detailed description of the DNA repair processes, the study of the dynamics of tissue formation and the reversion of the malignant phenotype, the effects of low-dose ionizing radiation, and the characterization of gene regulatory networks.

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 in the Life Sciences Division 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 areas related to the Office of Biological and Environmental Research mission. These include 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.

Berkeley Lab investigators conduct research to increase the understanding of radiation effects at very low doses to inform models of risk estimation. The radiation biology program in LSD encompasses molecular, cellular, and multicellular responses to low-dose radiation exposure. A major thrust is to identify genes involved in the response to DNA damage and to characterize genetic, molecular, and biochemical pathways associated with susceptibility to adverse radiation effects. The effect of radiation on the expression of specific genes is also being studied in cell signaling pathways. How radiation affects interactions between cells in the complex tissue environment is a central problem, and LSD researchers are using cell culture models and transgenic animals to address this issue. To gain further insights into rare and novel events underlying radiation effects, the ALS is being used for structural biology of DNA repair machines and microbeam irradiation, and further development of imaging bioinformatics is underway.

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 research on ocean carbon sequestration in partnership with Livermore Lab and other institutions is pursuing fundamental research on ocean sequestration including the assessment of the effectiveness and consequences of ocean fertilization and carbon dioxide injection. The research is fundamental to the feasibility, effectiveness, and environmental acceptability of ocean carbon sequestration. The effort includes 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.

Berkeley Lab computational scientists are collaborating with a multi-institutional team to merge two of the world's most advanced computer climate models, the Climate System Model (CSM) and the Parallel Climate Model (PCM). The merged Community Climate System Model (CCSM) is being designed to include the best features of both models and to perform well on a variety of computer architectures.

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. Recent efforts have resulted in the successful completion of low current experiments that addressed key science issues of space charge dominated beams, such as compression, merging, and focus ability. New experiments, now underway, involve driver scale currents in which new effects such as electron trapping may occur. Success in this work will allow the design of the Integrated Beam Experiment (IBX), which will conduct a wide range of experiments on beam dynamics, which essentially model a driver system. 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 Berkeley Lab fabricated Low-Energy Ring at the B Factory at Stanford Linear Accelerator Center is operating effectively, and the Laboratory has made essential contributions to the BaBar Detector, where all components are performing well. The experiments have successfully observed charge-parity violation in the B-meson system, and further physics analysis is underway.

The Collider Detector Facility at Fermilab (FNAL) 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, and has led commissioning activities at FNAL.

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 Scientific Vision below, and 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.

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 2002 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. 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). Exciting first physics results were presented at Quark Matter 2001. Berkeley Lab scientists play a leading role in all aspects of analysis and publication of STAR results, with a fruitful publications record. 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. The 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. Gammasphere will move to Argonne at the end of 2002. Plans are underway to acquire clover configuration Germanium Detectors that can be coupled to the Berkeley Gas-filled separator (BGS) to 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 2002 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 ion source 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 new 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. The 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. KamLAND was commissioned in January 2002 and data taking is underway. 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.

In addition, the Laboratory works with the Office of High Energy and Nuclear Physics 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.

Workforce Development for Teachers and Scientists

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 the professional development of teachers and also promote student achievement in the sciences by facilitating the inclusion of students from local urban backgrounds into careers in science and technology.

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 Student Undergraduate Laboratory Internship Program. In response to the nations needs qualified science, mathematics and technology teachers, undergraduate students preparing for teaching careers can participate in the 10 week summer research Preservice Student Teacher Fellowship Program. The Faculty Student Teams program supports collaborative summer research opportunities with an emphasis on faculty and students from community colleges and under represented minority service institutions. Students from community colleges in California and across the nation can apply for summer internships in the Community College Institute of Science and Technology. Selected science teachers from across the nation will participate in an 8 week summer research experience under the Laboratory Science Teacher Professional Development program.

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.

Office of Energy Efficiency and Renewable Energy

The Berkeley Lab program in Energy Efficiency and Renewable Energy comprises an integrated set of 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 the National Transmission Grid study 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 Electricity 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 federal/industry partnerships for advanced vehicles, including Freedom CAR, 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.

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's Yucca Mountain Project site characterization research was important to DOE's recent decision to proceed. The Laboratory is also contributing to international radioactive waste management 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 emissions reduction. 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.

National Nuclear Security Administration

Berkeley Lab's unique capabilities in accelerators have been 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.

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 onsite 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. The Front End has been completed and is being commissioned.
- 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 1300 users this year to 2000 by 2004. Concomitant with this increase is support in 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 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 a broad program of 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 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 (see Section IV, Initiatives).
- For the National Institute for Biomedical Imaging and Bioengineering (NIBIB), the Life Sciences Division is conducting research to improve scintillators for positron emission tomography, and to improve algorithms for image reconstruction.
- 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.

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 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.

All DOD research conducted onsite at Berkeley Lab is unclassified. The larger projects include:

- For the Department of Defense, the Life Sciences Division conducts a major breast cancer research program to analyze a large number of existing aggressive tumor cell lines and primary tumors in order to find novel ways of normalizing them with combination treatments that can reverse the malignant behavior of the cells.
- For ONR, the Physical Biosciences Division conducts a program for engineering biomolecules and biological processes to create novel cell-based sensory and signaling systems.
- For 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 (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, as well as studies in an autonomous profiler for carbon systems and biology.

Computational research supported by NASA includes spectrum synthesis of supernovae, development of cosmic microwave background analysis tools, and development of adaptive mesh refinement algorithms for simulating plasma effects in the magnetosphere. Berkeley Lab also provides program management for the Information Power Grid, NASA's high performance computational grid.

Environmental Protection Agency (EPA)

Research sponsored by the Environmental Protection Agency 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 at Berkeley Lab 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; international appliance standards under sponsorship of the Alliance to Save Energy; and foundation support for efficient water treatment systems in underdeveloped countries.
- 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, ten-meter telescope control systems, and atomic-scale studies of catalysts.

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 past year, LDRD funds were allocated to Berkeley Lab's Energy Sciences research area in, as examples, laser-assisted photoabsorption of x-rays, study of radionuclide-bacterial interaction mechanisms, geologic sequestration of carbon dioxide through hydrodynamic trapping mechanisms, carbon-climate interactions, isotopic analysis of carbon sequestration in terrestrial ecosystems, atmospheric chemistry changes at the interface between urban and regional scales, diesel particle detection and control, and nanoscale transport in ultra-thin films. Research efforts in the General Sciences included compact neutron generator for moderator design, first chemical study of element hassium, large astrophysical data sets, advanced simulation of complex beam systems, and design of digital signal processing electronics for high-resolution radiation detectors. Efforts in the Biosciences areas included transgenic mouse models for DNA damage sensing and repair, development and application of the general theory of hydrophobicity to interpret stability and dynamics of biological assemblies, transgenic optical sensors for live imaging of neural activity, high-sensitivity *in-vivo* crosslinking method, and tracking proteins in light and soft x-ray microscopy. Research in the Computing Sciences areas included high-precision arithmetic with applications in mathematics and physics, electron collision processes above the ionization threshold, feature-based representation and reconstruction of geophysical data, sparse linear algebra algorithms and applications for text classification in large databases, and interactive electron microscopy enhanced with virtual reality.

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. A few 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.
- **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.

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 DOE PROGRAM GOALS

Berkeley Lab participates in the development and implementation of DOE science and technology goals. Berkeley Lab's Scientific Vision (below) is based on supporting the strategic objectives articulated in DOE plans.

Supporting DOE Strategic Objectives

In support of the Office of Basic Energy Sciences (BES), Berkeley Lab is addressing the challenge to understand, design, and synthesize systems with nanoscale dimensions. This effort is part of a Laboratory research portfolio that supports the BES strategic objectives "to deliver the scientific knowledge and discoveries in the basic energy sciences that underpin DOE missions in energy, national security, and environmental quality; to advance the frontiers and the scientific interrelationships among materials sciences, chemical sciences, biosciences, and geosciences in order to expand the scientific foundations for safe, secure, and efficient systems of energy supply and utilization and for understanding and mitigating the adverse environmental impacts of energy use…" Berkeley Lab anticipated results for addressing the BES objectives include delivering on key BES targets (as examples):

- Begin construction of the Molecular Foundry BES Nanoscale Science Research Center, meeting the cost and scope within the proposed baseline.
- Maintain and operate the Advanced Light Source and the National Center for Electron Microscopy so that unscheduled downtime is significantly less than 10 percent of the total scheduled operating time, identified as the BES target.
- Fully meet the commitment for the Front End of the Spallation Neutron Source, including the delivery of the completed Front End to Oak Ridge National Laboratory, meeting the cost and scope defined in the baseline specified in the BES target.

The nanoscience 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 Research (ASCR) and in partnership with the system of DOE national laboratories, information technology is becoming a powerful new tool for scientific discovery. The Laboratory is working to address the ASCR strategic objective "to deliver scientific knowledge and discoveries in strategic areas of applied mathematics, computer science, and network and collaboratory research; to bridge the gap between advanced research in applied mathematics and computer science, and computational science research in the physical, chemical, biological, and environmental sciences; to operate the world class high performance computing and network facilities; and to maintain the vital human capital required for the success of the science programs and DOE missions." NERSC Center is managed to focus on this objective, ESnet provides nationwide and international connectivity enabling the entire DOE community to take advantage of multiteraflop power of DOE science computing infrastructure and data intensive science challenges. Berkeley Lab anticipated results for addressing the ASCR objectives include delivering on key ASCR targets (as examples):

- Begin installation of the next generation NERSC Center computer, NERSC-4, which will greatly increase the capability available to solve leading edge scientific problems.
- Maintain and operate NERSC Center and ESnet so that the unscheduled downtime is significantly less than 10 percent of the total scheduled operating time, identified as the ASCR target.
- Lead and collaborate with other research institutions on the ASCR program of Scientific Discovery through Advanced Computing (SciDAC), and deliver results as elements of SciDAC application teams.

Berkeley Lab conducts leading research in particle physics, astrophysics and nuclear physics. The efforts support the Office of High Energy and Nuclear Physics (HENP) goals "to deliver the scientific knowledge and discoveries to unlock nature's most fundamental and persistent secrets—the essence of matter and energy, the origin of mass, and the nature of the powerful forces that govern the universe; to extend the frontiers of high energy physics with experimental measurements and collaborations that challenge conventional theories (and advance new ones) on the complex and mysterious interactions between matter, energy, time, and space and that press the limits of design in particle accelerators with resulting benefits to many fields of science"…and…"to extend the frontiers of nuclear physics and the accompanying leading-edge tools that contribute to many other fields of science, testing conventional and new theories on the dynamic forces that govern the formation and behavior of nuclei, and theories of the processes by which quarks and gluons coalesce to form nucleons and ultimately, nuclei, the basis for all elements." 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. The Laboratory has developed and deployed the Solenoidal Tracker at RHIC for exploring the quark-gluon plasma and participates in the planning and development of the Rare Isotope Accelerator (RIA) an important priority of the nuclear physics community, and a stable beams accelerator at Berkeley Lab. Berkeley Lab anticipated results for addressing the HENP objectives include delivering on key HENP targets (as examples):

- Deliver on commitments for ATLAS detector components including tracking modules and other key elements of the ATLAS detector project.
- Deliver on commitments for the Large Hadron Collider (LHC) Accelerator components including the absorbers to protect magnets from particle flux; the distributed cryogenic feedboxes; and other key elements of the LHC project.
- Develop technologies and approaches to investigating dark energy and the state of the universe through space-based observation of supernovae, cosmic ray background, and other cosmological phenomena
- Continue the Collider Detector at Fermilab (CDF) and D0 silicon particle tracker upgrades, meeting radiation hardening requirements.
- Complete and test a prototype and components of the Gamma Ray Tracking Detector (GRETA).
- Maintain and operate the 88-Inch Cyclotron so that unscheduled downtime is significantly less than 10 percent of the total scheduled operating time, identified as the NP target.

With the Office of Biological and Environmental Research (OBER), Berkeley Lab is advancing fundamental biology to understand microbes, mammalian cells and organismic functions in their environments. The efforts at Berkeley Lab directly support OBER's strategic objectives "to extend the frontiers of biological and environmental research and discover the fundamental operating principles of biological systems through research in structural biology, genomics, and functional genomics; to explain the role of greenhouse gases in climate and environmental change; to enable, through basic research, novel biotechnology solutions for energy, environmental cleanup, and biothreat defense; and to provide innovative diagnostic and treatment technologies for human health." Berkeley Lab's Genomes-to-Life activities focus on an integrated program of environmental microbiology, functional genomic measurement, and modeling to understand the basic biology of microbial systems (see Section IV, Initiatives). Research directed to understand how molecules work in assemblies as molecular machines and how cell architecture develops from the one-dimensional DNA code and amino acid sequence complements these efforts. New imaging technologies help to determine the effect of low-dose radiation and other environmental factors. Non-invasive imaging is being developed to study the regulatory function of genes and their products in intact systems. In support of DOE's Functional Genomics efforts, Berkeley Lab is working with the Joint Genome Institute to understand the significance of gene coding and non-coding regions and the possible role of non-coding regions in the control of gene expression. Carbon cycle research in ocean and terrestrial system is addressing the role of greenhouse gases in environmental change. Berkeley Lab anticipated results for addressing the OBER objectives include delivering on key OBER targets (as examples):

- Increase the DNA sequencing capacity of the DOE Joint Genome Institute (JGI) to approximately eight billion base pairs of DNA sequence per year, a 100 percent increase in the projected capacity over 2001. The JGI has now exceeded this sequencing target, having recently completed 1 billion base pairs in a single month.
- Produce draft DNA sequences of more than 30 microbes vital to future U.S. interests and DOE missions.
- Improve climate model performance, increase spatial resolution, and increase the number of model years simulated (in conjunction with Computational Research Division, NERSC Center and other institutions).

For Fusion Energy Sciences, Berkeley Lab applies its accelerator physics, engineering, and plasma science capabilities to address the key questions for Inertial Confinement Fusion. These efforts support the strategic objectives of the Office of Fusion Energy Science (OFES) "to deliver knowledge and discoveries in plasma science, fusion energy sciences and fusion technology, providing the knowledge base needed for an economically and environmentally attractive fusion energy source; to extend the frontiers of the fundamental science of plasmas, exploring their complex and dynamic properties that are likely to lead to their application in other areas of science." In supporting this objective, Berkeley Lab focuses 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, multiple-beam experiments, source development, merging and focusing experiments provide encouragement and justification to conduct an integrated program of larger, more complex experiments on the road to such a driver. Berkeley Lab's expertise in this science has lead to diverse applications including in the development of the accelerator DARHT at Los Alamos, and for ion and beam sources for applications such as homeland defense. Berkeley Lab is conducting research for the OFES objective to develop the science and technology of high average power drivers and energy producing targets for attractive inertial fusion energy systems, including results from key experiments (as examples):

- Complete of low current experiments that address key science issues of space charge dominated beams, such as compression, merging, and focusability.
- Complete experiments on driver-scale currents to study effects such as electron trapping.
- Proceed with design of the Integrated Beam Experiment (IBX) for experiments on beam dynamics to model a driver system.

Berkeley Lab is developing energy-supply and energy-efficient technologies and minimizing the environmental impacts of energy use. The efforts support the Office of Energy Efficiency and Renewable Energy (EERE) research activities for "…Advanced energy-efficient technologies and practices that use less energy, as well as renewable energy and natural gas technologies that produce power and heat more cleanly than conventional sources, are well on their way to becoming today's answers to tomorrow's energy challenges. Advances springing from EERE's research and development (R&D) programs range from improvements already seen directly in our everyday lives (e.g., much more efficient light bulbs, refrigerators and other appliances, and electric motors) to new approaches for large baseload energy technologies (e.g., combined heat and power systems)." The majority of Berkeley Lab's activities are directed to EERE's strategic goal to "modernize energy conservation." These efforts continue to play a pioneering role in development of advanced energy-efficient building technologies and in studies of indoor air quality. Berkeley Lab anticipated results for addressing the EERE energy conservation objectives include delivering on key EERE program (as examples):

- Advance technology on key buildings technologies, including lighting and zero-energy buildings programs that are priorities in the EERE FY 2003 budget proposal.
- Conduct an indoor air quality program that delivers on EERE indoor air quality objectives and also contributes to homeland security through modeling the potential movement of hazardous agents in buildings.
- Contribute to EERE's research infrastructure through planning with EERE managers for an effective capital improvements program, including the development on an E-Lab at Berkeley.

BERKELEY LAB SCIENTIFIC VISION

Berkeley Lab's Scientific Vision identifies key scientific directions that support the strategic objectives 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 the Laboratory's Scientific Vision: 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.
- **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 the Laboratory's core capabilities. Understanding dark energy is emerging as an important national priority in the nation's physics community. 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 dark 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.** DOE now has some of the most powerful sequencing capabilities in the world and the most productive facilities for determining macromolecular structures. Further development of these and 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. Finding new methods to characterize the regulatory networks of microorganisms and creating validated models of biological responses in the environment are important new frontiers. Berkeley Lab's Genomes to Life efforts are directed towards an integrated program of environmental microbiology, functional genomic measurement, and computational analysis and modeling to understand the basic biology of microbial systems and to restore contaminated environments. Biology, mostly an observational science in the last century, is on its way to becoming a predictive quantitative science in the 21st century.

- **New Energy Sources and Solutions.** Three pivotal energy issues are appropriate subjects for Berkeley Lab Scientific Vision: How can the nation provide secure and reliable supplies of electricity and other forms of energy? How might technology be applied to reduce public energy consumption in support of DOE's goals to modernize energy conservation? What are the long-term global consequences of energy use and how can potential problems be mitigated? Berkeley Lab has been a leader in the areas of energy and the environment. Consumer products and energy-efficiency analysis tools developed here have saved billions of dollars in annual energy costs. The proposed E-Lab, an energy efficiency and electricity reliability laboratory will further the nation's goals in energy security. For two decades, the Laboratory has pursued the concept of heavy-ion fusion, increasingly viewed as a practical possibility in the effort to harness fusion energy. In addition, the Laboratory stands ready to develop a design for an Integrated Beam Experiment (IBX) 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.** The ability of computer-based simulation to predict the behavior of extraordinarily complex natural and engineered systems is growing steadily, but there is a gap between the theoretical peak performance of supercomputers and the actual performance of scientific application codes. Bridging this performance gap is a key goal of DOE's new initiative in Scientific Discovery through Advanced Computing (SciDAC). Berkeley Lab has made a major commitment to SciDAC by providing leadership on six projects, including the DOE Science Grid and three of the six Integrated Software Infrastructure Centers, as well as collaborating on another six projects. The National Energy Research Scientific Computing (NERSC) Center supports SciDAC and all of the Office of Science research efforts by providing the 5-teraflops IBM SP3/RS 6000 and 2.5 petabytes of data storage capacity. In addition to the comprehensive scientific support NERSC Center has traditionally provided, NERSC Center's strategy includes intensive support for Scientific Challenge Teams and deployment of Grid technologies to create a Unified Science Environment.

