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LAWRENCE BERKELEY LABORATORY

Institutional Plan
FY 1993–1998

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Lawrence Berkeley Laboratory
University of California
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PREFACE

The FY 1993–1998 Institutional Plan provides an overview of the Lawrence Berkeley Laboratory mission, strategic plan, scientific initiatives, research programs, environment and safety program plans, educational and technology transfer efforts, human resources, and facilities needs.

The Strategic Plan section identifies long-range conditions that can influence the Laboratory, potential research trends, and several management implications. The Initiatives section identifies potential new research programs that represent major long-term opportunities for the Laboratory and the resources required for their implementation. The Scientific and Technical Programs section summarizes current programs and potential changes in research program activity. The Environment, Safety, and Health section describes the management systems and programs underway at the Laboratory to protect the environment, the public, and the employees. The Technology Transfer and Education programs section describes current and planned programs to enhance the nation's scientific literacy and human infrastructure and to improve economic competitiveness. The Human Resources section identifies LBL staff composition and development programs. The section on Site and Facilities discusses resources required to sustain and improve the physical plant and its equipment. The Resource Projections are estimates of required budgetary authority for the Laboratory's ongoing research programs.

The plan is an institutional management report for integration with the Department of Energy's strategic planning activities that is developed through an annual planning process. The plan identifies technical and administrative directions in the context of the National Energy Strategy and the Department of Energy's program planning initiatives. Preparation of the plan is coordinated by the Office for Planning and Development from information contributed by the Laboratory's scientific and support divisions.

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1 DIRECTOR'S STATEMENT

Charles V. Shank, LBL Director

In the last year the Secretary of Energy, Admiral James D. Watkins, has placed a renewed emphasis on reassessing the roles and missions of the Department of Energy (DOE) and its national laboratories. The 1991 Leesburg Summit between the DOE Secretariat and the national laboratory Directors was unprecedented, both in scope and substance, and has led to a framework responding to the challenges and opportunities facing our country. The DOE is reexamining its activities in the light of the National Energy Strategy and is moving to use DOE resources to attack the problem of international competitiveness.

In order to respond to these and other changes in its environment, the Lawrence Berkeley Laboratory has begun a strategic planning process in 1992. This process will produce a vision that defines the Laboratory for the year 2000, our operating qualities, and how we will be serving the Nation. The development of this vision is involving broad participation of the Laboratory's management and scientific staff. The first phase of this process will be completed in early 1993. An initial formulation of a vision and the initiatives that are part of that vision are presented in this institutional plan. The strategic issues outlined here will be reviewed and analyzed in our strategic planning. The focus of this planning process is our continued role to provide DOE with outstanding scientific and technical achievements in support of its national programs. Our planning will also consider new missions that the Department should undertake in the light of the Lawrence Berkeley Laboratory's (LBL) broad capabilities.

Partnerships will be a crucial element of our approach to meeting the opportunities of the next century. Historically, the scientific excellence of LBL has been based, in part, on a strong partnership with the faculty and students of the University of California at Berkeley. Looking forward, this partnership will be expanded and strengthened to include other colleagues in industry and academia. The completion of the Advanced Light Source

(ALS) with its exciting capabilities for research in the materials, chemical, and life sciences will bring users and collaborators from all over the nation. One focus of these collaborations will be the Combustion Dynamics Initiative. Combining the capabilities of two national laboratories, this initiative between LBL and Sandia will bring together academic and industrial scientists to work on better understanding and control of combustion to improve the use and emission characteristics of fossil fuels and their alternatives. At LBL, the joining of the ALS with molecular beam stations will establish unique instrumental facilities for its users. This new facility will make fundamental contributions to meeting the goals of the National Energy Strategy.

Complementing the capabilities of the ALS, the National Center for Electron Microscopy has maintained U.S. leadership in electron microscopy through the atomic resolution microscope and the high-voltage microscope. Maintaining this forefront capability requires next-generation instruments—the quantitative subangstrom microscope and the magnetic-materials microscope. These instruments offer new scientific opportunities for industry, government, and universities to undertake studies in atomic identification, bonding, microstructure, and magnetic properties never before achieved.

LBL is working to establish new collaborations with industry. The synthesis and processing of advanced materials is being addressed by our Center for Advanced Materials, which is guided by industry review committees and is host to numerous industrial visitors. Our Human Genome Center is working with industrial colleagues to develop the advanced robotics and software required to carry out accurately the millions of repetitive procedures involved in sequencing the human genome. Our California Institute for Energy Efficiency, operating under a Cooperative Research and Development Agreement (CRADA) with the California utilities, leverages research in energy efficiency for the Department to develop customized efficiency innovations for California ratepayers.