These five themes describe our scientific vision, and we are maintaining our focus on the tools and resources that are needed to deliver on DOE's missions. These capabilities and research directions also address threats to homeland security, including the development of diagnostic beams and detectors, characterizing environmental hazards, and modeling chemical and environmental responses.

OPERATIONS STRATEGIC DIRECTION

A key management direction is to sustain high levels of scientific productivity now and for the future. As indicated below, achieving Berkeley Lab's Scientific Vision and delivering results is also a part of the Operations strategic planning effort, to provide support for science that is effective, efficient, and safe.

- **Best Operational and Administrative Practices**. Berkeley Lab is committed to improving management efficiencies, eliminating redundancy, and focusing on results. The Best Practices Pilot Study, conducted at the request of DOE leadership, identifies principles for efficiently and effecting administering and operating a scientific laboratory. These key best practices principles are: (1) Line Management Accountability (2) National Standards (3) Assurance Reviews by External Experts; (4) Bilateral Decision Process (5) Oversight and Incentives Based on Certified Systems Metrics; and (6) Results-Based Management Contracting. Berkeley Lab is focused on working with DOE, the UC Office of President to frame a five-year results-based DOE-UC Contract and management relationships anchored in Best Practices principles. A results-based contract and well-defined management relationships offers the prospect of effectively and efficiently delivering on goals of the Office of Science, DOE, and the Administration. The effort directly supports the new results-based policies of DOE and the Office of Management and Budget, the President's Management Agenda, and the Government Performance and Results Act of 1993.

- **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 Science Lab Infrastructure 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.
- **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 established a new Integrated Project Management Office that coordinates senior management reviews to assure high performance and a continued reputation as location-of-choice for major science projects. The Office coordinates an Integrated Project 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.
- **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. Berkeley Lab has 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; maintains 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.
- **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 division 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 Laboratory is working to improve minority recruitment in key areas through targeted outreach efforts and a long-term School-to-Work program. 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.
- **Integrated Safeguards and Security Management.** 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 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)
- DOE Scientific Networking Driven by High Impact Science

Office of Basic Energy Sciences

- Molecular Foundry
- Advanced Light Source Science Strategic Plan
- Dynamic Atomic Resolution Microscopy at the National Center for Electron Microscopy (NCEM)
- Femtosecond Structural Dynamics User Facility
- Multipurpose, Low-Cost Laboratory for Neutron Science
- Toward the Design and Construction of Autonomous Nanobots
- Science for Homeland Security

Office of Biological and Environmental Research

- Genomes to Life
- Center for Single-Molecule Studies
- Structural Cell Biology of DNA Repair Mechanisms
- Biological Imaging from Molecules to Cells and Tissues
- Biological Effects of Low-Dose Ionizing Radiation
- Decoding Genomes for Protein Binding Sites
- Neuroscience

Office of Fusion Energy Sciences

- Heavy-Ion Fusion Integrated Beam Experiment

Office of High Energy and Nuclear Physics

- Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP)
- Accelerators for the High Energy Physics Frontier
- GRETA (Gamma-Ray Energy Tracking Array)
- Experiments at the National Underground Science Laboratory

Workforce Development of Teachers and Scientists

- Securing the Next Generation of Scientists and Engineers

Office of Energy Efficiency and Renewable Energy

- E-Lab: Energy Efficiency and Electricity Reliability Laboratory

Office of Fossil Energy

- Geologic Sequestration

Office of Civilian Radioactive Waste Management

- New Science at Yucca Mountain

Work for Others

- Advanced Controls for Energy Efficiency and Distributed Energy Systems (California Energy Commission with EERE)

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. 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.

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.

Berkeley Lab scientists are leading the following six SciDAC programs (the first three are Integrated Software Infrastructure Centers):

- **Algorithmic and Software Framework for Applied Partial Differential Equations.** The goal is to develop a high-performance framework for solving partial differential equations arising from problems in magnetic fusion, accelerator design, and combustion—key mission areas for DOE.
- **Scientific Data Management Center.** Terascale computing (performing trillions of calculations per second) and large scientific experiments produce enormous quantities of data that require effective and efficient management, a task that can distract scientists from focusing on their core research. The goal of this project is to provide a coordinated framework for the unification, development, deployment, and reuse of scientific data management software.
- **Performance Evaluation Research Center (PERC).** This project focuses on how specific scientific applications can best be run on high-performance computers. The results of this research are expected to permit the generation of realistic performance levels, and to determine how applications can be written to perform at the highest levels and how this information can be applied to the design of future applications and computer systems.
- **DOE Science Grid.** This is a multi-laboratory collaborative project to develop, evaluate, and deploy the needed services to support the DOE Science Grid. A grid refers to an infrastructure that enables the integrated, collaborative use of high-end computers, networks, databases, and scientific instruments owned and managed by multiple organizations. Grid applications often involve large amounts of data and/or computing and often require secure resource sharing across organizational boundaries, and are thus not easily handled by today's Internet and Web infrastructures. Such an infrastructure is expected to revolutionize collaborative research by teams of scientists around the nation.
- **Advanced Computing for 21st Century Accelerator Science and Technology.** This project will establish a comprehensive terascale simulation environment for use by the U.S. particle accelerator community. This simulation environment will enable accelerator physicists and engineers across the

country to work together to solve the most challenging problems in accelerator design, analysis, and optimization, advancing the frontiers of accelerator science and technology. (Project leadership shared by Berkeley Lab and Stanford Linear Accelerator Center).

- **Advanced Methods for Electronic Structure.** This project is one of several in the area of chemical sciences and will focus on the calculation of the physical and electronic structure of molecules with greater accuracy. (Project leadership shared by Pacific Northwest National Laboratory and Berkeley Lab).

Berkeley Lab scientists are also collaborating with other national laboratories and universities on the following SciDAC projects:

- **Terascale Optimal PDE Solvers (TOPS) Center.** Large-scale simulations of importance to DOE often involve the solution of partial differential equations (PDEs). In such simulations, continuous (infinite-dimensional) mathematical models are approximated with finite-dimensional models. To obtain the required accuracy and resolve the multiple scales of the underlying physics, the finite-dimensional models must often be extremely large, thus requiring terascale computers. This project focuses on developing, implementing, and supporting optimal or near optimal schemes for PDE simulations and closely related tasks.
- **Collaborative Design and Development of the Community Climate System Model for Terascale Computers.** A multi-institutional team will develop, validate, document, and optimize the performance of this coupled climate model using the latest software engineering approaches, computational technology, and scientific knowledge.
- **Scalable Systems Software Center.** This project addresses the lack of software for effective management and utilization of terascale computing resources. This project will create a virtual center of experts working together to develop an integrated suite of machine-independent, scalable systems software needed for the SciDAC program. The goal is to provide open-source solutions that work on systems ranging in size from small to large.
- **National Collaboratory to Advance the Science of High-Temperature Plasma Physics for Magnetic Fusion Energy.** The National Fusion Collaboratory will advance scientific understanding and innovation in magnetic fusion research by enabling more efficient use of existing experimental facilities and more effective integration of experiment, theory, and modeling throughout the national magnetic fusion research community, comprising over 1,000 researchers from over 40 institutions. The National Fusion Collaboratory will enable networked real-time data analysis and instantaneous communication among geographically dispersed teams of experimentalists and theoreticians.
- **Earth Systems Grid II—Turning Climate Databases into Community Resources.** High-resolution, long-duration simulations performed with advanced DOE climate models will produce tens of petabytes of output. To be useful, this output must be made available to global change impacts researchers nationwide, both at national laboratories and at universities, other research laboratories, and other institutions. This project will create a virtual collaborative environment that links distributed centers, users, models, and data, significantly increasing the scientific productivity of U.S. climate researchers by turning climate datasets into community resources.
- **Particle Physics Data Grid Collaborative Pilot.** This pilot project will develop, acquire, and deliver vitally needed Grid-enabled tools for data-intensive requirements of particle and nuclear physics. Novel mechanisms and policies will be vertically integrated with Grid middleware and experiment-specific applications and computing resources to form effective end-to-end capabilities.

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

	2002	2003	2004	2005	2006	Total
Operating**	7.4	6.2	6.6	6.9	7.6	34.7

*Preliminary estimate of Berkeley Lab Budget Authority, including equipment (B&R Codes KJ, KC, KA, KB)
**Resource projections are per total submitted Field Work Proposals (FWP); actual funding decisions are under review by appropriate DOE program offices.

DOE Scientific Networking Driven by High Impact Science

The vision for DOE scientific networking is that major DOE applications and facility-based experiments will interconnect with widely distributed terascale supercomputing, petascale storage, high-performance visualization, and remote collaborators, to dynamically create virtual laboratories. This will provide unprecedented presence and interaction for all of the participating scientists, and enable the interplay of theory, simulation, and experiment, which in turn should lead to new ways of approaching science problems and new levels of scientific productivity.

In order to achieve this vision, Berkeley Lab and collaborators have prepared a white paper for consideration by DOE that proposes a multi-pronged approach. This approach describes the framework in which DOE provides the most effective and the highest possible performance networking where needed by its high impact science. This framework will continue to provide required high quality network capabilities to DOE and its community. At the same time, it will integrate the DOE's networking programs, facilities, and expertise into a more effective and efficient enterprise. This approach has six major components:

- **DOE science programs will identify the high impact projects that set the scientific networking priorities.** This approach is intended to tie the operation and evolution of DOE's scientific networking to DOE's high impact science projects, facilities, and teams. This entails: providing network expertise for high-performance, distributed science applications; involvement of distributed-application scientists for feedback to network engineers; and an Office of Science program-based mechanism for prioritizing network resources based on science project impact.
- **High-Performance Production Network (HPPN).** Provides a high bandwidth production network to enable integration of widely distributed DOE resources. The HPPN is the flagship Office for Science network that supports the scientific program with high quality networking and services to support distributed science.
- **Advanced Scientific Applications Pilot (ASAP) Network.** Provides advanced pilot networks to develop new capabilities for high-end science applications and deploy new network features. The ASAP Networks address key science application areas that have very bandwidth-intensive requirements and can benefit from early access to very high bandwidth and advanced services not yet deployable in full production. It will also bridge the gap between the network technology focused testbeds and the HPPN.
- **Advanced Network Technology Consortium Testbed (ANTCT).** Provides advanced network technology testbeds to shape the next generation networks for science. In order to meet the needs of science that is experiencing exponential growth in the collection and analysis of data, vastly higher effective bandwidths than are available with today's technology are needed. The role of the ANTCT is to explore network technology that DOE science networks will need in five, seven, or more years.
- **Advanced Services.** Provide a suite of shared middleware services for enabling distributed science applications. The success of advanced distributed science applications depends critically on distributed middleware services in order to build realistic and reliable distributed applications. A

suite of advanced services will be deployed in an integrated and non-redundant manner across the individual networks.

- **Provide improved ways to introduce new network technology that enhance networks for effective science and new middleware features.** The approach includes methods of information and technology flow between the three networks to enable timely introduction of new network services and features that improve the effectiveness of the science drivers using the networks.

The following table indicates some of the basic differences of the three networks:

Characteristics of the Networks

Service Characteristic	HPPN Network	ASAP Network	ANTCT Network
Bandwidth relative to current ESnet	4 times i.e., 2.5 Gigabytes per second (Gbps)	16 times i.e., 10 Gigabytes per second (Gbps)	Defining characteristics will probably be different network architecture, protocols, etc.
Number of sites	30 to 50	4 to 6	Determined opportunistically
Maturity of applications	Full range of production applications	Limited set of early adapter applications	Experimental applications and application kernels
Reliability	99.9%	95 to 98%	50 to 80%
Mean time between failure	Months	Weeks	Days
Mean time to repair	2 to 4 hours	Next business day	Days to weeks

Scope and Resource Requirements are currently under discussion with DOE and relevant parties.

Office of Basic Energy Sciences

Molecular Foundry

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 user facility 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 nearby 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 National Center for Electron Microscopy 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 Resource Requirements ($M)*

	2002**	2003	2004	2005	2006	2007	Total
Operating	3.0	3.0	3.0	3.0	6.0	24.0	42.0
Construction and equipment	1.4	6.8	35.0	32.0	9.8	0.0	85.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC)
** Includes prior year funding.

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.

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 workshops, 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 four to ten instrumentation staging areas. The number of users at the ALS has more than quadrupled in three years to over 1300 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 our strategic planning process, the high priority aspects of the plan are reflected in recent proposals for experimental facilities that enable the ALS to address forefront scientific areas:

- **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, narrowgap undulator beamline at the ALS. This beamline will is to be 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.
- **Ultrahigh Resolution Spectroscopy Beamline.** The high productivity of the heavily oversubscribed beamline 10.0 for high-resolution photoemission is leading to a proposal for a new beamline dedicated to ultrahigh resolution (meV) spectroscopy. The beamline would have a low energy (<100 eV) EPU and a monochromator with two innovative end stations, one dedicated to meV-resolution photoemission, and one to high-resolution inelastic scattering. The primary program would be directed towards the study of highly correlated materials.
- **Coherent Far-Infrared/Terahertz Synchrotron Source**. Intense broadband sources over the traditionally difficult wavelength range of 100 microns to a few millimeters will enable a number of exciting scientific applications. These include low energy excitations in highly correlated materials, nonlinear dynamics in novel materials, and new medical imaging techniques. We are exploring options for a small dedicated synchrotron for producing coherent far-infrared/terahertz radiation. The ring design will capitalize on existing ALS infrastructure such as an existing injection system and user support facilities. The new ring will extend and complement the scientific capabilities at the ALS.

- **Protein Crystallography.** The substitution of the central bend magnets in the ALS storage ring with high-field superconducting dipole magnets (superbends) has generated 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 is now establishing 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, metalinsulator 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 additional staff so that the facility takes over responsibility for the operation of the BES beamlines over a three-year period from FY 2004 through FY 2006.

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

	2002	2003	2004	2005	2006	2007	Total
Operating	31.8	33.2	38.0	40.9	43.9	46.8	234.6
Equipment	4.7	4.2	4.0	4.0	4.0	4.0	24.9
ARIM/AIP	2.1	2.2	4.0	4.0	4.0	4.0	20.3
WFO	1.3	1.2	1.2	1.2	1.2	1.2	7.3

*Preliminary estimate of total Berkeley Lab Budget Authority (B&R Code KC) and Work For Others

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 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 determination and refinement from individual nanocrystals and defects; real-time *in-situ* observation of atomic-level mechanisms and dynamics; and 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 sub-eV spectral resolution. As a forefront development project, with a single "beam line," this machine is expected to serve a more limited user community than the high-voltage instrument. Complementary instruments optimized for different performance criteria will be installed at the three sister facilities.

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

	2003	2004	2005	2006	2007	Total
Operating	1.0	1.0	2.0	2.0	2.0	8.0
Equipment	10.0	15.0	5.0	3.0	2.0	35.0
Construction	3.0	4.0	0.0	0.0	0.0	7.0

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

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 sponsored a workshop in April, 2002 that brought 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 was the core focus area for this workshop, which was 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 following the workshop. Written justification outlining the science and the machine is being prepared, and facility cost is currently being refined.

Femtosecond Structural Dynamics User Facility
Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	1.4	8.0	8.0	0.0	0.0	17.4
Construction	0.0	0.0	0.0	30.0	50.0	80.0**

*Preliminary estimate of Berkeley Lab Budget Authority.
**Additional out year construction resources being estimated. (B&R Code KC)

Multipurpose, Low-Cost Laboratory for Neutron Science

Neutrons offer unique advantages for studying the properties of materials and biological samples. They constitute a valuable scientific probe for use in neutron scattering, activation analysis, radiography, radiation biology, and medicine. Opportunities with cold neutrons in particular include investigation of disordered materials, magnetic structures, thin films and multilayers, and hydration structures of biological macromolecules. With the Spallation Neutron Source (SNS) now well into construction, the U.S. neutron scattering community will soon have the most advanced neutron scattering facility in the world. Providing more opportunities for neutron science and training is of great importance for developing a strong user community capable of taking full advantage of the SNS. In their December 2000 review, BESAC has recommended the establishment of a program to expand the university base for neutron scattering. This initiative offers a low-cost and timely response to this recommendation.

Novel, compact neutron generators are presently being developed at Berkeley Lab that are capable of producing a neutron yield several orders of magnitude higher than those of conventional neutron tubes. This new type of neutron generator offers an opportunity to set up low-cost neutron laboratories for science and teaching. Equipped with a suitable instrument for neutron scattering, such a laboratory could be used for neutron diffraction and reflectometry studies in condensed matter, material sciences, and biology. Further, the neutron laboratory would be very well suited to serve a number of other applications including instrumentation development, in particular moderator studies and detector development for spallation neutron sources, Prompt Gamma-ray Activation Analysis (PGAA), radiography, cold neutron depth profiling, and biology and medicine. The neutron laboratory would be ideal for training as it could provide hands-on experience for students in all areas of neutron science.

We propose to establish a neutron laboratory based on the high-intensity, compact neutron generator technology developed at Berkeley Lab. This is a joint initiative involving Berkeley Lab's Accelerator and Fusion Energy Research and Engineering Divisions, working together with Departments of the UC Berkeley campus. The proposed facility will be located at Berkeley Lab and provide access to researchers from many scientific divisions, as well as students and faculty from UC Berkeley. The neutron laboratory will provide space for a neutron scattering instrument, an area for detector and instrumentation development, and room for other types of measurements such as neutron activation and radiography. A modular moderator and shielding arrangement will allow for rapid reconfiguration and optimization for different applications. The neutron tube will be capable of producing a time averaged neutron yield of ~1×10^{12} neutrons per second using deuterium-deuterium (D-D) and ~1.5×10^{14} neutrons per second using deuterium-tritium (D-T) with a power consumption of 400 kilowatts when operated at a tube voltage of 120 kilovolts. Significantly higher neutron output is possible with more advanced tube designs. Because the fabrication of the generators themselves is rather inexpensive, tubes of different sizes and source strengths will be fabricated. The neutron laboratory will serve as a prototype for other laboratories to be built at research universities across the country. Easy accessibility will encourage researchers to utilize neutrons as a research tool in their studies.

Multipurpose Neutron Science Laboratory Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Construction	0.0	0.9	1.9	1.8	0.0	0.0	4.6
Operating	0.0	0.0	0.1	0.5	1.0	1.0	2.6
Equipment	0.0	0.0	0.0	0.0	0.1	0.1	0.2

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

Toward the Design and Construction of Autonomous Nanobots

The Advanced Instrumentation Initiative Towards the Design and Construction of Autonomous Nanobots proposes to develop the next generation of tools for single-molecule studies. These technologies will advance research into complex biomolecular systems underway in the OBER program M^3 (Microscopies of Molecular Machines) and are the foundation of the Center for Single-Molecule Studies initiative, described below in the Office of Biological and Environmental Research. These twin proposals form a core of research and resources from which to elucidate the complexity and dynamics of the living cell from its molecular components. The range of techniques proposed here, together with the concentration of expertise in these methods at Berkeley Lab, make this initiative the first of its kind in the U.S.

The pace of technological progress in single-molecule manipulation and detection techniques is developing rapidly throughout the world. During the last five years, the design and operation of techniques such as optical tweezers and force microscopes and single-molecule fluorescence microscopy has improved steadily and their performance is now robust. Moreover, there is a growing realization in the scientific community that single-molecule approaches may be the only way to address mechanistic questions about the complex dynamics processes of large molecular assemblies in the cell. Finally, new developments in the synthesis of nanoscale mechanical and optical devices are likely to have a decisive impact on the power of single-molecule methods to investigate the dynamics of complex biomolecular assemblies.

This project intends to develop the next generation of biophysical imaging and manipulation instrumentation that will permit direct visualization of molecular machines one at a time. Merging complementary, and partly established, microscopies including optical tweezers, atomic force microscopy (AFM), and fluorescence as well as unique instruments like those described below will cover spatial resolutions from 1 to 10^3 nanometers and have time resolutions from minutes to milliseconds. These novel techniques will be ideally suited to the large molecular dimensions and turnover times of these machines.

A number of new experiments in material science and molecular biology will become feasible for the first time. Examples of these new instruments and the applications they will enable follow:

- **Combined Optical Tweezers/Single-Molecule Florescence Microscope.** This instrument will make it possible to capture a fluorescence signal emitted from a single molecule while it is mechanically acted upon by an optical trap. Compared to the current generation of instruments, that either look at molecules (using fluorescence) or interact with them (using mechanical force), this corresponds to grabbing them and feeling *and* seeing how they respond to our manipulations.
- **Combined AFM/Single-Molecule Fluorescence Microscope.** This instrument will make it possible to simultaneously monitor the sample mechanically and spectroscopically. By using a conventional inverted optical microscopy configuration, it will be possible to apply this instrument to a wide variety of already established experimental geometries, e.g. manipulation of cultured cells in optically transparent dishes. Such an instrument will make it possible to determine the effect of pressure on the optical properties of quantum dots. One could also monitor changes in cytoskeletal or in transcription activity of cells acted upon by mechanical force, a subject of much interest today in cancer research.

- **Materials Science: Development of Nanoscale Sensors of Mechanical Force (Application).** What if one could directly measure mechanical forces inside living cells, using some form of microscopic sensor? One material that can be used to build such a sensor is RNA. Using a small RNA hairpin that has been chemically modified to include acceptor and donor fluorophores at its ends, the sensor can be calibrated using a combined AFM/single-molecule fluorescence microscope, by applying tension to the sensor (using the AFM probe) and monitoring FRET efficiency with the single-molecule fluorescence microscope. This method will clarify the relationship between FRET efficiency vs. force, allowing the sensor to be used to detect and quantify mechanical forces inside the cell. It should be possible to design RNA hairpins with different critical forces and thus a comprehensive family of sensors that span the entire range of biologically important forces (~ 1 to 40 pN).
- **Molecular Biology: Investigation of T7 DNA polymerase activity (Application).** The correlation of mechanical force with enzyme conformational changes and subsequent modification of its activities will elucidate how mechanical forces control biological processes. In particular, it will be interesting to follow the hypothesized periodic transitions between the 'open fingers' (nucleotide-sampling) and 'closed' states (nucleotide incorporation).

Toward the Design and Construction of Autonomous Nanobots Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Operating	0.0	0.5	0.2	0.0	0.0	0.0	0.7
Construction	0.0	0.7	0.0	0.0	0.0	0.0	0.7

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

Science for Homeland Security

The national welfare is dependent on advanced technology to support homeland security and on the underlying capabilities of fundamental and applied science. The Office of Science and other DOE departments, including the Office of Energy Efficiency and Renewable Energy, support research that is essential for the nation's need to detect, prevent, and respond to terrorist attacks involving chemical, biological, and radiological threats. Further support of this research has the potential to impact a broad set of technology needs, providing significant return on research investments. Berkeley Lab is also examining an integrated threat analysis capability to assess the uncertainty and sensitivity needed for a suite of threat reduction capabilities. Several key areas serve as examples of this important research:

- **Compact Neutron Sources.** Field deployable, high-intensity, short-pulse neutron sources are ideal systems for detecting and characterizing explosives and many other materials. Berkeley Lab has developed a new generation of neutron tubes, which can produce two-to-three orders-of-magnitude improvement over those currently available. A low-cost multipurpose compact neutron source that takes advantage of these neutron tubes is proposed as an initiative (see above). The increase in available neutron flux and the short pulse capability made possible by this laboratory will allow the development of neutron-based techniques for countering terrorist threats, including detection of conventional explosives and fissile materials. High-energy neutrons can penetrate metal containers to rapidly interrogate or image the contents. This is a dual use technology of importance not only to counter-terrorism but also to providing laboratories at universities, industrial companies, and law enforcement agencies with convenient access to neutron based analysis techniques without a nuclear reactor.

- **Ultrasensitive Detectors.** Science underpins the technologies for ultrasensitive, nonintrusive, fieldable detection systems that could be important in identifying and characterizing hazardous agents. Berkeley Lab is conducting research on several new advanced detection methods that offer unique sensitivity and characterization capabilities. One major advance is research on high-resolution nuclear magnetic resonance (NMR) spectroscopy for field use, where the hazards detected are outside the radiofrequency (rf) coil of conventional NMR systems. This new approach uses carefully chosen sequences of rf pulses to "refocus" the precessing nuclei of samples in the nonuniform field outside the coil. This novel method allows scanning of objects and subjects to provide images and chemical analysis of contents, with applications to walls, soil, and humans as examples. Berkeley Lab also is investigating an extremely sensitive, fast, and versatile technique for detecting pathogenic organisms or molecules using a "microscope" based on a Superconducting QUantum Interference Device (SQUID). Very small quantities can be detected using this SQUID-based technology, which is the world's most sensitive detector of magnetic flux. This technique could be used to detect bacteria, viruses, and molecules such as toxins. Other sensors are also being developed based on fundamental research in materials science, biology, and chemistry.
- **Transport Modeling.** Advanced modeling systems to predict and analyze the transport of hazardous agents in buildings and the environment is an important application of DOE science and technology to understand and respond to atmospheric or waterborne hazards. Berkeley Lab has indoor and outdoor air transport modeling capabilities with important hazards analysis applications. The Laboratory initiated and continues to improve the COMIS model (Conjunction Of Multizone Infiltration Specialists) which is the most advanced system for understanding the distribution of indoor air contaminants. This tool has been essential for the design of "smart" buildings as well as the development of simple tools for first responders. Additional basic work on attachment of aerosolized biological agents to surfaces and their survival in the ambient environment would improve development of realistic tools. The Laboratory also has capabilities in the areas of hydro-meteorology and waterflow into and out of aquifers. This is useful for assessing the potential for chemical and biological attacks on water supplies. In addition, Berkeley Lab is conducting research on the biology and ecology of microbes (using non-toxic organisms) that combined with the water supply tools discussed above, gives a more complete understanding biohazard threats. Part of this research is development of a "bacterial nose," analogous to the "dog's nose" used in vapor detection, which is based on bacterial chemotaxis.

Berkeley Lab has made significant initial progress in identifying basic research needs and novel technologies to assist with our nation's counterterrorism needs. The Joint Genome Institute, for example, is now analyzing DNA fragments of bacterial select agents (no toxic organisms are on site, and the fragments themselves are not hazardous), making vital contributions to the future assessment of biohazard threats. Further support of the research applications identified above, may make an important contribution to the nation's goal of reducing the threat of terrorism in the United States. The budget indicated below includes equipment and construction of a small neutron science/forensics demonstration laboratory.

Science for Homeland Security Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	2.0	3.0	4.0	6.0	6.0	21.0
Construction and Equipment*	0.0	3.0	0.0	0.0	0.0	3.0

*Preliminary estimate Berkeley Lab Budget Authority for Construction of the Compact Neutron Source Laboratory (B&R Code KC). Operating Funds are KC and DP

Office of Biological and Environmental Research

Genomes to Life

Metal and radionuclide contamination of soil and groundwater at (DOE) sites continues to be the major cleanup mission of DOE. It currently has more than 350 cleanup projects, with a total life-cycle cost of $220 billion and a completion schedule of more than 70 years. Without major technical breakthroughs, the cost could go higher. Natural and accelerated bioremediation of radionuclides and metals has received the least research attention of any natural or accelerated *in-situ* subsurface remediation process, yet this field holds the greatest promise for significant breakthroughs. A thorough understanding of subsurface mobilization and immobilization of radionuclides and metals will allow us to manipulated, stabilize, and predict long-term stability of these contaminants and their relative risks.

Berkeley Lab's proposed Genomes to Life project, the Virtual Institute of Microbial Stress and Survival (VIMSS), directly addresses the need to provide biological solutions for DOE missions. The Genomes to Life roadmap specifies the need "to provide knowledge about using natural populations of microorganisms to degrade or immobilize contaminants and accelerate the development of new, less costly strategies for cleaning up DOE waste sites." This initiative has also been designed to address each of the three aims in Goal 2 of the Genomes to Life roadmap: (1) characterize gene regulatory networks, in terms of mapping microbial regulatory circuitries; (2) connect regulatory network properties with their biological outputs; and (3) develop computational modeling tools to predict the dynamic behavior of natural or designed regulatory networks. The initiative is part of a broader collaborative effort among the DOE national laboratories and universities (including Oak Ridge National Laboratory, University of California at Berkeley, Sandia National Laboratory, University of Washington, and University of Missouri) applying the respective strengths of each partner.

There are three major components of the Berkeley Lab proposal:

- **Applied Environmental Microbiology Core.** The Applied Environmental Microbiology Core is the source of environmental data and samples that determine the stressors that will be studied, provides the environments for growing the organisms to be tested, simulates stressed environments, and verifies the conceptual models to determine how these stress regulatory pathways control the biogeochemistry of contaminated sites.
- **Functional Genomics Core.** The Functional Genomics Core is to develop the experimental methods to elucidate the regulatory networks in the stress responses of three particularly promising bacteria for direct studies as well as cross-comparisons: *Desulfovibrio vulgaris*, *Shewanella oneidensis*, and *Geobacter metallireducens*.
- **Computational Core.** In order to interpret all the information generated by the Applied Environmental Microbiology Core and the Functional Genomics Core and use it to develop new conceptual models for how microbes respond to stress conditions in natural environments, a sophisticated data storage and analysis environment must be designed.

The initiative brings together a broad multi-disciplinary team that can conduct the necessary research and development in the areas of biogeochemistry and fundamental environmental process modeling of metal and radionuclide contaminant plumes in soil and groundwater. Taken together with a project now being developed on the "bacterial nose," VIMSS offers an integrated program to study the ability of microorganisms to respond to and survive external stresses; research that is crucial to the fundamental science needed for effective homeland defense.

Genomes to Life Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Operating	0.8	2.5	2.6	3.2	3.2	3.0	15.3
Equipment	0.6	0.2	0.5	0.1	0.1	0.4	1.9

*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 (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 response 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 than 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 offers several complementary techniques for single-molecule spectroscopy focusing on force probes (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 molecular 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:

- 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 computer simulations to perform simulations and develop software that will focus on individual molecular trajectories as revealed by single-molecule FRET and on the effect of a force on the conformations of a molecule.
- 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.

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

	2002	2003	2004	2005	2006	2007	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 Source KP)

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. Responses of all cells including bacteria to both changing internal conditions and to external stimuli are mediated by changes in the protein interactions within and between such complexes. Thus, development of approaches and technologies for understanding how these "molecular machines of life" are assembled and regulated is an integral goal of the Genomes to Life program and of its proposed Facilities initiative. Characterizing such dynamic assemblies is an extremely challenging problem. Major initiatives at Berkeley Lab are addressing this challenge by developing techniques and facilities to bridge the size and resolution gap between electron microscopy of large biological assemblies and x-ray diffraction structures of individual proteins. Highly complementary studies to develop such approaches are currently funded in the Life Sciences Division both by OBER and by the National Cancer Institute of NIH. While the focus of these funded studies is on dynamic assemblies of DNA repair protein complexes that maintain genomic integrity and stability in human cells in the face of DNA damage from endogenous sources and from environmental agents and is thus particularly relevant to the Low Dose Radiation Research program, the approaches being developed will be widely applicable and of considerable importance for Genomes to Life. This effort builds upon major strengths of Berkeley Lab in Life Sciences, Physical Biosciences, and the Advanced Light Source Divisions and links them through a "virtual Center" for DNA Repair at Berkeley Lab recently funded by the National Cancer Institute with major NIH-funded research efforts in DNA repair and structural cell biology by academic collaborators from many universities.

This initiative provides the full application of a structural cell biology synchrotron beamline that has been purpose-designed to integrated studies of multi-protein complexes. This tunable wavelength beamline, named SIBYLS for **S**tructurally **I**ntegrated **B**iolog**Y** for **L**ife **S**ciences, 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 is being provided by the National Cancer Institute (NCI) of NIH as part of a multi-institution program project (a "virtual Center") on Structural Cell Biology of DNA Repair Machines centered at Berkeley Lab. Such a cooperative and highly synergistic approach to furthering development of resources for research areas of mutual interest to both NCI and OBER provides a paradigm for further collaborative efforts centered around the SIBYLS beamline at Berkeley Lab in the future.

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, such as those that might occur following Adenosine TriPhosphate (ATP) binding and/or cleavage. SAXS will also be used 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)*

	2002	2003	2004	2005	2006	2007	Total
Operating	4.0	4.4	4.1	3.4	3.6	3.6	23.1
Construction	2.5	0.0	0.0	0.0	0.0	0.0	2.5

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

Biological Imaging from Molecules to Cells and Tissues

Electron microscopy is used to obtain images of large macromolecular assemblies and machines at the highest end of the resolution scale (angstroms). Single-particle cryo-electron microscopy (EM) makes it possible to obtain three-dimensional density maps of very large, complex macromolecular assemblies, which are objects that become increasingly difficult to crystallize for x-ray diffraction studies as the size and complexity of the particle increases. The emphasis at Berkeley Lab is currently on the automation. Automation of data collection and increased speed in data processing will make it possible to merge data from 105 to 106 particle-images, a requirement that must be met to push the resolution to 8 angstroms or better. At this resolution it then becomes possible to very accurately dock together the already-known, atomic-resolution structures of the component macromolecular pieces of the assembly, thereby providing an essential interface between subcellular structure and high-resolution structural genomics.

Electron microscope tomography is used to visualize subcellular structures in situ, at the highest possible resolution. EM tomography is currently limited to ~70-angstrom resolution, but has the potential to extend down to ~25-angstrom resolution. Its unique capability is to visualize a variety of large, macromolecular assemblies without disrupting the surrounding subcellular structure or the context within which these machines are situated. While EM tomography provides the highest resolution that can be obtained for the internal structure of the cell, this technique is limited to sample thicknesses of one micrometer or less. Current work on the subcellular structure of micro-organisms is partially funded through the Microbial Cell Project and is focused on automation of the data collection and achieving the highest possible resolution. EM tomography will expand rapidly over the next year or two with the installation of a recently purchased 300 keV electron microscope that is equipped with an in-column energy filter.

X-ray tomography is also used for in situ visualization of subcellular structure. Its unique advantage is the ability that it provides to work with sample thicknesses as great as 10 micrometers. As is true for EM tomography, it is possible to visualize subcellular morphology in native, unstained samples. This capability can be augmented with labeling and specific-staining techniques, but currently this can only be done at the expense of cell-permeabilization and chemical fixation. The resolution provided by this technique is currently in the range of 500 angstroms, and 250 angstroms or better is certainly achievable. X-ray tomography therefore provides an important link between EM tomography, with its higher resolution but smaller sample size, and light microscopy, with its considerably poorer resolution but superb arsenal of labeling techniques and even live-cell observation. Research at Berkeley Lab in X-ray microscopy and tomography is making significant advances in automation of data collection, labeling methods such as genetically encoded and nano particle probes, and higher throughput preparation methods.

In the area of light microscopy, groups at Berkeley Lab are developing technologies and applications for obtaining information about molecular interactions in fixed and living cells and tissues. Novel approaches in optical sectioning in fluorescence microscopy, novel applications of existing microscopy techniques such as FRET (fluorescence resonance energy transfer, for studying protein-protein interactions) and FRAP (fluorescence recovery after photobleaching, for studying protein dynamics), and advances in image analysis coupled with methods in fluorescence labeling (e.g. quantum dots developed at Berkeley Lab) provide ways to study the dynamics of cellular and inter-cellular processes in live cells and organisms. New imaging applications driving novel biology include measurement of distribution of nuclear proteins in 3D mammary cancer models, chromosome structure in the C. elegans model organism, development of the map of the gene regulatory network of Drosophila embryos, and high-throughput screening of compounds affecting morphology and molecular changes in 3D cell culture models of human mammary cancer. Through close collaborations with groups in the computing research area, all imaging studies take advantage of quantitative analysis of images and a database infrastructure.

All biological imaging projects are closely associated with and driven by either DOE-funded initiatives in DNA-damage response and cellular responses to low-dose radiation research, structural cell biology of DNA repair mechanisms, and interaction of genome and cellular microenvironment in carcinogenesis, or are currently taking direction from the goals of the Genomes to Life initiatives.

Biological Imaging from Molecules to Cells and Tissues
Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Operating	0.0	4.0	4.0	4.0	4.0	3.5	19.5
Equipment	1.0	0.5	0.0	0.0	0.0	0.0	1.5

*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. 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 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. Novel biological responses to radiation have been revealed by using three-dimensional models of cell interactions, which indicate that radiation exposure can lead to persistently altered phenotypes. New transgenic mouse models coupled with powerful image-based phenomic, genomic, and proteomic analysis technologies are being exploited to correlate specific gene expression pattern(s) with relevant LLIR-induced biological consequences. Major developments are underway in bioinformatics that implement computer science strategies for storing, annotating, and analyzing multiparametric biological data.