As we approach the coming century, LBL will face challenges of management within the Laboratory. The new expectations for excellence and compliance in Environment, Safety, and Health (ES&H) performance and business practices has been embraced by the Laboratory. Minimizing health and environmental risks to our employees and to the public is being internalized in our daily operations and management of the Laboratory. We are evaluating our business practices with attention to both DOE requirements and cost effectiveness. An important outcome of the Leesburg Summit was a mutual commitment of the DOE and its laboratories to continuous improvement of Laboratory performance within a framework of reasonable, cost-effective requirements.

LBL's strategic planning efforts over the next few years will carry a strengthened Laboratory into the next century. As a result, LBL will have a clear articulation of its contribution to the missions of DOE and its other sponsors and partners. It will define its scientific initiatives and strategic objectives in the context of improved operations and business management. Finally, it will continue to carry out fundamental research at the scientific frontiers, which is key to attracting and retaining our outstanding staff — the foundation of LBL's quality.

Charles V. Shank
Director

2 MISSION

The Lawrence Berkeley Laboratory, operated by the University of California for the Department of Energy, provides national scientific leadership and technological innovation through its mission to:

- Perform leading multidisciplinary research in the energy sciences, general sciences, and biosciences in a manner that ensures employee and public safety and the protection of the environment;
- Develop and operate unique national experimental facilities that are available to qualified investigators: The Advanced Light Source, National Center for Electron Microscopy, 88-Inch Cyclotron, Bevalac, and National Tritium Labeling Facility;
- Educate and train future generations of scientists and engineers; and
- Transfer knowledge and technological innovations and foster productive relationships between LBL research programs, universities, and industry.

Implementation of this mission supports the fundamental and applied research and development (R&D) goals of the National Energy Strategy, integrates the environment, safety, and health goals with research programs, and strengthens DOE's national efforts for science education and technology transfer. Core LBL research areas in support of this mission are:

Energy Sciences

- **Chemical Sciences**—chemical physics and the dynamics of chemical reactions; structure and reactivity of transient species; electron spectroscopy; surface chemistry and catalysis; chemistry of the actinide elements; and atomic physics.

- **Earth Sciences**—structure, composition, and dynamics of the earth's subsurface; geophysical imaging methods; chemical and physical transport in geologic systems; isotopic geochemistry; and physicochemical process investigations.
- **Energy and Environment**—building energy efficiency, environmental effects of technology, energy storage and distribution, fossil-energy conversion, industry and utility energy use, and national and international energy policy studies.
- **Materials Sciences**—advanced ceramic, metallic, polymeric, magnetic, biological and semi- and superconducting materials for catalytic, electronic, optical, magnetic, structural, and specialty applications; exploration of low-dimensional materials; development and use of instrumentation including spectroscopies, electron microscopy, x-ray optics, nuclear magnetic resonance (NMR), and analytical tools for ultrafast processes and surface analysis.

General Sciences

- **Accelerator and Fusion Research**—fundamental accelerator physics research, accelerator design and operation, advanced accelerator technology development, accelerator and ion-source research for heavy-ion fusion and magnetic fusion, and construction of the Advanced Light Source.
- **Nuclear Science**—relativistic heavy-ion physics, medium- and low-energy nuclear physics, nuclear theory, nuclear astrophysics, nuclear chemistry, studies of transuranium elements, nuclear-data evaluation, and detector development.
- **Physics**—experimental and theoretical particle physics, advanced detector development, particle data base for the high-energy physics community, astrophysics, and applied mathematics.