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

	2002	2003	2004	2005	2006	2007	Total
Operating	2.5	3.0	3.0	3.0	2.5	2.5	16.5

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

Decoding Genomes for Protein Binding Sites

The genome sequences of many species—including our own—provide a rich treasure trove of information; they are quite literally "blueprints for life". However, especially for the complex genomes of animals, we cannot interpret the majority of this sequence information. Much of this uninterpretable DNA is thought to code for the binding sites of regulatory transcription factors, which dictate where and when in the organism specific gene products (proteins) will be expressed. The control of where and when genes are expressed is the basis for animal development and physiology and is central to all disease processes. Thus two fundamental problems in modern biology are linked: understanding the highly complex gene expression networks in animals and learning how to read the books of life to solve these problems. The Genome Sciences Division has initiated a large interdisciplinary project that is closely aligned with the fundamental aims of the DOE's Genomes to Life initiative.

The main limitation holding back progress on these two problems has been the lack of techniques and strategies for generating and analyzing the large amounts of data required to study such massive, complex problems. To overcome this limitation, teams of MDs, biochemists, geneticists, bioinformaticists, engineers, and imaging physicists are being employed in two areas. One focuses on the gene network associated with cardiovascular disease, cholesterol, and lipid metabolism in humans and mice. The other makes use of the powerful genetic and other techniques available in the fruit fly to make a fundamental study of an entire gene expression network. This work, over the last few years, has already developed new strategies and methods and uncovered key general principles.

Currently, new approaches are being initiated to maximize Berkeley Lab's capabilities in order to establish novel biochemical and genetic protocols, automate processes, build new devices, and develop new algorithms and databases. These include: (1) accurate quantitative determination of *in-vitro* DNA binding specificities, (2) genome-wide measurement of *in-vivo* DNA binding of transcription factors by new *in-vivo* crosslinking methods that use genomic microarrays to measure binding to thousands of promoter regions, (3) quantitative analysis of animal gene expression in three-dimensions at cellular resolution by development of improved imaging and image analysis methods, (4) discovery of functional binding sites through evolutionary conservation obtaining and comparing genomic sequence information from several closely related animal species for a set of target genes, (5) identification of protein/protein complexes using mass spectrometry in order to determine which specific transcription factors interact with each other, (6) high-throughput automation of data collection methods for analysis of results from all these approaches, and (7) bioinformatic analysis and modeling of animal networks by development of database and visualization tools to evaluate and compare the different data classes generated and methods to utilize these data and genome sequences to model crucial aspects of animal transcriptional networks. By iterative refinement of both data production methods and bioinformatic algorithms, an efficient strategy will be established for studying entire networks that can be applied to all animals.

Decoding Genomes for Protein Binding Sites
Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Operating	0.0	3.0	3.0	3.0	3.0	3.0	15.0
Equipment	0.0	1.2	0.4	0.4	0.4	0.4	2.8

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

Neuroscience

A new initiative led by the Life Sciences Division in collaboration with the Engineering and Accelerator and Fusion Research Divisions focuses on the study of the development, functioning, and diseases of the brain. This initiative grew from our past accomplishments in the earliest studies of Alzheimer's disease in collaboration with medical centers at San Francisco and Davis as well as our animal and human subjects investigations of the chemical basis for mental disorders including schizophrenia and manic-depressive diseases. Added to this, in the last three years is the successful gene therapy trials monitored by positron tomography in non-human primates. The rationale for this initiative Berkeley Lab is in good part due to unique instrumentation and nuclear chemistry resources and scientists. The current capabilities of high-resolution positron emission tomography (PET), dynamic single-photon emission computed tomography (SPECT), high-resolution animal imaging by radiopharmaceuticals and optical techniques, and the current complement of biochemists, neuroscientists, physicists, and collaborating neurologists are being brought together to address specific areas of study, including:

- How progenitor cells and gene therapy can be used for neuron repair and neurogenesis.
- Effect of environmental factors and trauma on brain function.
- Drug delivery methods to overcome the blood/brain barrier limitations (e.g. new approaches through trigeminal and olfactory nerve structures of the nose; bioengineering approaches to direct injection) using radiotracer methods.
- Better understanding of molecular basis of schizophrenia and manic depressive disorders and their treatment.

These studies will be made possible by combining an array of unique facilities mentioned above and development of interdisciplinary resources at Berkeley Lab, including:

- Combinatorial and computational drug discovery.
- Tracer molecules labeling with positron emitters, gamma emitters, or NMR contrast agents.
- An advanced detector for high-resolution positron emission tomography in small animals and the human brain.
- Advanced scintillators for positron emission tomography of the brain that allow the rejection of scattered radiation and time-of-flight information, resulting in a tenfold improvement in signal to noise ratio.
- The 12-Tesla Initiative, for building an ultra high field magnetic resonance spectrometer that would be national resource capable of safely performing magnetic resonance studies that promise record-breaking resolution approaching 50 microns and improved sensitivities to important body chemistry.

This initiative brings together a unique collection of expertise and tools to address national problems that DOE, in general, and Berkeley Lab, in particular, are especially suited to address.

Neuroscience Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	0.5	0.5	0.5	0.5	0.5	2.5
Equipment	0.5	0.0	0.0	0.0	0.0	0.5

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

Office of Fusion Energy Sciences

Heavy-Ion Fusion Integrated Beam Experiment

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, Integrated Beam Experiment (IBX), 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 High Current Experiment (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. These experiments will provide information that will enable the VNL to design a more cost-effective IBX and ultimately an 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 milliamps to 1 amp. 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 milliamps to 1 amp.** A new 500 kilovolt 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 2004 enables the full HCX experimental program, vigorous pursuit of the other three areas, and preparation for the IBX.

Heavy-Ion Fusion Integrated Beam Experiment
Resource Requirements ($M)*

	2001	2002	2003	2004	2005	2006	2007	Total
Operating	4.4	5.4	6.1	7.9	5.2	4.1	4.1	37.2
Equipment	1.1	0.4	1.1	1.1	0.8	0.7	0.7	5.9
IBX Construction	0.0	0.0	0.0	0.0	4.4	7.1	7.7	19.2

*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 designed that would increase the discovery rate for such supernovae to about 2,000 per year. Discovery of so many more supernovae 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 two-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 one 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)*

	2002	2003	2004	2005	2006	2007	Total**
Operating	1.8	6.0	9.0	20.0	0.0	0.0	36.8
Equipment	0.0	0.0	0.0	0.0	40.0	85.0	125.0

*Preliminary estimate of Budget Authority (B&R Code KA) and Work for Others: NSF and NASA. Full scope of science partners is under development.
**Contingency budgets not included in spending profiles. Total includes prior year operating funding.

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.

Following the imperatives set out in the HEPAP Subpanel report, Berkeley Lab has focused its accelerator research program in support of National collaborations in the areas of: Fermilab Run 2, the Large Hadron Collider Accelerator Research Program (LARP) at CERN, and the Next Linear Collider (NLC). For the past three years LBNL has 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. Recognizing the realities of the rapidly declining funding for this program, the Laboratory is evaluating redirecting effort from this activity into the higher priority programs. The Laboratory also supports the country's premiere program in very-high field superconducting magnets for accelerator applications.

Berkeley Lab has core competencies in many areas needed to design and construct the next generation of accelerators for high energy physics, including expertise in accelerator simulations and theory, and in the design of vacuum systems, radiofrequency (rf) hardware and diagnostic devices, superconducting magnets, and induction linacs.

One of the main recommendations of the Subpanel is to obtain as much physics as possible from the existing facilities. To this end our scientists are collaborating with both SLAC and FNAL to increase the luminosities achievable by the PEP-II and Tevatron colliders, and to upgrade the detectors so that the increased interaction rates can be handled.

With respect to the LHC, the laboratory is part of the US LHC Accelerator Project, a national collaboration that works on critical accelerator physics issues, and that will deliver accelerator hardware to CERN. In our case this includes theory and simulation of the electron-cloud instability, and the delivery of the cryogenic distribution boxes, specialty superconducting cable, and cable diagnostic instruments. Laboratory staff are also taking leadership roles in the new initiative towards supporting accelerator research at the LHC – the LHC Accelerator Research Program (LARP). The work of the proposed LARP is essential to maximizing the return on investment in the LHC by enabling the collider to reach its design luminosity at the earliest possible time. The proposed LBNL efforts in building bunch-by-bunch luminosity and beam density monitors are especially critical in this regard.

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, Brookhaven 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 very high gradient 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 lattice design and layout, instabilities and their suppression, and engineering designs for the radiofrequency (rf) power systems and components, magnets, damping wiggler, and vacuum systems.

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)*

	2002	2003	2004	2005	2006	2007	Total
Operating**	1.9	2.0	2.1	2.2	2.3	2.4	12.9

*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, a proposal has been submitted to DOE (March 2000), and initial funding has been received 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. The 2002 Nuclear Science Advisory Committee Long Range Plan has endorsed the merit of the proposed GRETA.

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 2005 (TEC ~$58M). 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)*

	2003	2004	2005	2006	2007	Total
Operating	0.2	0.2	0.5	0.6	0.6	2.1
Construction	2.3	2.2	5.1	11.8	13.9	35.3

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

Experiments at the National Underground Science Laboratory

The nuclear physics, particle physics, astrophysics, geophysics, and microbiology communities have recently called for the establishment of a National Underground Science Laboratory (NUSL) and a proposal has been submitted to the National Science Foundation. The advances in neutrino physics, double-beta decay, dark matter searches, and related low-background sciences have increasingly emphasized the need for ultra-lower background environments and dedicated scientific facilities made possible by a deep underground facility. The Homestake Mine near Lead, South Dakota, is an ideal location for a deep scientific facility. The Homestake Mine offers depth access to 8,000 feet, along over 400 miles of drifts and ramps on 57 different levels with an extensive infrastructure in this most productive gold mine in the United States.

Berkeley Lab has a long history in underground science from a variety of fields including nuclear physics, particle physics, and earth sciences. Berkeley Lab played critical roles in the process review process (co-chairing joint NSF-DOE committee) and championing NUSL during the Nuclear Physics planning process. Berkeley Lab played a pivotal role in the assessment of the science case for a national facility and in defining the characteristics and facility requirements 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, as well as providing critical technology for these projects and for the Antarctic Muon and Neutrino Detector Array and its successor (KM3). In these fields NUSL would permit the development of next-generation experiments with its significantly decreased backgrounds and with the required institutional support of a dedicated facility. 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 neutrino 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 assist wit the design and development of the facility to ensure its quality.

The Earth Sciences Division (ESD) participated in this national initiative from its inception and is in a leadership position to further develop deep science research collaboration in this unique site. NUSL initiative follows ESD historical emphasis on underground research facilities to serve DOE's mission in addressing resource assessment and energy-related environmental impacts. The NUSL offers an outstanding opportunity to investigate earth processes at depth, including fundamental multi-disciplinary, multi-scale studies of the interaction between solid earth and its fluid, improved use of underground space, and ecological perturbations on the deep environment.

Scientific emphasis would be placed on those areas where pre-existing laboratory expertise brings the most to bear, including ultra-low background screen facilities, double beta decay experiments, low energy solar neutrino experiments, long-baseline accelerator neutrino experiments, geoscience heating hydrology, and chemical tracer migration. NUSL offers excellent interdivisional research opportunities. The first scientific experiments could be deployed within a year or two of starting a facilities project. Geoscience research could begin in the planning and transitional phases of the Homestake mine into a scientific facility. 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 for at least two experiments—one in nuclear/particle physics and one in geoscience.

National Underground Science Laboratory Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Earth Sciences Operating	0.5	1.0	2.0	3.0	4.0	10.5
General Sciences Operating	0.0	0.2	0.4	0.4	0.4	1.4
Construction	0.0	0.0	2.0	6.0	2.0	10.0

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

Workforce Development of Teachers and Scientists

Securing the Next Generation of Scientists and Engineers

A secure future for our Nation requires a strong science and technology capability. The number of American students choosing to pursue science, engineering, computing sciences and technology careers is not keeping pace with the need. The demographics of science and engineering students in our colleges and universities does not represent the diversity of our population. Many students are not receiving quality mathematics and science education at the precollege level that promotes science literacy and ensures access to scientific and technological careers. Many of these students are being taught by teachers lacking adequate academic preparation in science and mathematics. The Department of Energy educates future scientists and engineers through mentored research and training experiences at its National Laboratories. The Berkeley Lab will increase the number of students and teachers receiving education and training at our Laboratory. Partnerships will be developed with faculty at colleges and universities serving large populations of underrepresented minorities and with local and regional community colleges and school districts.

Berkeley Lab through its Center for Science and Engineering Education will:

- Increase the number of U. S. students who become scientists and engineers through education and training of students preparing for post graduate studies.
- Promote access to scientific and technical careers for all students, including women, minorities, the handicapped, and the economically disadvantaged.
- Increase the number and strengthen the preparation of precollege mathematics and science teachers.
- Support increased classroom emphasis knowledge of frontier science and technology and the methods of scientific inquiry.
- Promote scientific literacy and public understanding of science and technology.

Berkeley Lab will increase the number of undergraduate science, engineering, and technology students and precollege science, mathematics and technology teachers participating in mentored research and training experiences. Support will be provided for faculty/student teams to collaborate in research projects at Berkeley Lab. The Office of Science has established a successful online national recruitment and selection process. The Center for Science and Engineering Education establishes partnerships with faculty at minority serving institutions, with universities preparing future teachers, with science and technology centers, and with local and regional school districts. These strategic partnerships ensure that education and training opportunities at Berkeley Lab meet the needs of the participants, promote follow through and tracking of participants, and strengthen the quality of education at the partner institutions.

Berkeley Lab's Center for Science and Engineering Education develops and improves student and teacher mentors and facilitates participation in education outreach by staff at the Berkeley Lab. Training, communication, evaluation, and recognition of staff participating in these activities are key components that will be enhanced to support the proposed increased opportunities for students and faculty and a strong education component in public affairs.

Securing the Next Generation of Scientists and Engineers
Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	1.5	2.5	3.0	3.0	3.0	13.0

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

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

E-Lab: 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 for the following research areas will potentially be included: lighting systems; window systems; ventilation systems ; air quality; building simulation; commissioning and diagnostics ; appliance and component testing; indoor environmental conditions; battery and fuel cell; combustion; sensors and controls for industry; and thin film deposition for large-scale coating applications.

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.

E-Lab: Energy Efficiency and Electricity Reliability Laboratory
Resource Requirements ($M)*

	2002	2003	2004	2005	2006	2007	Total
Construction	0.0	0.0	1.9	16.2	0.9	0.0	19.0

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

OFFICE OF FOSSIL ENERGY

Geologic Sequestration

One of the proposed strategies to reduce the buildup of greenhouse gases in the atmosphere is to capture carbon dioxide from large point sources, such as fossil fueled power plants, and sequester it in the deep underground. Geologic formations such as oil fields, coal beds, and aquifers are likely to provide the first large-scale sinks.

Study of geologic sequestration of carbon dioxide is carried out on behalf of DOE's Fossil Energy Program in the Berkeley Lab-led GEO-SEQ Project. This is 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 reservoir, 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.

Experience developed in the GEO-SEQ Project ideally positions Berkeley Lab to lead the development of a Regional Carbon Sequestration (RCS) Center in California. The California RCS Center would be one of perhaps five such centers established to address the challenges posed by the diversity of carbon dioxide sources, geologic sinks, and technology options present throughout the United States. The California RCS Center will provide California-specific scientific data, technology development, and public outreach needed to ensure environmentally safe, technologically sound, and publicly acceptable options for geologic sequestration of carbon dioxide. This broad scope requires a partnership between national laboratories, academia, energy producers and users, and state and local agencies. The Center will conduct and manage studies to support performance assessment, monitoring, and capacity assessment of sequestration sites in California, leading, ultimately, to verification and validation of sequestration approaches in large-scale demonstrations. The Center will work with its industrial partners to develop commercially viable sequestration technologies, with field demonstrations once again providing proof of concept. Development of sequestration-based enhanced oil and gas recovery will be early focuses. The Center will work with state and federal regulatory agencies, providing input on health and safety risk and other factors needed to establish a regulatory framework for geologic sequestration. Finally, the Center will work with state and local agencies to inform and educate the public about geologic sequestration.

Geological Sequestration Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	1.0	3.0	6.0	8.0	10.0	28.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Codes AA)

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

New Science at Yucca Mountain

In February, 2002 the President of the United States notified the Congress that he considers Yucca Mountain as qualified for a construction permit application, taking the next in a series of steps required for approving the site as a nuclear materials repository. This milestone marked the conclusion of the site characterization phase for the Yucca Mountain Project and, pending congressional approval, will usher in a new phase, that of preparation for License Application to the Nuclear Regulatory Commission in year 2004. Work leading to License Application will be performed in a scheduled driven, compliance framework. The DOE Office of Civilian Radioactive Waste Management is concurrently developing a new Science Initiative to promote pursuits of important scientific investigation of the Yucca Mountain site in an environment supportive of scientific research. This science program is intended to be a parallel effort to the fast tract licensing activities.

The stated purpose of this science initiative is a plan for enhancing confidence, technology, and efficiency in the repository program and the larger waste management program. Criteria for identifying and selecting investigations for the Science Initiative include: reducing uncertainty as it relates to performance of the natural and engineered systems in the regulatory time and post regulatory time frames, cost and time savings to the repository program, and results to be available in the 2004 to 2010 timeframe. Competition for funding from the Science Initiative will be opened to both the national laboratories and universities. Berkeley Laboratory is well positioned to contribute to this Science Initiative.

Berkeley Lab has played a key role in the site characterization phase of the Yucca Mountain Projects. Our work has focused on *in-situ* hydrological and thermal testing and the development of comprehensive numerical models of flow and transport in the unsaturated zones. Results of our investigations have greatly advanced the knowledge of flow and transport in thick fractured, unsaturated rocks, and contribute to the successful recommendation the Yucca Mountain Site to the President. Scientific issues still remain and need to be addressed to enhance confidence and reduce uncertainty in the ability of the natural system to isolate the radioactive waste. The remaining issues include:

- Flow focusing and discrete flow paths in the mountain.
- Impact of coupled processes (thermal, hydrological, chemical, mechanical) on flow and transport;
- Function of the zone of reduced water saturation and flow beneath the waste emplacement drifts to favor diffusive release of radionuclides into the rock matrix and to substantially reduce the rate of radionuclide transport.

These topics are excellent candidate areas for Berkeley Lab's contribution to this DOE Science Initiative. Anticipated award of funding to Berkeley may be on the order of two to five million dollars per year beginning FY 2003.

New Science at Yucca Mountain Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	3.0	3.5	4.0	5.0	6.0	21.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code: Nuclear Waste/Other DOE Contractor)

WORK FOR OTHERS

Advanced Controls for Energy Efficiency and Distributed Energy Systems

Over 65% of electricity use in the United States is in buildings. About half of that total is in commercial buildings. There have been dramatic improvements in the energy efficiency of many of the specific technologies in commercial buildings: lighting, heating, air conditioning, and ventilation systems, as well as the shell of the building (windows and walls). As a result of these improvements, a typical office building constructed today uses considerably less energy than one built two or three decades ago.

However, there are very large, and likely cost-effective, energy improvements possible that go well beyond today's levels. The key to achieving many of these improvements is in control systems for commercial buildings. The basic concept is often called continuous commissioning, in which inoperable or incorrectly operating elements are identified and fixed. The commissioning also involves balancing various set points in buildings that have drifted from optimal settings or are inappropriate for the weather conditions that the building is experiencing. Numerous recent efforts carried out by highly skilled technical personnel have shown 20 to 30% savings in typical office buildings as a result of interventions by skilled personnel (with no or little investment in equipment). However, labor costs are high and highly skilled technical personnel who can achieve such results are rare. Thus, there is a need to create building systems that simulate the behavior of highly skilled practitioners and do this automatically. For this to happen, and be affordable, low cost control systems with very inexpensive sensors (points) are needed. One possibility to create such systems is to combine the control system design at Berkeley Lab with the creation of a new generation of wireless communication systems being created at UC Berkeley, and simple chips in energy-using equipment that can serve as control points. This, among other approaches, will be explored in the development of the new generation of control for commercial buildings.

There is at present considerable interest in energy sources that can be located within or near commercial buildings and in many cases coordinated with end-use devices. Examples of distributed energy systems sized for commercial buildings (or small groups of such buildings) include microturbines used alone or as cogeneration systems, fuel cells, and (perhaps in larger application within a decade) photovoltaic arrays. An idea of particular interest that may increase the viability of these distributed energy systems, by making them perform in ways that provide value to the electricity grid, is the concept of the microgrid. The microgrid consists of the following components: (1) end-use equipment (including electricity- and heat-using devices), (2) distributed power systems (e.g., fuel cells, microturbines, cogenerators, photovoltaic arrays), (3) electricity storage devices (e.g., batteries, flywheels, capacitors) and (4) a hierarchy and variety of information, communication, power electronics, and control systems. The microgrid concept that is of interest to us is one that is connected to the grid, and can receive power from the grid or supply power to it.

The major issues that we expect to explore involve the ability of control systems to enable the grid to serve as more valuable than the sum of its parts. We anticipate that hierarchical control, in which the overall microgrid is controlled by a supervisory control system, and different types of control will operate for the distributed generation, end-use equipment, and storage. We anticipate creating small-scale demonstrations of microgrids to study their technical characteristics, understand ways in which stability of the local system can be maintained under a variety of conditions, and analyze the critical issues in linking with the local distribution grid. We also anticipate modeling of the microgrid. The result of this assessment will indicate the technical challenges that need to be overcome to make the microgrid a widespread commercial enterprise and the conditions under which the microgrid is most likely to be viable. It is our anticipation to perform this work in close collaboration with private firms, as well as other research centers (especially members of the Consortium of Electricity Reliability Technology Solutions, a consortium of four national labs, leading universities, and private firms that Berkeley Lab leads).

Advanced Controls for Energy Efficiency and Distributed Energy Systems Resource Requirements ($M)*

	2003	2004	2005	2006	2007	Total
Operating	2.0	4.0	5.0	5.0	5.0	21.0

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

V. OPERATIONS STRATEGIC PLANNING

Berkeley Lab's Operations strategic planning focuses on aligning Berkeley Lab's administrative and support systems to the needs of the program scientists that conduct DOE national research programs. These efforts are directed at providing the services who help deliver scientific results and support the achievement of the Berkeley Lab's Scientific Vision (see Section III). A number of organizational systems have been identified as critical factors for Berkeley Lab's efficient and effective performance. These systems directly support DOE's strategic science objectives and the conduct of research in a safe and secure manner, protecting employees, DOE assets, the public and the environment. The Operations planning efforts, currently underway are directed towards achieving the Operations Vision:

- Berkeley Lab will be the best place in the world to conduct scientific research. Our effective and efficient infrastructure, systems, engineering, and health and safety programs will be world class.
- We will be part of a unified Laboratory, where the full contribution of every individual is expected, respected and recognized. Working across organizational boundaries, we will develop new synergies that deliver effective innovative solutions. We will appreciate and benefit from our diversity. Our environment will be rich with opportunities and we will be challenged to grow to our fullest potential.
- We will have constructive relationships with and be trusted by our sponsors, neighbors, and collaborators. We will cultivate relationships with competence, integrity, and openness. Our partnerships will open new opportunities to serve our communities, the nation, and the world.

The Operations strategic planning efforts are directed toward improving management and systems during a multiyear effort, with a focus on four important areas:

- **Operational Efficiency and Effectiveness.** Integrate best business practices to provide efficient and effective operational support to the scientific mission of the Laboratory.
- **Infrastructure Enhancement.** Improve facilities and our engineering and information technology systems to support the current and future programs of Berkeley Lab.
- **Employee and Organizational Development.** Improve individual and organizational effectiveness while creating a motivating work environment that attracts and retains high-caliber employees.
- **External Relations.** Build constructive and supportive relationships with key constituent groups and improve the identity and reputation of the Lab within the community.

Initial actions that have been implemented included a new employee Performance Review and Development process; a new Activity Based Budgeting system for indirect cost management, revisions to the Laboratory's Comprehensive Planning Calendar, and an analysis of Laboratory's recharge system.

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'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 Labs sustains a strong environmental protection program with many key elements. Among then are programs in waste management, air/groundwater/sewer monitoring, pollution prevention, waste minimization, and environmental restoration, as well a numerous programs designed to ensure compliance with relevant environmental laws and regulations. Berkeley Lab tracks many performance measures used to assess progress against environmental goals in these programs. Measures include controlling radiation doses, avoiding all environmental releases, achieving superior results from environmental audits, and waste minimization. Another goal, specific to the waste management program, measures our ability to increase efficiency by reducing the total costs of managing waste shipped off-site for treatment and disposal.

Within environmental management, there is a strong emphasis on pollution prevention. The goal is to incorporate it into all planning so difficult to manage and expensive wastes can be avoided. Specific pollution prevention goals are addressed through a program of awareness, recognition, information exchange, and training.

There is an important change in the waste management program this year. In FY 2000, Environmental Management (EM) terminated its support of that portion of our program that manages "newly generated wastes." Throughout FY 2001 and FY 2002, the Office of Science through the High Energy Physics Office. Provide line item funding that generally match the level of support EM had historically provided. In FY2003, however, all forms of external budget support cease. The Laboratory is considering various alternatives of indirect funding to support its waste management program.

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 and web technology that provides electronic access to consistent, timely administrative information, making full use of Berkeley Lab's computing and network infrastructure. To provide appropriate access, 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, modern

administrative computer applications, information access and protection. 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 Communications

A key element of the Laboratory's strategic planning is to strengthen communications and involvement at all levels, internal and external, in order to build trust with the public and Berkeley Lab employees is. This emphasis parallels DOE's goal to maintain a culture of openness, communication, and trust. Community relations has been an important element of Berkeley Lab strategic planning and is integral to the Operations Vision and strategic planning for FY 2003 and beyond. The Laboratory has taken many steps to enhance community interaction and understanding, including a fire services agreement with the City of Berkeley, 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.

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.

An Open House, a biannual event staged most recently in the Spring of 2000 and planned for the Fall of 2002, 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. Berkeley Lab employees make additional commitments to their communities through participation in the annual Berkeley Lab SHARES, a charity giving campaign. 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, and other communication mechanisms and programs.

MANAGEMENT PRACTICES

Human Capital Development

People are Berkeley Lab's critical asset. Effective human resources development activities are essential to the success of the Berkeley Lab's programmatic initiatives. The Human Resources mission statement is "to act as a partner by providing Human Resources programs, services and support to the people of the Berkeley Lab to enable them to perform the strategic, scientific, and operational mission of the Laboratory.

The objectives of the Berkeley Lab human resources development program are to:

- Promote human resources practices that contribute to making Berkeley Lab a great place to work and the best place to do science.
- Champion programs and services that support a work environment where diversity, individual and team contributions are expected and valued.
- Develop and sustain collaborative relationships with our customers, sponsors, and partners that assures their confidence in our programs and services.
- Advocate for a culture that values employee development and where learning crosses organizational boundaries through adaptive practices, systems, and processes that encourage teamwork, creativity, and discovery.

To meet these objectives several centers and activities have been established. Human Resources Service Centers has been established to fully assist divisions to develop their human assets in a number of ways. They are developing human resources strategic plans to meet business needs of client divisions and consulting with division management on human resources solutions and issues. The Centers are key to advancing four strategic human resources goals:

- **Recruitment**. To establish recruitment programs, systems and support services that enable the Laboratory to attract and retain an outstanding and diverse scientific and operations workforce.
- **Diversity**. To establish work-life programs and services that promote and support a diverse employee population at all levels.
- **Development**. To partner with divisions to create a continuous learning environment and to identify and establish employee and management development programs that enable the Laboratory to fulfill its scientific mission.
- **Continuous Improvement**. To streamline and continuously improve Human Resources policies, systems, and processes so the Laboratory is able to meet its strategic scientific and operational objectives efficiently and effectively.

An important development for FY 2002 has been the introduction of a new Performance Development and Review process with an emphasis on greater feedback, career growth, and evaluations based on work performance. The Human Resources Department continues to work 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.

Table V (1) LABORATORY STAFF COMPOSITION (FY 2001)

Full & Part Time Employees	Total		PhD		MS/MA		BS/BA		Other	
Scientists*	857	23%	773	90%	42	5%	21	2%	21	2%
Faculty	256	7%	246	96%	4	2%	-	-	6	2%
Professional*	587	16%	95	16%	166	28%	203	35%	123	21%
Executive	6	0%	6	100%	-	-	-	-	-	-
Administrative	585	16%	22	4%	93	16%	196	34%	274	47%
Technical	916	24%	21	2%	101	11%	206	22%	588	64%
All Other	563	15%	12	2%	78	14%	249	44%	224	40%
Grand Total	3770	100%	1175	31%	484	13%	875	23%	1236	33%

* 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

With workforce diversity being an integral part of senior management’s vision, Berkeley Lab took significant steps during FY 2001 toward its recommitment to diversity—a recommitment notable for its actions toward instilling diversity as a value and practice throughout the Laboratory. All levels of management and staff are now involved in diversity awareness and recruitment and in making Berkeley Lab a research organization that is welcoming and productive for all employees. This new diversity performance measure focuses on leadership and awareness. Affirmative action programs and targeted recruitment efforts that include specific metrics are a part of the Self-Assessment Section on Human Resources.

Workforce Diversity Plans

These customized diversity leadership actions were to be critical to each division director’s diversity management goals. As a key follow-up to these activities, Director Shank formalized the new diversity activities in two significant ways: (1) instituting the Laboratory Diversity Performance Measure 1.1.e; and (2) adding diversity management to the performance criteria of division director job expectations. In addition, senior management’s collective responsibility for diversity was made evident in the Division Director job description, which includes the following: “Enhance cultural diversity among your workforce and actively pursue plans and programs to incorporate effective affirmative action activities. Develop a Divisional Diversity Plan for review by the Director on an annual basis. Serve as a model for providing equal employment opportunities in the recruitment, assignment, and development of personnel.”

In addition, in order to enhance diversity and an inclusive work environment, senior management concluded that the collective movement of all divisions and departments toward diversity must follow diversity best practices. The Laboratory’s diversity best practices incorporate the following principles:

- Leadership and awareness
- Employee involvement
- Strategic planning
- Evaluation and measurements
- Linkage to organizational goals and objectives

The diversity best practices model was built around these principles in order to create a process that conveys a shared understanding of diversity’s importance.

Progress on Action Plans

Every division director submitted a diversity action plan summary for the Laboratory Director’s and Deputy Directors’ joint review and critique. Division directors then used the Director’s comments to refine their plan, forming a systematic approach suitable to their specific division’s needs. Every division director prepared a final plan for review and approval. Also, three Operations Area Department Plans were approved (Administrative Services, Financial Services, and Facilities Departments).

By early calendar year 2001, all divisional diversity action plans were approved for publication on the Diversity Action Plan Web Site (http://www.lbl.gov/Workplace/WFDAP/). The site illustrates the wide variety of diversity issues faced by Laboratory management across Berkeley Lab, and the specific actions used to improve workforce diversity.

All plans addressed two main elements: innovative actions to enhance the work environment for all employees, and methods of assuring hiring pools that are as diverse as possible. Each customized diversity plan mirrors the unique needs and concerns of a division or a department. There are five categories (Diversity Recruitment, Training and Education, Diversity Outreach, School-to-Career Partnerships, and Pipeline Mentoring) that represent the variety of diversity tools available to senior management, and illustrate the wide variety of divisional diversity actions throughout the Laboratory.

In FY 2002, Berkeley Lab instituted the following Performance Development Review expectation to reinforce its commitment to diversity: "Employees at all levels of the organization are expected to work effectively within our diverse culture by promoting and supporting an environment in which all employees are valued, respected, and included. Managers and supervisors have the additional responsibility to enhance this development by modeling and sustaining the commitment among team members and staff."

Berkeley Lab's action plans and performance measures represent the Lab's recommitment to 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 continuing leadership in workplace diversity.

Table V (2) **Equal Employment Opportunity (FY 2001)**

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	116	53	92	48	24	5	6	1	6	1	12	3	0	0
	68.64%	31.36%	54.44%	28.40%	14.20%	2.96%	3.55%	0.59%	3.55%	0.59%	7.10%	1.78%	0.00%	0.00%
Total male and female	169		140		29		7		7		15		0	
	100%		82.84%		17.16%		4.14%		4.14%		8.88%		0.00%	
PROFESSIONALS														
Scientists/Engineers	970	272	745	190	225	82	26	10	21	10	176	61	2	1
	78.10%	21.90%	59.98%	15.30%	18.12%	6.60%	2.09%	0.81%	1.69%	0.81%	14.71%	4.91%	0.16%	0.08%
Total male and female	1242		935		307		36		31		237		3	
	100%		75.28%		24.72%		2.90%		2.50%		19.08%		0.24%	
Management/Administrative	47	169	37	110	10	59	0	16	2	10	8	32	0	1
	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.70%	21.76%	21.76%
Total male and female	216		147		69		16		12		40		1	
	100%		68.06%		31.94%		7.41%		5.56%		18.52%		0.46%	
TECHNICIANS	300	67	225	41	75	26	19	5	20	5	36	15	0	1
	81.74%	18.26%	61.31%	11.17%	20.44%	7.08%	5.18%	1.36%	5.45%	1.36%	9.81%	4.09%	0.00%	0.27%
Total male and female	367		266		101		24		25		51		1	
	100%		72.48%		27.52%		6.54%		6.81%		13.90%		0.27%	
CLERICAL	42	203	19	95	23	108	7	69	8	17	5	22	3	0
	17.14%	82.86%	7.76%	38.78%	9.39%	44.08%	2.86%	28.16%	3.27%	6.94%	2.04%	8.98%	1.22%	0.00%
Total male and female	245		114		131		76		25		3		27	
	100%		46.53%		53.47%		31.02%		10.20%		11.02%		1.22%	
CRAFTSMEN/LABORERS	125	1	90	1	35	0	12	0	13	0	8	0	2	0
	99.21%	0.79%	71.43%	0.79%	27.78%	0.00%	9.52%	0.00%	10.32%	0.00%	6.35%	0.00%	1.59%	0.00%
Total male and female	126		91		35		12		13		2		8	
	100%		72.22%		27.78%		9.52%		10.32%		6.35%		1.59%	
SVC. WORKERS/APPRENTICES	75	21	30	8	45	13	23	6	16	3	5	3	1	1
	78.14%	21.88%	31.25%	8.33%	46.88%	13.54%	23.96%	6.25%	16.67%	3.13%	5.21%	3.13%	1.04%	1.04%
Total male and female	96		38		58		29		19		8		2	
	100%		39.58%		60.42%		30.21%		19.79%		8.33%		2.08%	
Total All Categories	**2461**		**1731**		**730**		**200**		**132**		**386**		**12**	
	100%		**70.34%**		**29.66%**		**8.13%**		**5.36%**		**15.68%**		**0.49%**	

Figures are based on end of fiscal year 2001.

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 Laboratory'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 on site or classified 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 important information, including export control information, personnel information, financial information, computer operations, as well as site protections for property and personnel.

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 based on cost and risk, 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 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, which files and prosecutes appropriate patent applications. Intellectual property is evaluated and transferred to the private sector by the Technology Transfer Department—typically under license, option, bailment, or similar agreements. Berkeley Lab's technologies tend to be very nascent and require substantial development by a private sector company before any 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 2001, Berkeley Lab reported 81 new inventions, filed 38 new U.S. patent applications and had 38 patents issued. A total of 35 new licenses and options were executed. These numbers are generally typical of those reported since the late 1990s.

Berkeley Lab's Technology Transfer Department regularly develops and manages partnerships with the private sector to commercialize technology for the public benefit. A particularly innovative partnering strategy resulted in FY 2001 in the successful commercial launch of the energy-efficient "Berkeley Lamp" that delivers both 50% -plus reduction in energy use and superior lighting quality. Despite compelling performance and energy-efficiency characteristics, conventional licensing approaches were not generating interest from lighting manufacturers. To overcome the barriers to commercial adoption, a team from Berkeley Lab organized a partnership of three California utilities, Sacramento Municipal Utility District, Southern Cal Edison, and Pacific Gas and Electric. The utilities issued coordinated Request for Quotes, to which over ten lighting companies bid to manufacture an initial order. The Berkeley Lab team also used high visibility demonstration projects to show market acceptance and the energy saving approach at model sites in municipal governments, universities, hotels, and federal agencies. Today, the Berkeley Lamp is available through various distributors and on the Web. Berkeley Lab's commercialization efforts were honored with the 2002 Federal Laboratory Consortium Award.

Table V (3) Intellectual Property Management

Category	FY 2000	FY 2001	FY 2002 (est.)	FY 2003 (est.)	FY 2004 (est.)
Number of New Licenses*	42	35	45	50	50
License Income ($K)**	933	1,107	1,200	1,350	1,500
Software Disclosures	28	19	10	20	20
Invention Disclosures	81	76	70	75	75
U.S. Patent Applications ***	38	44	35	40	45
U.S. Patents Issued	38	29	31	35	40

*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 2001 saw income from licensing exceed the one million dollar level for the first time, and continue a double-digit growth rate (approximately 11.5% in comparison to the FY 2000 income). 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. INFRASTUCTURE STRATEGIC PLANNING

A key Department of Energy (DOE) objective is to "provide leading research facilities and instrumentation to expand the frontiers of the natural sciences." Mission performance is inextricably coupled to the assets that house and facilitate this research—buildings and infrastructure that are dedicated to and operated for science. To address this DOE mission performance objective three infrastructure needs are priorities for infrastructure investments at Berkeley Lab:

- **Science Programs and User Needs**. During the period of this plan, the most critical programmatic buildings are the Molecular Foundry for the Office of Basic Energy Sciences; a User Support Building providing users from many programs with staging, labs, offices and services (a multi-program Science Facilities Infrastructure project); and an E-Lab for the Office of Energy Efficiency and Renewable Energy.
- **Bevatron Dismantling**. The Bevatron had been one of the most productive accelerators for high energy physics, nuclear physics and biomedical research during its operation from 1954 to 1993. Since its 1993 decommissioning, it has become an increasing problem as a 165,000 gross square feet (gsf) dysfunctional, dilapidated sarcophagus in the center of the Laboratory, impeding DOE programs and creating a maintenance nuisance and an obstacle to site rehabilitation. Resources have been provided in FY 2002 to make inroads on the problem, but DOE must make this dismantling project a priority for FY 2003 and beyond to mitigate the impairment and gross inefficiency caused by this abandoned facility.
- **Science Support Infrastructure**. The Science Facilities Infrastructure program has been a critically important resource for Berkeley Lab's revitalization. Priority proposed building projects for the near term are the Research Support Building which replaces a condemned and demolished building with new program space dedicated to direct support of Laboratory-wide research; and a User Support Building providing users from many programs with staging, labs, offices and services.