Biosciences

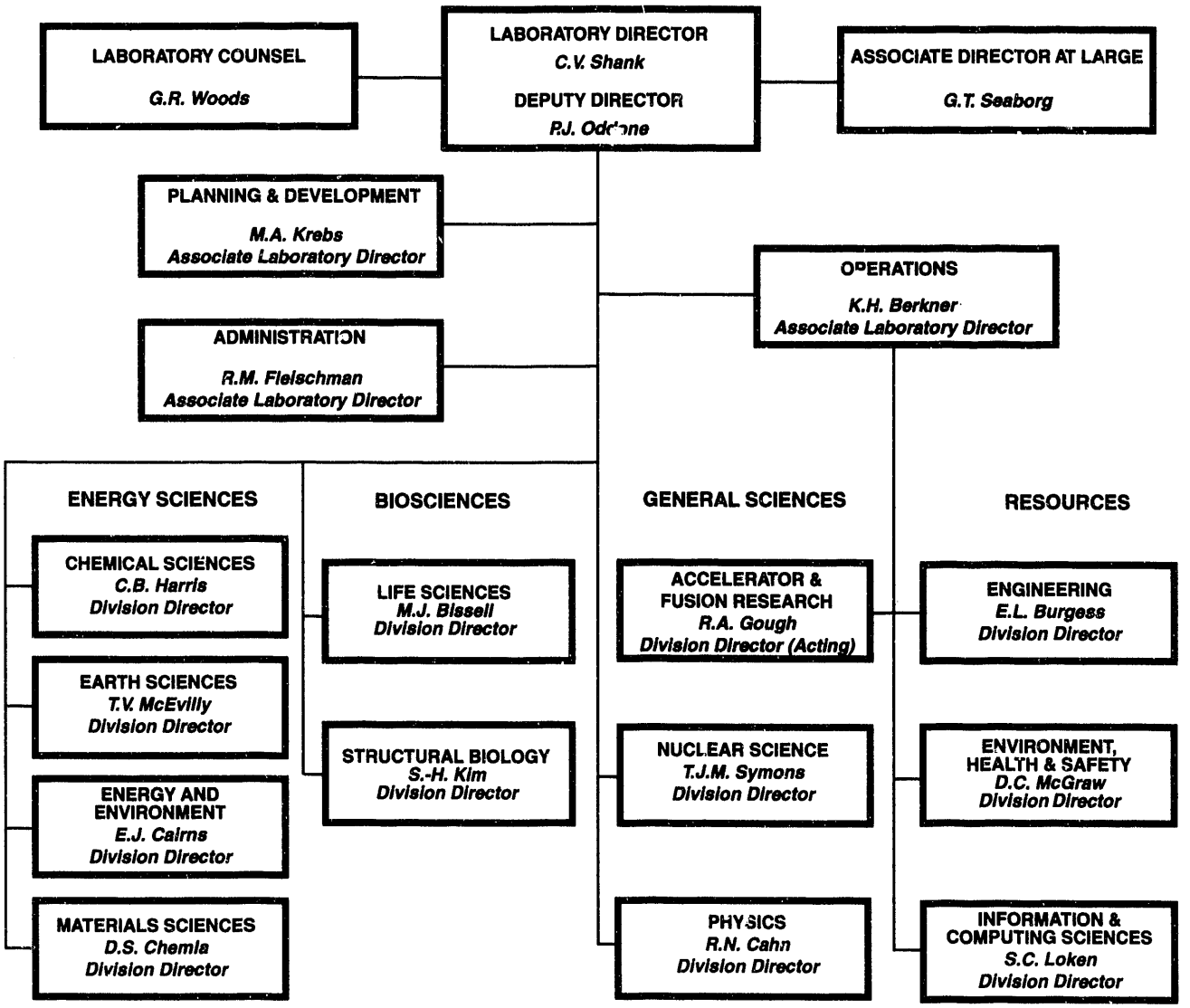
- **Life Sciences**—gene expression, molecular genetics and human genome studies, cellular differentiation and carcinogenesis, hematopoiesis, macromolecular structure, DNA repair and recombination, nuclear medicine, diagnostic and functional imaging, radiation biology, radiotherapy, and radiosurgery.
- **Structural Biology**—structural and molecular biology of nucleic acids and proteins, genetics and mechanisms of photosynthesis, photochemistry, and mechanisms of mutagenesis.

Resources and Operations

- **Engineering**—engineering design, planning, and concept development; shops and technical support for scientific programs and research facilities; advanced accelerator components; electronic and mechanical instrumentation systems; and fabrication of detectors and experimental systems.
- **Environment, Health and Safety**—technical support for safety and environmental protection, radiation associated with accelerator technology, advanced dosimeters, dispersion of radionuclides, and waste management.

- **Information and Computing Sciences**—advanced software engineering, information management, scientific imaging and visualization tools, computation tools for the human genome project, and biostatistics.

The Laboratory benefits from its close working relationship with the University of California at Berkeley and other universities, national laboratories, and industrial institutions. The Laboratory is structured, as indicated in the organization chart, to implement this mission safely and effectively.



LBL organization chart.

3 LABORATORY STRATEGIC PLAN

This year, LBL has initiated a strategic planning process to assess the Laboratory's programmatic and operating context, refine its mission and vision, and address specific issues and program objectives. The Laboratory has undertaken these activities while also working with other national laboratories to enhance a mutual R&D role in support of the National Energy Strategy (NES). The full outcome of these planning activities will be incorporated in the FY 1994–1999 Institutional Plan.

The strategy outlined in this section is a response to underlying changes in the R&D environment that affect the Laboratory's research priorities and the allocation of its resources. As a national laboratory, LBL is committed to addressing the critical research problems and technical concerns of the nation. This section identifies these concerns and proposes a direction that will maintain the Laboratory's position of scientific and engineering leadership into the 21st century.