Research at Berkeley Lab is directly tied to quality facilities and site improvements through 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. Research-driven requirements are coupled with knowledge of facility characteristics and needs to form the basis of Berkeley Lab's infrastructure strategic planning.

FACILITIES CONTEXT

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. 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.

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.

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 2002, there were 110 buildings of conventional construction and 86 trailers and other structures at the main site. Additional space on the UC Berkeley campus includes 79,000 net square feet (nsf); and 330,000 gsf are located in leased buildings in the cities of Berkeley, Oakland, and Walnut Creek (leased gsf includes 45,000 gsf of exterior warehouse space).

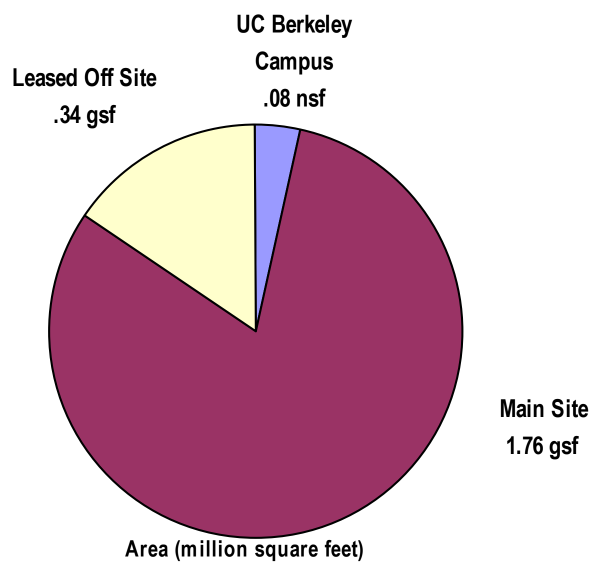


Figure VI (1) Laboratory Space Distribution

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 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.

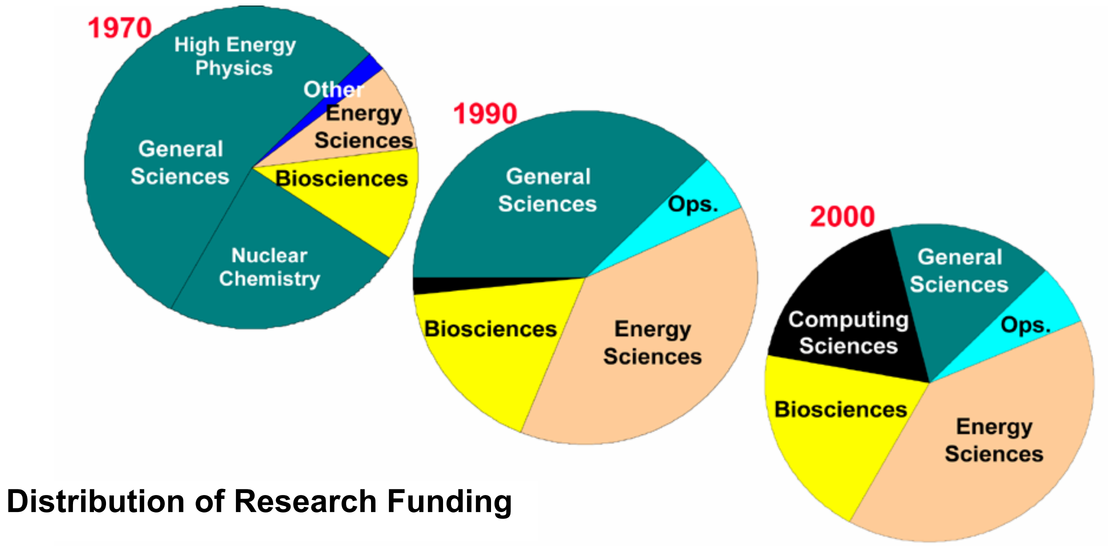


Figure VI (2) Change in Berkeley Lab Programmatic Areas

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.

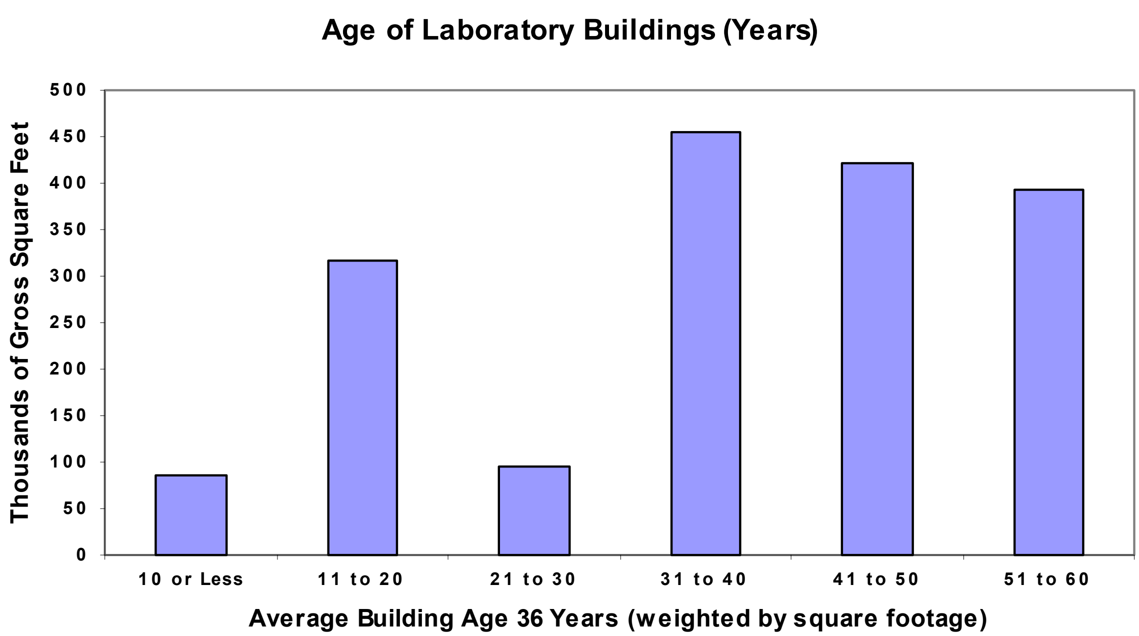


Figure VI (3) Age of Laboratory Buildings, Modulars, and Trailers

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 and SuperHILAC accelerator areas, and the buildings that have been shut down, all occupiable offices, laboratories, and support facilities at Berkeley Lab are 100 percent utilized.

The total replacement plant value (RPV) of active buildings and infrastructure is $887M[1], [see Table VI (1)], as reported in the DOE Facilities Information Management Systems (FIMS). The value of the equipment in the buildings is $439M. 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 for active buildings and infrastructure or a turnover time of approximately 100 years (excluding additional program construction funds).

Table VI (1) Facilities Replacement Plant Value (FY 2002)

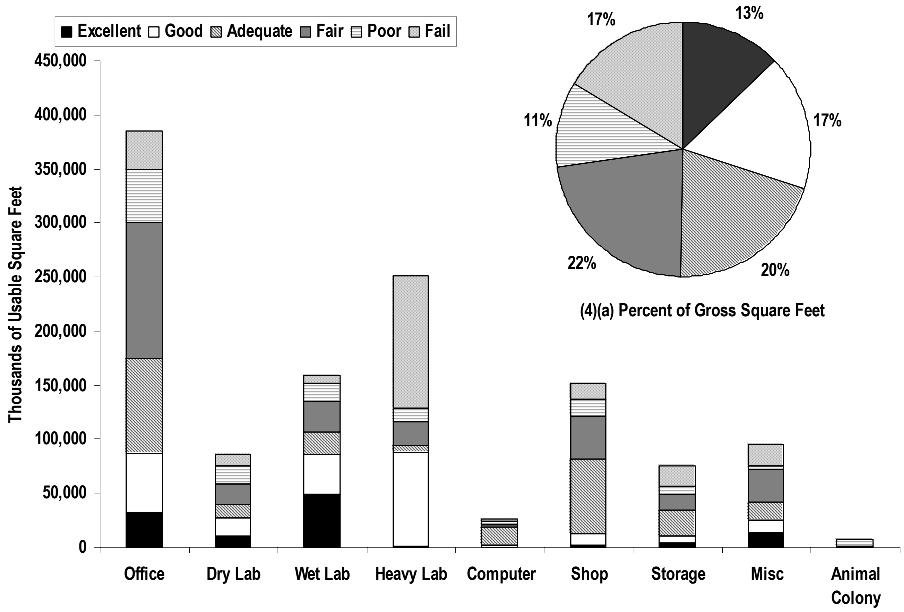
Facility Type	Value ($Million)	% of Total
Active Buildings & Infrastructure*	887[1]	74
Accelerators and OSFs	315	26
TOTAL	1202	100

* Building RPV includes property tracked in the FIMS database (incl. buildings and trailers), does not include off-site contract/lease space or programmatic OSF.

Approximately 473,000 gross square feet (28%) of Berkeley Lab's space (at the main site) is substandard (rated Poor or Fail)[2] 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 72% 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) updated as of September 2001.

Space is at a premium and capabilities must be increased in order to reduce overcrowding. Figure VI (4b), illustrates that 83% of computer space, 71% of wet lab space, and 90% of dry lab space are rated as functional (Excellent, Good Adequate, or Fair) in 2002. However, Berkeley Lab must continue to upgrade functional facilities that are not rated as "Excellent" to ensure that they continue to meet researcher needs and all applicable health, safety, environmental, and performance standards.

[1] The significant increase (from last year) in reported total replacement plant value is due partially from the result of a thorough re-evaluation of Berkeley Lab's electric generation, transmission, and distribution system assets.
[2] Also includes buildings flagged as "Excess" in FIMS.



(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: *Excellent*: Deferred maintenance is <2% of RPV; *Good*: Deferred maintenance is 2 to <5% of RPV; *Adequate*: Deferred maintenance is 5 to <10% of RPV; *Fair*: Deferred maintenance is 10 to <25% of RPV; *Poor*: Major Deferred maintenance is 25 to <60% of RPV; *Fail*: Replacement is required because Deferred maintenance cost is 60% 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.

Required maintenance is identified through Condition Assessment Surveys conducted by an independent consultant. Their findings, along with cost estimates, are prioritized and entered into five-year and ten-year maintenance plans. Maintenance that is not performed when scheduled is then categorized as Deferred Maintenance. Actual maintenance costs are accumulated through the Maximo Work Order tracking system.

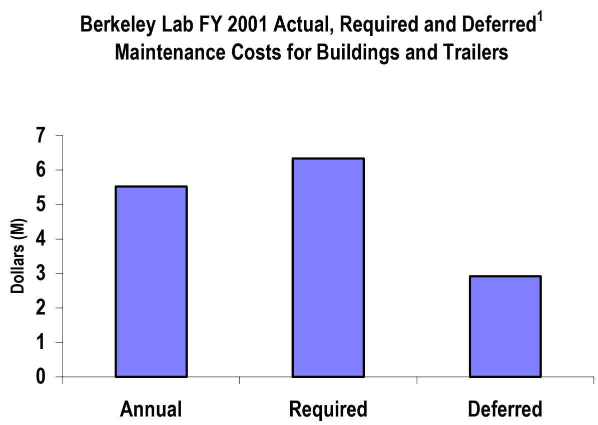


Figure VI (5) FY 2001 Maintenance Costs and Needs

[1] The deferred maintenance figure in this graph includes critical and non-critical deferred maintenance costs as reported to DOE by the Laboratory's Maintenance group. For FY 2001, the figure reported in FIMS was calculated using a different formula and is, therefore, different from the figure above. The $160M plus reported in FIMS includes: maintenance work not performed when scheduled (deferred maintenance) and estimated rehabilitation and improvement projects with consideration of functionality and suitability objectives.

Other Facilities Trends

The Laboratory's historic trend in space has been an average increase of 30,000+ square feet a year. Over the past five years the trend in the increase to the total square footage has been flat. The last building completed at the laboratory was Building 84 with 55,000 gsf in 1997. The Laboratory has continued to meet DOE's mission requirements over the past five years, but has done so through increasing density and leasing off-site space. These two recent trends need to be reversed; the Strategic Facilities Plan outlines a program to address this problem (see Strategic Facilities Plan section below).

The Laboratory has 86 trailers at the main site. The Laboratory's Long Range Development plan calls for the removal of trailers and their eventual replacement by more efficient buildings of conventional construction. During the past five years, four small trailers have been removed from the site due to their advanced stage of deterioration.

The historic trend in the space leased off site by the Laboratory has increased as outlined in the preceding section. This increase in space leased off site is reflected in the number of staff housed in leased space off site. The number of staff housed in leased space off site has increased from 75 in 1986 to 325 in 2002. This option has proven effective for some support units, for example the warehouse function. However most other off-site units are somewhat less efficient at off-site locations and plans to return them to the main site so that they are more readily accessible to researchers have been prepared.

The Laboratory has no surplus buildings and does not anticipate any in the future; all usable space, with the exception of the Bevatron, is fully used, and has been over the past five years. The Laboratory's Strategic Facilities Plan provides a path to replace buildings when they are no longer suitable for modern science (See the Strategic Facilities Plan section). The Laboratory does have an excess building, which is excess as design characteristics and poor structural, mechanical, and electrical conditions, render reuse non-cost justified. This structure is Building 51, also known as the Bevatron. Preparatory work has begun in FY 2002 to 2003 to dismantle the Bevatron. The Laboratory also has four small trailers that, due to advanced state of deterioration, are shut down pending demolition.

The percentage of space identified as storage on the main laboratory site has declined slightly since 1986. In 2002 75,000 square feet was space identified as storage on the main laboratory site. The laboratory continues to lease an offsite storage facility to accommodate its storage needs.

STRATEGIC FACILITIES PLAN

Berkeley Lab has prepared a Strategic Facilities Plan in order to prioritize and guide infrastructure and facility developments to advance the physical and multidisciplinary sciences that have been a key to the nation's prosperity. Modern, effective, and efficient physical infrastructure is critical to maintaining the capabilities of the multiprogram laboratories and to serve the users of the specialized instrumentation at the Laboratories. This infrastructure and specialized instrumentation has provided first-of-a-kind enabling discoveries and technologies that drive national science and technology advances.

The Berkeley Lab *Strategic Facilities Plan* has been prepared to sustain Berkeley Lab's contributions to DOE's mission. This 10-year Strategic Facilities Plan was prepared for DOE's Office of Science as part of its "Laboratories of the 21st Century" initiative. The Plan describes the scientific mission of this Laboratory, and the facilities and infrastructure changes needed to support the planned research mission. The plan addresses the operational and performance issues that must be addressed to meet the modernization goals described in this plan.

This plan identifies existing and anticipated infrastructure deficiencies, and it proposes actions that can be taken to address these deficiencies before they can have any impact upon the science that is at the core of our mission. Current roles and anticipated changes call for strategic investments in the renewal of the scientific and support infrastructure that is essential for Berkeley Lab to meet its mission and program obligations.

As Berkeley Lab is the oldest of the DOE National Laboratories, significant portions of its infrastructure and a number of facilities are candidates for renovation and replacement at this time. The physical plant must be modernized so that it appropriately supports the science of today and the coming decades and ensures that the infrastructure is not a barrier to achieving programmatic goals. The primary portions of the Strategic Facilities Plan, which apply to the timeframe of this Institutional Plan, are summarized below.

Buildings for DOE Programs

The critical scientific investments that advance the Laboratory's facilities stem from the value of the Laboratory's research to the DOE program offices. 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 for the national user community, 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), the National Center for Electron Microscopy, the 88-Inch Cyclotron, and the National Energy Research Scientific Computing Center. The most immediate requirement is to meet the needs of advancing nanoscience, while addressing the growing needs of the ALS user community.

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 DOE's participation in the National Nanotechnology Initiative (NNI) (see Section IV, Initiatives). The Molecular Foundry will conform to 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.)

Advanced Scientific Computing Research

The National Energy Research Scientific Computing (NERSC) Center is the flagship general-purpose, high performance computing resource for the Office of Science research community. Accommodating the space requirements of the next-generation supercomputer, "NERSC-4," to be delivered in early 2003, requires completion of the planned build-out of the NERSC Center computer room at the Oakland Scientific Facility.

Oakland Scientific Facility

Berkeley Lab's Oakland Scientific Facility (OSF), located at 20th and Franklin in downtown Oakland, and is the home of NERSC Center's computing and data storage systems. The 15,000-square-foot OSF computer room was designed for flexibility and expandability. In order to accommodate NERSC-4 and additional generations of computing systems, the computer room must be expanded to 20,000 square feet by removing a non-load-bearing wall.

Office of Energy Efficiency and Renewable Energy

Berkeley Lab conducts essential research for the nation's programs in Energy Efficiency and Renewable Energy (EERE). 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.

E-Lab

The proposed Energy Efficiency and Electricity Reliability Laboratory (E-Lab) will serve as a regional resource to focus federal, state and private sector resources on advancing energy efficiency and renewable energy technologies and achieve their rapid commercial deployment. The E-Lab is a 29,000-gsf research facility featuring innovative design elements. It will provide excellent experimental facilities and will function as a living laboratory and collaborative center to develop, evaluate, and demonstrate advanced energy efficiency and renewable energy technology components, systems, and processes. The Laboratory will build on Berkeley Lab's research experience in lighting, windows, ventilation, laboratory and office equipment, building simulation and design tools, performance benchmarking, advanced sensors and controls, diagnostics and commissioning, appliance standard-setting research, electricity storage and transmission, and electric reliability. It will extend the Laboratory's successes in working with private sector and state organizations. E-Lab will contribute significantly to achieving EERE's energy savings goals by introducing new technologies and practices in both existing and new buildings. The work will also directly address the growing need to effectively manage electric loads in buildings so as to enhance electricity grid reliability. Testing and demonstration of energy-efficient technologies and practices in a "living laboratory," in close cooperation with industry and public sector partners, will encourage both innovation and market acceptance. The estimated cost is $19.0M. (See Section IV, Initiatives.)