LABORATORY CONTEXT

As a DOE multiprogram energy research laboratory, LBL serves essential national research programs that address vital energy, economic, and educational interests. Changing priorities in the international and national scene, the Laboratory's capabilities and research opportunities, and the constraints and limitations on its resources are all factors that have changed the Laboratory's operating context. This section addresses this new operating context and describes the Laboratory's objectives, issues that affect these objectives, and strategies directed to achieve LBL's mission.

National and International Environment

As one of DOE's energy research laboratories, LBL has been a leader in meeting national scientific and technological challenges. The dramatic end of the Cold War has resulted in a re-evaluation of national research roles and priorities within the larger world community. As a result, meeting the challenge of U.S. Global economic competitiveness is emerging as an important federal role. LBL is addressing this challenge and is collaborating with other laboratories to utilize and develop DOE's multiprogram research capabilities.

The DOE national laboratories provide opportunities to develop precompetitive science and technology in partnership with industry and academia to help the nation remain competitive. Historically, DOE's national laboratories have been sources of new ideas and technology that have improved the competitiveness of U.S. industries. Today, in the midst of recession and facing high capital costs, American industry has cut back its investments in long-term research. This retreat has brought about a new recognition by industry of the resources available at federal laboratories, along with an increasing demand that those resources be directed toward long-term private sector needs.

The NES outlines the energy policy directions for DOE and calls for research and development to meet strategic goals. The NES explicitly calls for fortifying the foundations of energy and economic development by maintaining the preeminence of U.S. science and engineering. Toward these ends, the national laboratories will be called upon to contribute to improving national energy efficiency, providing an improved basis for securing adequate domestic energy supplies, protecting health and the environment, and developing the foundations of scientific and engineering research.

At the same time that these new R&D objectives are developing, the research agenda supported by the Office of Energy Research will be constrained by limits on overall federal investment in the nation's infrastructure. Specific limits on research spending will require the development of a strong consensus among diverse constituencies if new programs are to be developed. Under these conditions, advance planning, broad participation, and forefront scientific potential will be prerequisite to the success of any new research initiatives. The following points summarize R&D issues for LBL:

- **Energy Sciences.** Research in this area continues to be influenced by international patterns of energy supply and use and by related economic and environmental policies. The development of new, efficient, and clean systems for energy production, use, and transmission will be increasingly important to national research programs. This research will involve, for example, advances in the understanding and use of advanced materials and chemical processes such as combustion research, high-temperature superconducting materials and technologies, alternative means of generating electricity, processes for more efficient end-use technologies, and improved methods of finding and producing fuels. Critical programs that will receive continuing national support include those funded by the Offices of Basic Energy Sciences, Fusion Energy, Fossil Energy, and Conservation and Renewable Energy.

- **General Sciences.** LBL develops its general science programs in conjunction with the high-energy and nuclear physics communities. National support for the Superconducting Super Collider (SSC) and the Relativistic Heavy Ion Collider (RHIC) provide the basis for forefront general sciences research, redirecting resources from facilities such as the Bevalac, whose nuclear physics program will end in FY 1993. Critical programs to LBL are those funded by the Office of High Energy and Nuclear Physics and by the Office of the Superconducting Super Collider. These involve close collaborations with the Superconducting Super Collider Laboratory (SSCL) and RHIC.
- **Biosciences.** LBL's bioscience research holds promise for the understanding and prevention of both hereditary and environmentally caused disease, as well as for establishing health and environmental protection standards. Continued DOE commitment in health and environment will sustain support for human genome, structural biology, and the underlying cell, molecular biology, and molecular nuclear medicine research programs. DOE's R&D strategic planning will expand the roles of both the Office of Health and Environmental Research and the Environmental Restoration and Waste Management program.

Laboratory Capabilities and Opportunities

LBL's capabilities and opportunities arise from its strengths in forefront multidisciplinary research and from its close working relationship with the University of California. LBL's long-range strategy focuses on optimal development of these strengths, making contributions to key national programs in keeping with the size and setting of the Laboratory. Key capabilities that contribute to national programs are:

- **Basic Energy Sciences.** The Advanced Light Source (ALS) will be operational in FY 1993. It will provide the world's brightest beams of soft x-rays and ultraviolet light. A Combustion Dynamics Initiative is being proposed in collaboration with Sandia National Laboratories that combines special capabilities in physical chemistry and combustion science, offering significant opportunities to understand and improve the combustion process and prevent air pollution. Significant capabilities in atomic scale synthesis, processing, and characterization at facilities such as the National Center for Electron Microscopy and Center for X-Ray Optics offer critically important opportunities for advanced materials research.
- **Health and Environment.** LBL's Human Genome Center is a national source of expertise in automated techniques for mapping human chromosomes, sequencing selected human-gene DNA fragments, and improving data analysis and interpretation. The ALS will give biologists access to the world's brightest source of soft x-rays, strengthening DOE's national position in structural biology. LBL's research medicine programs provide new insights using imaging and molecular nuclear medicine research techniques and developing the highest-resolution diagnostic systems in the world. Cell and Molecular biology research involves understanding differentiation and malignancy in selected areas and potentially controlling carcinogenesis. Environmental

research capabilities in pollution sensing, transport, effects, and cleanup promise to reduce costs for environmental remediation problems.

- **Conservation and Renewable Energy.** LBL's capabilities extend to all the energy end-use sectors: utilities, industry, transportation, and buildings. Major contributions include substantial improvements in windows, lighting systems, insulation, thermal performance, and air quality in buildings and development of long-life, high-power rechargeable batteries for vehicles and stationary power systems. Integrated Resource Planning for energy utilities, geothermal energy sources, and more efficient industrial processes are among other key areas of interest.
- **Nuclear Physics.** LBL's nuclear physics capabilities emphasize development of new detector systems, including detectors at RHIC, that explore nucleonic and quark-gluon matter. The 88-Inch Cyclotron will provide an expanded range of light-ion and heavy-ion beams for nuclear structure studies with the Gammasphere detector now under construction. The Equation of State (EOS) Time Projection Chamber opens new capabilities for heavy-ion research with an experimental program under way at the Bevalac.
- **High-Energy Physics.** LBL's capabilities in forefront detector systems have been demonstrated at the Tevatron, the Stanford Linear Accelerator Center, and now, with the Solenoidal Detector Collaboration, at SSCL. LBL also continues to advance theoretical physics and develop new accelerator concepts necessary for the continuing strength of high-energy physics. The benefits will include uniquely configured, more-efficient, and more-powerful accelerators for new insights with beams of electrons, ions, and photons.
- **Fusion Energy.** LBL has the special expertise and facilities needed to develop induction linear accelerator systems of a type that, suitably scaled up, would provide intense and focused heavy-ion beams capable of compressing and igniting a deuterium-tritium pellet for inertial confinement fusion. For magnetic confinement fusion, LBL's expertise in and test facilities for high-current neutral beams may play a key role for plasma heating systems for the International Thermonuclear Experimental Reactor (ITER).

LBL's relations with universities and industry have created new opportunities for science education and technology transfer. The San Francisco Bay area is a center for technological innovation in the areas of large-scale engineering, biotechnology, electronics, and computing industries, to name a few. The Laboratory's collaborations with industrial partners, both regionally and nationwide, have resulted in the transfer of some of the most advanced scientific concepts, including high-temperature superconducting devices for electronics, direct liquefaction of methane, and new window technology and electrochemical storage systems. The transfer of these technologies to industry represents achievements directly supporting the NES.

LBL ties to educational institutions, including the University of California at Berkeley, other schools and colleges in the Bay Area, and the Lawrence Hall of Science, are resulting in a new class of partnerships that are achieving reforms in science education. The Bay Area Science and Technology Education Consortium (BASTEC) and the Science and Education

Academy of the Bay Area are new models for utilizing the national laboratories to advance NES educational objectives.

Laboratory Constraints

As the Secretary of Energy's budget overview indicates, scientific and technological advances are critical if we are to achieve the energy, economic, and environmental objectives of the NES. National laboratory initiatives are constrained by limited budget resources, despite their key role in long-term economic security. Constrained funding is a recognized factor in energy research strategic planning. The costs of state-of-the-art facilities and added operational requirements limit the opportunities for setting new research objectives. Under these conditions, it is essential that initiatives be well coordinated and managed and involve effective scientific review. Setting priorities will be essential to initiating new programs that are vital to the national interest.

The national laboratories are undertaking management performance improvements in many sectors of their research and support operations to meet best management practices. These activities call for improved environmental, health, and safety programs; strengthened financial, acquisition, and personnel management; and improvement in the quality of services and delivery of information at all levels. A Laboratory must have sufficient research funding to support these raised performance expectations. Additional program growth will permit enhancement of LBL's support services while maintaining the Lab's high level of research capabilities and performance.

National laboratories have been perceived as enclaves for government-directed research. From the perspective of industry, national laboratories may be viewed as partners of last resort. In the past, U.S. industry has been inclined to doubt that national laboratories can develop industrial technology of high value. Contributing to this attitude has been the lack of a specific mission to work with industry and develop the financial resources for successful long-term research that supports critical industrial technology needs. Efforts are under way to remove the barriers to industry-laboratory cooperation.