Science Support Infrastructure

Bevatron Removal

Berkeley Lab works with the Office of Science as steward for the Laboratory's maintenance and scientific infrastructure to address priority needs for site rehabilitation. 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 abandoned Bevatron accelerator.

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 very limited funds for its dismantling. A key element of the facilities planning is the deconstruction of the Bevatron facility so this costly maintenance nuisance and impediment to site management can be eliminated and the site used for DOE research and laboratory needs. The Laboratory has provided a seven-year dismantling plan for the Bevatron. With funding consistent with the Plan, this project will be complete in 2010. The total project cost can be reduced with increased funding in the early years of the project.

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.

Support Buildings, Roads, and Utilities

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, has corrected 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 research support functions to a central area where these services can be efficiently managed and easily accessed by all staff and guest researchers. This new building will house key Laboratory research support service functions that are now scattered across the site. This 25,000-gsf building will house ~70 people from a variety of essential research support functions including Library Services, the Center for Science and Engineering Education, Technology Transfer, Procurement Department and the Patent 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.
- **User Support Building.** The new User Support Building will provide critically needed modern research support space for users of the Advanced Light Source and other national user facilities. The building will support research in all disciplines (condensed matter physics, materials, chemistry, environmental, and earth sciences, biology, atomic and molecular physics, plasma sciences, nanosciences, etc.). The new multi-user structure includes a high bay for assembly of experimental apparatus; as well as modern analytical laboratory and office space to support the over 2,000 scientific facility users. This space will support activities to prepare experiments and to address other critical but short term high-activity work activities. Demolition of sub-standard space and improved productivity combine for a payback of approximately ~7 years. This new 30,000 gsf building (20,100 nsf, eff. 67%) will replace Building 10, a wooden 15,575 gsf structure constructed as a service building during WW II, a building with contains structural and life safety elements that restrict use. Building 10 can not be cost-effectively upgraded to serve modern science requirements. The estimated cost is $20.0M.
- **Building 62 and 74 —Rehabilitation of Building Operating Systems.** The rehabilitation of these two laboratory buildings will eliminate operational problems that present hardships to researchers and correct structural safety issues – this project will ensure many additional decades of beneficial scientific use of these otherwise fine research buildings.

  The scientific utility of Building 62, a forty-year old laboratory building, is severely limited by inadequate and deficient building systems. This project will improve operational performance and safety. This project will replace aged wooden fumehoods, install a new centralized laboratory exhaust system and make other HVAC modifications to allow for constant air temperature and pressure conditions in the laboratories. The project will upgrade the low-conductivity water (LCW) system to meet modern chemistry research requirements.

  Building 74 has serious utility and life-safety issues that make it less than fully adequate for modern research. The building was constructed as an animal research facility in four stages beginning in the early cold-war period. As the use of experimental animals has declined, conventional laboratory spaces have expanded in an incremental fashion that now stresses utility services and operations. These stressed and disjointed operating systems present difficulties to the research function. In addition, there are both fire and seismic life-safety concerns that will be corrected under this project.

This project will rehabilitate the infrastructure of two primary but aged laboratory buildings so that they are able to meet the fundamental operational expectations of the researchers, and are consistent with modern life safety and engineering design standards. This project has an estimated cost of $19.5M.

- **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 $15.0M.
- **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.** Building 25 is an assembly of building additions surrounding a core building constructed during World War II. This 27,975-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 3,603-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. The University in FY 2002 issued both a Request for Qualifications and a Request for Proposals for this project. Pending identification of an actual name, this project is designated Building 50X in reference to its proposed location near the Building 50 complex.

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 predicted would 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.

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 (2). 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.

Asset Management

The Laboratory has an active assets management program to identify and divest materials, equipment and excess facilities no longer needed at the laboratory based upon DOE's mission and functions. All assets are tracked and managed. Berkeley Lab has received "Outstanding" ratings in the review of its Asset Management program. A critically important effort currently under way at Berkeley Lab in assets management is the removal of Building 51 Bevatron Complex. The project consists of dismantling, demolishing and any required decontamination of the Building 51 Bevatron Complex. The work includes removal of the accelerator, shielding, buildings, related structures and surface foundation. This site will then be productively used to meet DOE's emerging scientific missions (see Science Support Infrastructure above).

Sustainable Design

Berkeley Lab follows the Executive Order 13123 on "Greening of America" by promoting environmentally responsible design and construction. The environmental impact of new construction is reduced through paying attention to sensitive site development, water and energy conservation, indoor air quality, waste reduction, and environmentally responsible building materials that minimize environmental impact throughout their life cycle.

Green buildings provide healthy and environmentally responsible workplace. It is Berkeley Lab goal to qualify for LEED (Leadership in Energy and Environmental Design) rating in design and construction of new buildings. LEED Green Building Rating System is developed and administered by US Green Building Council.

Berkeley Lab has been widely recognized for its innovative and effective recycling and reuse programs; efforts that span across all aspects of the Laboratory's operations. In addition to the conventional paper and metal recycling programs, laboratory chemicals are made available for re-use whenever this is proper, and former shielding blocks are reused within the DOE complex where possible. These programs are summarized in an annual performance measure report to DOE.

Table VI (2) Major Construction Projects (FY 2003-2009)

($ in M)

	GSF New Const.	GSF Demo'ed	Net New GSF	TEC	2003	2004	2005	2006	2007	2008
Funded Program Related Projects										
None										
Funded Science Lab Infrastructure (SLI) Projects (KG):										
Sitewide Water Distribution Upgrade, Phase 1 (FY 2001 start)				**8.30**	**2.90**					
Budgeted SLI Projects (KG)										
None										
Proposed Program -Related Projects *										
Molecular Foundry (BES) **	94,500	0	94,500	**83.70**	**6.80**	**35.00**	**32.00**	**9.40**		
E-Lab (EE)	29,000	0	29,000	**19.00**					**1.90**	**16.20**
Total Proposed Program-Related Projects	123,500	0	123,500	**102.70**	**6.80**	**35.00**	**32.00**	**9.40**	**1.90**	**16.20**
Proposed Science Lab Infrastructure (SLI) Projects:										
Building 77 Rehabilitation of Building Structure & Systems, Phs 2				**13.36**	**1.10**	**11.29**	**0.97**			
Research Support Building	25,000	15,173	9,827	**15.00**		**1.60**	**12.60**	**0.80**		
User Support Building	30,000	15,575	14,425	**20.00**			**2.40**	**16.70**	**0.90**	
Buildings 62 & 74 - Rehabilitation of Building Operating Systems				**19.50**			**1.10**	**9.60**	**0.80**	
Operations Building	25,000	16,975	8,025	**15.00**				**1.50**	**13.00**	**0.50**
Engineering Support Facility	19,000		19,000	**15.30**					**1.50**	**1.70**
Replace Building 25 (Seismic Stability) *****	25,000	27,975	-2,975	**20.20**					**1.50**	**1.70**
Environmental, Health and Safety Support Facility *****	21,000	3,603	17,397	**16.40**						**1.50**
Total Proposed SLI Projects	145,000	79,301	65,699	**134.76**	**1.10**	**12.89**	**17.07**	**28.60**	**17.70**	**5.40**
Proposed Operating Funding Needed for Removal of Retired Facilities:										
Removal of Building 51 Bevatron Complex *******		164,000	-164,000	**74.45**	**0.95**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
Total Proposed Operating Projects:		164,000	-164,000	**74.45**	**0.95**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
Total net change (increase) in GSF **** :**			25,199							

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, and important user infrastructure at the ALS (submittal in preparation).*

**= *Project TEC includes $0.5M funded in FY 2002.*

***= *Project under review; revised scope, schedule and budget will be presented in 2003 Strategic Facilities Plan*

****= *Project TEC includes funding in years beyond those shown of this table.*

*****= *Project cost estimate (conceptual) does not include $0.85M needed in FY 2002/03 for environmental review and planning; but does include $11M funding projected in FY 2010. TEC includes $2.5M in prior year funding (FY02).*

******= *New construction (GSF) will be matched to demolitions "one-to-one" using on-site demolitions and Secretarial waiver.*

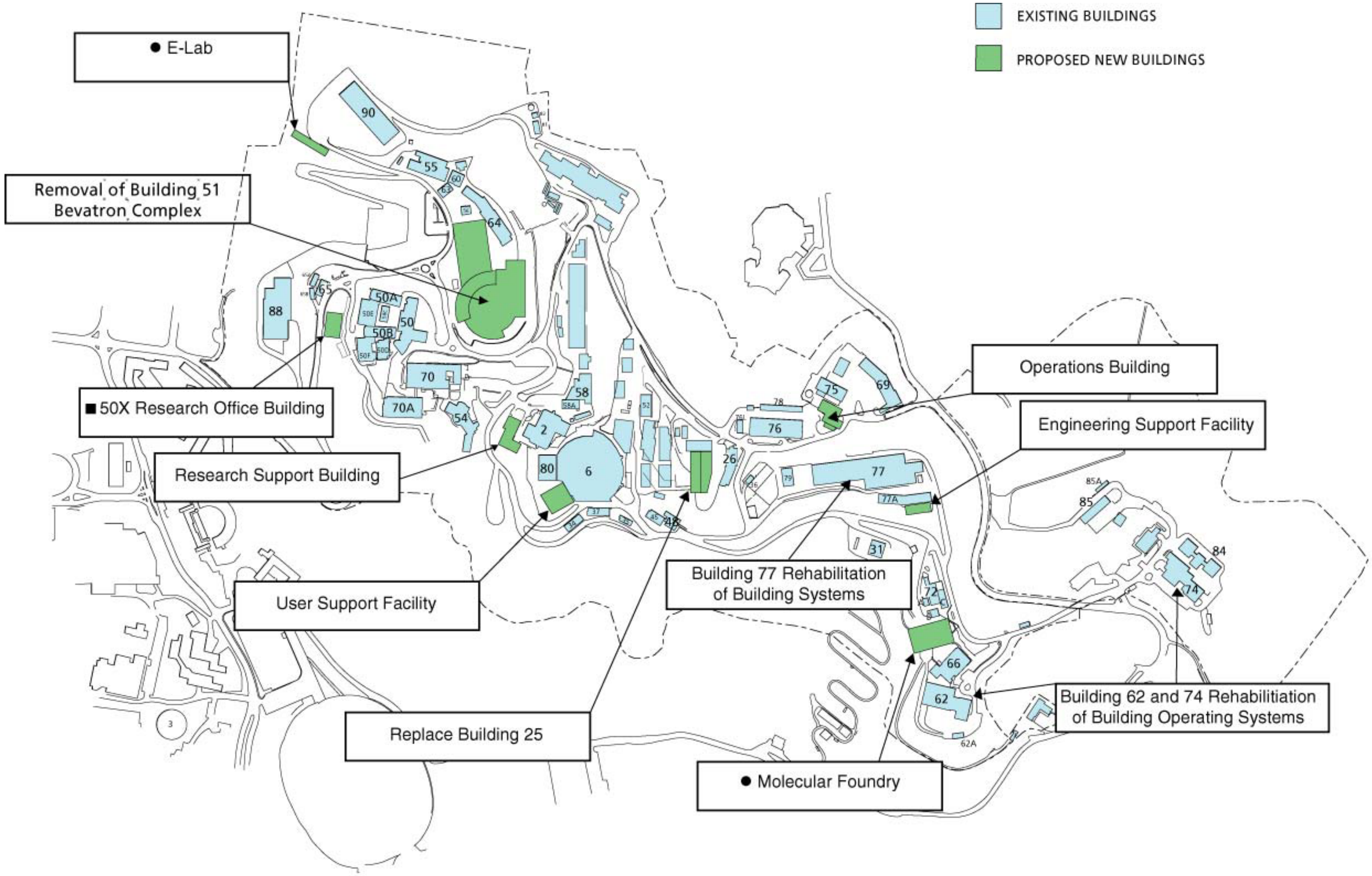


Figure VI (6) Map of Science Line Infrastructure (SLI) and Programmatic Line item construction projects, and Bevatron Removal project, as identified in Table VI(2). Programmatic projects are designated with a dot (•) in title block. Note: This map also shows the proposed site of a possible building to 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.

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 to be addressed regularly through meetings and discussions with DOE management at the Berkeley Site 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 promulgated outside of the Office of Science line management organization, including new financial, security, and safety administrative requirements. 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.

BEST PRACTICES PILOT IMPLEMENTATION

As indicated in the Director's Statement (Section I) DOE and the Administration are committed to improving management efficiencies, eliminating redundancy, and focusing on results. At the request of DOE leadership, Berkeley Lab, with the assistance of the University of California Office of the President, has completed a Best Practices Pilot Study that identifies principles for efficiently and effecting administering and operating a scientific laboratory. Pending the Secretary of Energy's decision to on a contract extension, DOE, the UC Office of President, and Berkeley Lab are preparing to frame results-based implementation anchored on the Best Practices: (1) Line Management Accountability, (2) National Standards, (3) Assurance Reviews by External Experts, (4) Bilateral Decision Process, (5) Oversight and Incentives Based on Certified Systems Metrics, and (6) Results-Based Management Contracting. Reassessing contracting terms offers the prospect of effectively and efficiently delivering on goals of the Office of Science, DOE and the Administration. It is critical that all parties focus on the key mission results, and forge terms that embody best practices principles.

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 SuperHILAC, 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 dismantle the Bevatron. In FY 2002 the Office of Science provided $2.5 million to begin a long term demolition effort. However, the prospects for a successful demolition effort were disrupted by the apparent shortfall to provide level or expanded funding for the program in FY 2003. Bevatron dismantling 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 sustain the implement a viable deconstruction effort.

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 Science Lab Infrastructure 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 E-Lab (Energy Efficiency and Electricity 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 36 years, and of the 1.7 million square feet of existing building space, approximately 299,000 square feet of space is rated "fail" and 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 Science Facilities Infrastructure program 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.

FUNDING FOR ENVIRONMENTAL RESTORATION

The FY 2003 Presidential budget request reduced the level of funding requested for the Environmental Restoration Program at Berkeley Lab by approximately $600K relative to the amount originally requested by DOE field offices. Berkeley Lab's Environmental Restoration Program has consistently performed in an outstanding manner both in meeting milestones within Berkeley Lab's control and remaining within its approved budget. The above budget cut, if approved at this level, will jeopardize the planned program completion date from FY 2006 to FY 2009, and may adversely impact the working relationship between the Laboratory and its stakeholders. Milestones currently proposed to the regulators for the Project Action Plan will be delayed.

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, and now has a fully validated ISM management plan. 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. However, a past DOE Environment, Safety, and Health Office (ES&H) "scoping visit" framed an 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.

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) 2001 budget authority and FY 2002 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)
  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 2001), Table VIII (6)
- University and Science Education, Table VIII (7)
- Laboratory Directed Research and Development, Table VIII (8)

The FY 2002 estimate is based on FY 2002 DOE budget guidance, the President's Request, and assessments by Berkeley Lab Divisions. For fiscal years 2003 and beyond, operating cost projections are in FY 2002 dollars, and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 2003 to FY 2007, 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. Projections in FY 2005-2007 includes planned funding for the Molecular Foundry project in Office of Basic Energy Sciences (B&R:KCO2) and SuperNova/Acceleration Probe (SNAP) in High Energy and Nuclear Physics (B&R:KA). The projections include research subcontracts and other collaborative activities that are conducted by other institutions outside of Berkeley Lab.

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)

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
DOE Effort	285.8	307.8	336.6	364.8	399.4	381.4	414.3
CRADA	5.2	3.4	3.4	3.3	3.3	3.3	3.3
WFO	106.7	95.0	102.2	108.7	115.4	117.8	120.5
Total Operating	**397.7**	**406.2**	**442.2**	**476.8**	**518.1**	**502.5**	**538.1**
Capital Equipment	48.5	49.5	28.5	31.5	30.5	75.5	126.3
Program Construction	18.3	6.5	9.4	38.4	40.9	21.0	12.2
General Purpose Facilities	2.1	4.4	4.0	11.3	1.0	3.0	4.9
General Plant Projects	3.0	3.3	3.5	3.5	3.5	3.5	3.5
General Purpose Equipment	2.1	1.9	2.0	2.0	2.0	2.0	2.0
Total Lab Funding	**471.7**	**471.8**	**489.6**	**563.5**	**596.0**	**607.5**	**687.0**

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
DIRECT							
DOE Effort	1,602	1,685	1,845	1,978	2,091	2,160	2,220
Work for Other than DOE	487	481	501	511	511	511	511
CRADA	28	22	19	18	18	18	18
TOTAL DIRECT	2,117	2,188	2,365	2,507	2,620	2,689	2,749
TOTAL INDIRECT	748	753	758	782	785	791	796
Total PERSONNEL	**2,865**	**2,941**	**3,123**	**3,289**	**3,405**	**3,480**	**3,545**

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Office of Science (SC)							
Operating	220.1	240.7	265.0	288.3	319.9	298.8	331.4
Capital Equipment	49.6	50.0	30.5	33.5	32.5	77.5	128.3
Construction	7.8	10.9	16.9	53.2	45.4	27.5	20.6
Total	**277.5**	**301.6**	**312.4**	**375.0**	**397.8**	**403.8**	**480.3**
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Operating	28.5	29.2	31.2	34.1	34.2	34.8	35.6
Capital Equipment	-	0.9	-	-	-	-	-
Total	**28.5**	**30.1**	**31.2**	**34.1**	**34.2**	**34.8**	**35.6**
Assistant Secretary for Fossil Energy (FE)							
Operating	6.9	7.6	7.2	8.2	10.2	12.3	12.6
Total	**6.9**	**7.6**	**7.2**	**8.2**	**10.2**	**12.3**	**12.6**
Assistant Secretary for Environmental Restoration (EM)							
Operating	7.4	7.2	6.8	6.5	6.7	6.4	6.6
Total	**7.4**	**7.2**	**6.8**	**6.5**	**6.7**	**6.4**	**6.6**
Office of Civilian Radioactive Waste Management (RW)							
Operating	0.1	-	0.5	2.0	2.0	2.0	2.0
Total	**0.1**	**-**	**0.5**	**2.0**	**2.0**	**2.0**	**2.0**
National Nuclear Security Administration (NA)							
Operating	3.5	6.1	4.4	6.4	7.8	8.3	7.8
Capital Equipment	0.3	-	-	-	-	-	-
Construction	7.1	-0.5	-	-	-	-	-
Total	**10.9**	**5.6**	**4.4**	**6.4**	**7.8**	**8.3**	**7.8**
Office of Security and Emergency Operations (SO)							
Operating	0.3	-	-	-	-	-	-
Total	**0.3**	**-**	**-**	**-**	**-**	**-**	**-**
Assistant Secretary for Environment, Safety and Health (EH)							
Operating	0.3	0.8	0.6	0.6	0.6	0.6	0.7
Total	**0.3**	**0.8**	**0.6**	**0.6**	**0.6**	**0.6**	**0.7**
Work for Other DOE Contractors							
Operating	18.8	16.3	21.0	18.7	18.1	18.3	17.7
Capital Equipment	0.7	0.5	-	-	-	-	-
Construction	8.5	3.8	-	-	-	-	-
Total	**28.0**	**20.6**	**21.0**	**18.7**	**18.1**	**18.3**	**17.7**
Total DOE							
Operating	285.9	307.9	336.7	364.8	399.5	381.5	414.4
Capital Equipment	50.6	51.4	30.5	33.5	32.5	77.5	128.3
Construction	23.4	14.2	16.9	53.2	45.4	27.5	20.6
Total	**359.9**	**373.5**	**384.1**	**451.5**	**477.4**	**486.5**	**563.3**