VISION AND PLANNING ACTIVITIES

LBL has developed a vision statement as the first step of a strategic planning process to maintain the Laboratory as one of the nation's premier scientific institutions. Drafted by senior management, LBL Vision 2000 calls for building upon LBL's strong scientific, technical, and educational resources to gain a competitive advantage that will carry the Laboratory forward well into the next century. Elements of the draft LBL Vision 2000 are:

- *Distinguish ourselves as a premier DOE multiprogram national laboratory by performing research of the highest scientific quality.* We will build on our educational and technical resources to gain a competitive advantage for addressing problems of national significance and advancing the mission of the DOE.
- *Create value for the economy, enhance education, and contribute to the community* through partnerships with industry, universities, and other laboratories.

- *Make LBL the location of choice for facilities and programs.* Our operational, administrative, and technical resources will integrate seamlessly with the research and engineering programs to make an LBL that works. All of our activities will be conducted with full regard for the environment, health, and safety.
- *Commit to developing our people to their fullest potential.* We value and seek diversity in our work force. We will create an environment that respects the individual, encourages leadership, stimulates innovation, fosters integrity, and demands excellence.

The foundation of LBL Vision 2000 is the Laboratory employees. The goal is to create an environment where diversity is valued, individuality is respected, and leadership and innovation are encouraged. In return, the Laboratory has expectations for excellence in employee performance. LBL Vision also calls for the integrated operational, administrative, and technical resources that work seamlessly with the Laboratory's scientific and engineering research programs. The goal is to make LBL the location of choice for major new facilities and scientific programs.

LBL Vision 2000 focuses on the Department of Energy as our primary sponsor but also recognizes the opportunity and need to support other national missions. The vision establishes a commitment to reaching out and forging new partnerships with industry, academia, and other national laboratories in order to create value for the economy, enhance education, and contribute to the community. The vision also stresses the conduct of operations with full regard for environment, health, and safety. Since all employees have a stake in the Laboratory's future, mechanisms for broad involvement in developing the strategic plan have been established. Specific task forces have been established to define issues and objectives and develop recommendations in the following areas:

- National Research Needs
- Distinctive Competencies
- Scientific Initiatives
- Partnerships
- Commitment to Our People
- Making an LBL That Works

LBL Vision 2000, through its task forces and strategic planning process, commits the Laboratory to positive actions geared to increasing LBL's competitiveness and ensuring that the Laboratory will continue to perform research of the highest scientific quality.

STRATEGIC ISSUES

In order to maintain the scientific leadership identified in LBL Vision 2000, including the development and full utilization of the Laboratory's capabilities and resources and sustaining quality programs in compliance with environmental and safety laws, LBL has identified strategic management issues that it is addressing with DOE. These issues, which will be modified and more fully developed following LBL's strategic planning activities, include expanding the mission, advancing core competencies,

implementing initiatives, modernizing research facilities, and further improving ES&H performance.

Expanding Missions and Roles

Historically, the research and development missions of the DOE national laboratories have supported energy research, defense, and the physical and life sciences. This mission reflects world conditions of past decades and must be reexamined with an eye to strengthening the basis of R&D to support the NES and address the economic security issues of the nation. These changes in LBL's R&D role can be facilitated by DOE management policies that enable the national laboratories to work more effectively with industry and with other government agencies such as NIH and NASA.

- **Implement R&D for the National Energy Strategy.** LBL has developed initiatives in energy supply, energy efficiency, fundamental research, and in technology transfer and education that are directed toward implementation of the NES. The Laboratory is working closely with DOE to further define the R&D base for the NES and to seek the resources for its implementation.
- **Broaden the DOE Mission for Technology Research and Critical Technologies.** DOE programs need to more fully support research that is broadly responsive to the long-term economic vitality of the nation. LBL is working with DOE and other national laboratories to affirm technological competitiveness as a mission for DOE and to develop programs that make full use of current technical capabilities to benefit the nation.
- **Enable Industrial R&D Partnerships.** In the past, DOE organizational structures and policies have often impeded the timely development of cooperative research with industry. The Laboratory is working with DOE to develop work for others conditions and CRADA documents that reduce obstacles to the development of R&D partnerships.
- **Establish alliances and agreements with NIH, NASA, EPA, and other agencies.** The Laboratory's research relationships with NASA, NIH, and EPA have strengthened national research programs in space research, health, and environment. Agreements need to be forged to reinforce these mutually constructive relationships and reduce administrative barriers.

Advancing Core Competencies

The Laboratory's ability to conduct forefront multidisciplinary research is based on its effective management of research teams, a pool of creative research scientists and engineers, and an outstanding support infrastructure. These elements form the basis for achieving a nationally significant level of scientific accomplishment while maintaining high levels of safety and environmental protection.

LBL maintains core competencies in a number of interdependent scientific and technical disciplines. The ability to maintain these essential research competencies is challenged by the need to strengthen the support organization. To strengthen the support organization while also maintaining core competencies, the Laboratory must increase its size and more fully utilize its research capabilities.

- **Fully utilize laboratory and university capabilities.** LBL is unique among the multiprogram national laboratories in being located next to a large university. The Laboratory and DOE must continue working constructively to strengthen relationships with the Berkeley campus as well as with other universities and to devise an administrative framework that minimizes barriers to university and other partners seeking access to facilities. The Laboratory's unique research facilities must also be effectively utilized. For example, effective utilization of the ALS will require additional beamlines and the development of the second-floor offices and laboratories for users. Utilization of these capabilities is required to gain the full benefit of the investment in these unique national facilities.

- **Strengthen the fundamental science and technology base.** LBL technical expertise and infrastructure is built on a core of fundamental science and technology that serves DOE's energy research and general sciences missions. Collaborative research support can significantly leverage DOE's investment in technology research for national critical technologies. Existing programs, such as those at the Center for Advanced Materials and the Human Genome Center, also address these vital national needs.

- **Validate the framework for expected support services.** The Laboratory's FY 1992 programs have been conducted with 762 support FTEs, serving 1812 direct FTEs. To fulfill support demands at the projected levels of expectation for ES&H and administrative management, additional indirect FTEs may be required. Within the existing burden levels this will require programmatic growth to approximately 2000 direct FTEs. This overall growth to a critical size will enable the Laboratory to meet its Corrective Action Plans for ES&H and administrative compliance while maintaining program objectives.

- **Human Resource Development.** The Laboratory owes its performance to the combined efforts of its staff. The focus of LBL's vision for human resource development is on outreach and professional growth for members of the Laboratory's teams. In the past, multidisciplinary teams have been a key element of the vision. For the future, the diversity of these teams will be strengthened to improve their performance and to enrich their ideas.

Implementation of Initiatives

Limited DOE resources set constraints on the range and scope of LBL's initiatives. In this environment, scientific excellence alone is no guarantee of success; the Laboratory must also demonstrate that its initiatives contribute to national needs. The Laboratory is working with DOE, the scientific community, and state and industry participants to establish priorities and to support initiatives that can best serve the nation under financial constraints. Examples from three key DOE program areas illustrate the Laboratory's priorities for initiatives that support the NES:

- **Office of Basic Energy Sciences.** The Combustion Dynamics Initiative, proposed in partnership with Sandia National Laboratories, supports DOE's Chemical Sciences Division commitment to the environmental, energy supply, and fundamental science goals of the NES. The Laboratory is working with broader state and national scientific

communities to seek additional support for this project to complement DOE funding. The Laboratory is also supporting the efforts of the Materials Sciences Division and other national laboratories to upgrade DOE's forefront electron microscope capabilities, including those at LBL's National Center for Electron Microscopy. The Laboratory proposes additional beamlines and the completion of the second floor of the ALS building for user offices and laboratories.

- **Office of Health and Environmental Research.** LBL's Human Genome Laboratory and the ALS give biologists access to advanced technology needed to address fundamental life science challenges: to understand the genetic and structural basis of energy-derived and environmentally derived health issues. LBL is working with the Office of Health and Environmental Research to establish a scientific and management framework that will ensure the success of these initiatives.
- **Office of Fusion Energy**. The Induction Linac Systems Experiments can further evaluate the potential for using intense and focused heavy-ion beams as drivers for inertial confinement fusion. The Laboratory is working with the Office of Fusion Energy to construct this test facility.

The FY 1993–1998 Institutional Plan identifies important initiatives that support the NES in other DOE programs, including the Offices of Energy Research, Conservation and Renewable Energy, and Environmental Restoration and Waste Management and the Civil Space Mission. To fulfill the Laboratory's mission, the timely implementation of initiatives is essential.