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Office of Science (SC)							
Direct FTE	1,251	1,362	1,472	1,580	1,679	1,735	1,791
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Direct FTE	144	130	156	172	172	175	178
Assistant Secretary for Fossil Energy (FE)							
Direct FTE	38	36	40	44	53	63	65
Assistant Secretary for Environmental Restoration (EM)							
Direct FTE	37	30	33	33	33	32	33
Office of Civilian Radioactive Waste Management (RW)							
Direct FTE	1	1	1	5	5	5	5
National Nuclear Security Administration (NA)							
Direct FTE	19	15	24	34	41	41	41
Assistant Secretary for Environment, Safety and Health (EH)							
Direct FTE	3	3	3	3	3	3	3
Work for Other DOE Contractors							
Direct FTE	109	109	115	108	105	105	103
Total DOE							
Direct FTE	**1,602**	**1,686**	**1,844**	**1,979**	**2,091**	**2,159**	**2,219**
Work for Others--Non-DOE							
Direct FTE	487	481	501	511	511	511	511
CRADA							
Direct FTE	28	22	19	18	18	18	18
TOTAL LAB DIRECT	2,117	2,189	2,364	2,508	2,620	2,688	2,748
TOTAL INDIRECT	748	753	758	782	785	791	796
Total PERSONNEL	**2,865**	**2,941**	**3,123**	**3,289**	**3,405**	**3,480**	**3,545**

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
AT Fusion Energy Sciences							
Operating	4.4	5.4	6.1	8.0	5.2	4.2	4.2
Capital Equipment	1.1	0.4	1.1	1.1	0.8	0.7	0.7
Construction	-	-	-	-	4.4	7.1	7.7
Total	**5.5**	**5.8**	**7.2**	**9.1**	**10.4**	**12.0**	**12.6**
FS Field Security							
Operating	3.5	4.7	4.8	4.8	4.8	4.8	4.9
Total	**3.5**	**4.7**	**4.8**	**4.8**	**4.8**	**4.8**	**4.9**
KA High Energy Physics							
Operating	27.9	28.8	35.1	39.5	52.3	33.5	34.7
Capital Equipment	9.4	12.0	11.2	11.4	9.7	51.3	94.9
Construction	3.0	3.3	3.5	3.5	3.5	3.5	3.5
Total	**40.3**	**44.1**	**49.8**	**54.4**	**65.5**	**88.3**	**133.1**
KB Nuclear Physics							
Operating	16.2	16.7	18.1	18.0	18.9	19.7	20.1
Capital Equipment	2.0	2.9	2.4	4.6	5.4	8.6	15.8
Construction	0.5	0.4	0.4	0.4	0.5	0.5	0.5
Total	**18.7**	**20.0**	**20.9**	**23.0**	**24.8**	**28.8**	**36.4**
KC02 Material Sciences							
Operating	49.7	50.6	55.2	61.5	65.4	69.9	96.8
Capital Equipment	10.1	10.3	7.6	7.6	7.7	7.9	8.9
Construction	2.1	2.6	9.0	38.0	36.0	13.4	4.0
Total	**61.9**	**63.5**	**71.8**	**107.1**	**109.1**	**91.2**	**109.7**
KC03 Chemical Science							
Operating	10.4	11.1	12.5	13.2	13.9	14.7	15.6
Capital Equipment	2.5	2.2	1.4	2.2	2.4	2.5	1.5
Total	**12.9**	**13.3**	**13.9**	**15.4**	**16.3**	**17.2**	**17.1**
KC04 Engineering and Geosciences							
Operating	2.7	3.4	2.8	3.0	3.5	4.0	4.1
Capital Equipment	-	0.3	-	-	-	-	-
Total	**2.7**	**3.7**	**2.8**	**3.0**	**3.5**	**4.0**	**4.1**
KC06 Energy Biosciences							
Operating	0.5	1.3	0.7	0.7	0.7	0.7	0.7
Capital Equipment	-	-	0.1	0.1	-	-	-
Total	**0.5**	**1.3**	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**
KG Multiprogram Energy Laboratories - Facilities Support							
Operating	0.0	0.0	0.0	1.6	12.6	0.6	0.2
Construction	2.1	4.4	4.0	11.3	1.0	3.0	4.9
Total	**2.1**	**4.4**	**4.0**	**12.9**	**13.6**	**3.6**	**5.1**
KH Facilities and Infrastructure							
Operating	-	2.5	1.1	4.0	4.0	4.0	4.0
Total	**-**	**2.5**	**1.1**	**4.0**	**4.0**	**4.0**	**4.0**

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
KJ Advanced Scientific Computing Research							
Operating	62.1	62.2	65.8	67.5	69.9	72.6	75.7
Capital Equipment	4.0	3.7	3.0	3.0	3.0	3.0	3.0
Total	**66.1**	**65.9**	**68.8**	**70.5**	**72.9**	**75.6**	**78.7**
KP Biological and Environmental Research							
Operating	42.2	53.4	61.2	64.9	66.9	68.3	68.8
Capital Equipment	20.4	18.2	3.7	3.5	3.5	3.5	3.5
Construction	-	0.2	-	-	-	-	-
Total	**62.6**	**71.8**	**64.9**	**68.4**	**70.4**	**71.8**	**72.3**
KX Office of Science - Program Directions							
Operating	0.5	0.6	1.6	1.7	1.7	1.7	1.7
Total	**0.5**	**0.6**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**
Total, Office of Science							
Operating	220.1	240.7	265.0	288.4	319.8	298.7	331.5
Capital Equipment	49.5	50.0	30.5	33.5	32.5	77.5	128.3
Construction	7.7	10.9	16.9	53.2	45.4	27.5	20.6
Total	**277.3**	**301.6**	**312.4**	**375.1**	**397.7**	**403.7**	**480.4**
Direct FTE	1,252	1,362	1,472	1,580	1,680	1,635	1,790

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
EB Solar and Renewable Resource Technologies							
Operating	4.0	4.3	7.1	9.6	9.7	9.7	9.9
Total	**4.0**	**4.3**	**7.1**	**9.6**	**9.7**	**9.7**	**9.9**
EC Building Technology, State and Community Sector							
Operating	14.5	14.0	13.3	13.3	13.3	13.6	14.0
Capital Equipment	-	0.4	-	-	-	-	-
Total	**14.5**	**14.4**	**13.3**	**13.3**	**13.3**	**13.6**	**14.0**
ED Industrial Sector – Total							
Operating	2.6	3.0	2.8	2.8	2.8	2.8	2.8
Capital Equipment	-	0.2	-	-	-	-	-
Total	**2.6**	**3.2**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**
EE Transportation Sector							
Operating	4.4	4.6	4.6	5.0	5.2	5.4	5.5
Capital Equipment	-	0.3	-	-	-	-	-
Total	**4.4**	**4.9**	**4.6**	**5.0**	**5.2**	**5.4**	**5.5**
EH Policy and Management							
Operating	0.1	-	0.3	0.1	-	-	-
Total	**0.1**	**-**	**0.3**	**0.1**	**-**	**-**	**-**
EK Utility Sector							
Operating	0.1	-	-	-	-	-	-
Total	**0.1**	**-**	**-**	**-**	**-**	**-**	**-**
EL Federal Energy Management Program							
Operating	2.8	2.7	3.1	3.2	3.2	3.3	3.5
Total	**2.8**	**2.7**	**3.1**	**3.2**	**3.2**	**3.3**	**3.5**
EO – Power Technologies							
Operating	-	0.6	-	-	-	-	-
Total	-	**0.6**	**-**	**-**	**-**	**-**	**-**
Total, Assistant Secretary for Energy Efficiency and Renewable Energy							
Operating	28.5	29.2	31.2	34.0	34.2	34.8	35.7
Capital Equipment	-	0.9	**-**	**-**	**-**	**-**	**-**
Total	**28.5**	**30.1**	**31.2**	**34.0**	**34.2**	**34.8**	**35.7**
Direct FTE	144	130	157	172	172	175	179

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
AA Coal							
Operating	1.5	1.9	2.3	3.0	5.0	7.0	7.0
Total	**1.5**	**1.9**	**2.3**	**3.0**	**5.0**	**7.0**	**7.0**
AB Gas							
Operating	1.7	1.8	1.7	1.9	1.8	1.9	1.9
Total	**1.7**	**1.8**	**1.7**	**1.9**	**1.8**	**1.9**	**1.9**
AC Petroleum							
Operating	3.7	3.9	3.3	3.3	3.4	3.4	3.7
Total	**3.7**	**3.9**	**3.3**	**3.3**	**3.4**	**3.4**	**3.7**
Total, Assistant Secretary for Fossil Energy							
Operating	6.9	7.6	7.3	8.2	10.2	12.3	12.6
Total	**6.9**	**7.6**	**7.3**	**8.2**	**10.2**	**12.3**	**12.6**
Direct FTE	38	36	40	44	54	64	65
CG Cerra Grande Fire Emergency							
Operating	0.0	-	-	-	-	-	-
Construction	1.5	-	-	-	-	-	-
Total	**1.5**	**-**	**-**	**-**	**-**	**-**	**-**
DP Defense Programs							
Operating	0.0	0.0	-	-	-	-	-
Construction	5.6	-0.5	-	-	-	-	-
Total	**5.6**	**-0.5**	**-**	**-**	**-**	**-**	**-**
NN Nonproliferation and Verification R&D							
Operating	3.5	6.1	4.4	6.4	7.8	8.3	7.8
Capital Equipment	0.3	-	-	-	-	-	-
Total	**3.8**	**6.1**	**4.4**	**6.4**	**7.8**	**8.3**	**7.8**
Total, National Nuclear Security Administration							
Operating	3.5	6.1	4.4	6.4	7.8	8.3	7.8
Capital Equipment	0.3	-	-	-	-	-	-
Construction	7.1	-0.5	-	-	-	-	-
Total	**10.9**	**5.6**	**4.4**	**6.4**	**7.8**	**8.3**	**7.8**
Direct FTE	19	15	24	34	41	41	41
DF Waste Management System							
Operating	0.1	**-**	0.5	2.0	2.0	2.0	2.0
Total	**0.1**	**-**	**0.5**	**2.0**	**2.0**	**2.0**	**2.0**
Total, Office of Civilian Radioactive Waste Management							
Operating	0.1	-	0.5	2.0	2.0	2.0	2.0
Total	**0.1**	**-**	**0.5**	**2.0**	**2.0**	**2.0**	**2.0**
Direct FTE	1	1	1	5	5	5	5

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
EW Environmental Restoration and Waste Management - Defense							
Operating	3.4	3.1	3.7	3.6	3.8	3.5	3.7
Total	**3.4**	**3.1**	**3.7**	**3.6**	**3.8**	**3.5**	**3.7**
EX Environmental Restoration and Waste Management - Non-Defense							
Operating	4.0	4.1	3.1	2.9	2.9	2.9	2.9
Total	**4.0**	**4.1**	**3.1**	**2.9**	**2.9**	**2.9**	**2.9**
Total, Assistant Secretary for Environmental Restoration							
Operating	7.4	7.2	6.8	6.5	6.7	6.4	6.6
Total	**7.4**	**7.2**	**6.8**	**6.5**	**6.7**	**6.4**	**6.6**
Direct FTE	37	30	33	33	33	33	34
GD Nuclear Safeguards and Security							
Operating	0.3	-	-	-	-	-	-
Total	**0.3**	**-**	**-**	**-**	**-**	**-**	**-**
Total, Office of Security and Emergency Operations							
Operating	0.3	-	-	-	-	-	-
Total	**0.3**	**-**	**-**	**-**	**-**	**-**	**-**
Direct FTE	-	-	-	-	-	-	-
HA Environment, Safety, and Health							
Operating	-	0.3	-	-	-	-	-
Total	**-**	**0.3**	**-**	**-**	**-**	**-**	**-**
HD Environment, Safety, and Health (Defense)							
Operating	0.3	0.6	0.6	0.6	0.6	0.6	0.7
Total	**0.3**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.7**
Total, Assistant Secretary for Environment, Safety and Health							
Operating	0.3	0.9	0.6	0.6	0.6	0.6	0.7
Total	**0.3**	**0.9**	**0.6**	**0.6**	**0.6**	**0.6**	**0.7**
Direct FTE	3	3	3	3	3	3	3

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Work for Others--Federal Agencies							
Department of Commerce	0.7	0.1	0.5	0.5	0.5	0.6	0.6
Department of Defense	8.4	11.8	12.5	14.5	16.5	16.5	16.5
Department of Interior	0.6	0.1	0.4	0.4	0.4	0.4	0.4
Environmental Protection Agency	5.2	4.0	4.0	4.0	3.7	3.7	3.7
National Aeronautics and Space Admin.	5.8	5.1	6.3	6.1	5.9	6.0	6.0
National Institute of Health	47.2	43.8	42.0	44.6	47.6	50.6	52.6
National Science Foundation	0.4	0.2	1.4	1.4	1.4	1.4	1.4
Other Federal Agencies - Energy Related Activities	1.5	1.5	1.1	1.5	1.5	1.5	1.5
Other Federal Agencies	-	0.4	0.5	0.5	0.5	0.5	0.5
Total Federal Operating	69.8	67.0	68.7	73.5	78.0	81.2	83.2
Total	**69.8**	**67.0**	**68.7**	**73.5**	**78.0**	**81.2**	**83.2**
Work for Others--Non-Federal Agencies							
Universities and Institutes	14.8	12.9	12.5	11.8	12.1	11.3	11.0
State and Local Governments and Non-Profit Org.	16.2	9.1	12.4	14.6	14.6	14.6	14.6
Industry	5.5	5.3	8.4	8.4	10.1	10.2	11.2
Foreign Government	0.4	0.7	0.3	0.4	0.4	0.5	0.6
Total Non-Federal Operating	36.9	28.0	33.6	35.2	37.2	36.6	37.4
Total	**36.9**	**28.0**	**33.6**	**35.2**	**37.2**	**36.6**	**37.4**
Total Work for Others--Non-DOE Contractors (no CRADA)							
Operating	106.7	95.0	102.3	108.7	115.2	117.8	120.6
Direct FTE	523	481	501	511	511	511	511
CRADA							
Operating	5.2	3.4	3.4	3.3	3.3	3.3	3.3
Direct FTE	28	22	19	18	18	18	18

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

	FY01	FY02	FY03	FY04
Subcontracting and Procurement from:				
Universities	14.3	14.6	14.9	15.2
All Others	151.8	154.8	158.1	161.4
Transfers to Other DOE Facilities	4.5	4.6	4.7	4.8
Total External Subcontracts and Procurement	**170.6**	**174.0**	**177.7**	**181.4**

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

	FY01	FY02
Procurement from Small and Disadvantaged Business	60.3	54.6
Percent of Annual Procurement	46.6%	41.3%
Available Subcontracting Dollars	129.7	132.3

Table VIII (6) Experimenters at Designated User Facilities (FY 2001)

	Number of Experimenters	Number of Organizations	Percentage of Use
Advanced Light Source			
Laboratory	378	12	32
Other DOE Laboratories	63	13	6
Other U.S. Government	7	3	1
University	411	97	35
Industry	110	43	9
Foreign Laboratory	34	23	3
Foreign University	142	72	12
Foreign Industry	11	8	1
Other	7	7	1
Total	**1,163**	**278**	**100**
National Energy Research Scientific Computing			
Laboratory	296	1	5
Other DOE Laboratories	602	15	41
Other U.S. Government	77	25	2
University	1089	163	48
Industry	100	21	4
Other (private labs)	9	5	<1
Total	**2,173**	**230**	**100**
88-Inch Cyclotron			
Laboratory	52	1	39
Other DOE Laboratories	13	4	8
Other U.S. Government	14	2	14
University	71	23	16
Industry	24	10	2
Foreign Laboratory	18	5	3
Foreign University	53	16	16
Foreign Industry	10	4	2
Total	**255**	**65**	**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	87	1	41
Other DOE Laboratories	1	1	<1
Other U.S. Government	0	0	0
University	97	19	46
Industry	10	9	5
Foreign Laboratory	3	2	1
Foreign University	14	14	7
Total	**212**	**46**	**100**
National Tritium Labeling Facility[+]			
Laboratory	—	—	—
Other DOE Laboratories	—	—	—
Other U.S. Government	2	3	5
University	2	2	5
Industry	4	4	10
Foreign Industry	—	—	—
Total	**8**	**9**	**20**
Grand Total			
Laboratory	**813**	**15**	**23**
Other DOE Laboratories	**679**	**33**	**10**
Other U.S. Government	**100**	**33**	**1**
University	**1670**	**304**	**63**
Industry	**248**	**87**	**2**
Foreign Laboratory	**55**	**30**	**<1**
Foreign University	**209**	**102**	**2**
Foreign Industry	**21**	**12**	**<1**
Other	**16**	**12**	**<1**
Total	**3,811**	**628**	**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 Berkeley Lab and at other institutions. The facility permanently closed at the end of the year.

Table VIII (7) University and Science Education

	FY2001*			FY2002*		
	Total	Minorities	Women	Total	Minoritie	Women
<u>PRE-COLLEGE PROGRAMS</u>						
Student Programs	25	11	11	30	15	15
Teacher Programs	51	8	32	8	6	4
Special Programs	851	364	459	500	200	250
<u>UNDERGRADUATE PROGRAMS</u>						
Student Programs	84**	41	31	87**	35	37
Faculty Participating Guests	—	—	—	3	2	0

*estimate

**Includes ethnic group unspecified

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

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Budget	10.2	12.4	13.5	14.5	15.5	16.0	17.5

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Earth Sciences	Linda Wuy
Environmental Energy Technologies	Donald Grether
Engineering	James Triplett
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