Facilities Modernization

The Laboratory will continue to give priority to modernizing and restoring facilities to sustain national programs while also achieving standards of excellence in the areas of environment and safety. The Laboratory has integrated its work on the Site Development Plan with the processes of institutional planning, safety and health planning, and environmental restoration, so that a safe working environment will be provided for implementation of DOE scientific programs. Critical elements of LBL capital resource and modernization planning are implemented through:

- **General Plant Projects (GPP)**. GPP funds for LBL have been provided by DOE's Nuclear Physics Division. Small capital projects ($100 K to $1.2 M) supported by GPP are essential for small program modifications and additions; for compliance with environmental, health, and safety standards; and for upgrades of obsolete and deteriorated equipment such as transformers, switching stations, boilers, chillers, and roofs. At $3.1 M the current budget for GPP is inadequate to make substantial progress in meeting identified needs. The Office of Energy Research should coordinate GPP plans to ensure a coherent framework for GPP improvements of the multiprogram laboratories.
- **General Purpose Equipment (GPE)**. The Laboratory uses GPE funds to replace its essential support equipment. This equipment includes environmental, safety, and health equipment; essential physical plant equipment for maintenance and repairs; mechanical and electrical engineering shop equipment; transportation vehicles, including shuttle vehicles; data processing and telecommunications equipment; and other equipment used by support divisions. In FY 1981 support for GPE was $1.3 M per year, a level that allowed essential services to

continue but did not reverse obsolescence. During the next few years funding slid to $800 K. In FY 1992, GPE funds are $1.7 M, but, compared with 1981, the purchasing power is equivalent to about $700 K, or one-half the 1981 funding. This level of need has resulted in equipment being used beyond its normal lifetime, sustained high maintenance costs, and substandard equipment performance.

- **Multiprogram Energy Laboratories Facilities Support (MEL-FS).** The MEL-FS program has been effective in replacing mechanical and electrical utilities, upgrading buildings, and improving segments of roadways at LBL. A key element for the program in the 1990s will be the continued improvement of these systems and modernization of support buildings and general purpose research facilities. Many of these buildings are temporary structures, World War II vintage wooden barracks, or sheet metal structures that do not meet the Laboratory's standards.
- **Capital Resources Programs.** The Laboratory has developed a five-year plan and outlook for GPP, GPE, and MEL-FS that establishes priorities against quantitative Capital Asset Management criteria to meet programmatic, environmental, and safety needs. The Laboratory will work with the Office of Energy Research and the San Francisco Field Office to reconcile the discrepancy between the current funding model and GPP and GPE resource needs. The proposed coordination and funding of these programs at the PSO level should provide a basis to implement an effective capital resources planning and modernization program.

ES&H Performance

It is the policy of the Lawrence Berkeley Laboratory to integrate its performance in the areas of environment, safety, and health into the planning and conduct of all of the Laboratory's operations to ensure employee and public safety and the protection of the environment. The Laboratory has developed a comprehensive Corrective Action Plan, five-year Safety and Health (S&H) Plans, and Environmental Restoration and Waste Management Plans that integrate ES&H requirements into all activities. All new initiatives include specific identification of ES&H needs, and their Conceptual Design Reports and other supporting materials indicate ES&H requirements for program planning. Laboratory leadership and staff continue to make every effort to maintain the momentum and support the culture change mandated by LBL's Self-Assessment Program and the Tiger Team Assessment Corrective Action Plan. The following critical issues continue to be addressed:

- **Resources for required safety and health plans.** Although management arrangements and interactions with DOE are being strengthened, commitments must be obtained from DOE to ensure that the ES&H momentum can be maintained. Within the Office of Energy Research (ER), support must be provided to fully develop and implement LBL's ES&H plans and programs. The landlord support from the Division of Nuclear Physics has been insufficient to fully satisfy ES&H needs.
- **ES&H facilities for essential programs.** As indicated by the Tiger Team, many of LBL's ES&H facilities are inadequate and in poor condition. An Environmental Monitoring and Industrial Hygiene Building is necessary to correct deficiencies identified by the 1991 Tiger Team Assessment, implement the Corrective Action Plan, and fulfill the personnel and program obligations in ERWM and S&H five-

year plans. The facility will allow the Laboratory to meet accepted standards for LBL's environmental, health, and safety programs, including providing adequate monitoring and sample processing laboratories, adequate emergency command and response facilities, and sufficient space for on-site offices for industrial hygiene, environmental, and other essential ES&H staff.

- **ES&H reviews and oversight.** DOE and LBL should work toward eliminating redundancy of reviews and direct efforts to improve performance within a well-defined management framework. DOE should work to implement proposed rules that clarify implementation of the National Environmental Policy Act and should conduct NEPA document reviews and issue determinations in a timely manner. The system of DOE orders should be revised to reduce redundant paperwork requirements and to clarify and improve the efficiency of operations.
- **Bevalac decommissioning.** LBL has developed a decommissioning plan for support and program facilities. The Bevalac may possibly be supported after FY 1993 by the Civil Space Mission. Should such a plan not be implemented, ERWM D&D support should be secured promptly. The importance of the Bevalac site and its location within an urban area make this project a high priority for the Laboratory and the University if the scientific program is curtailed.

STRATEGIES

These issues of expanding the mission, maintaining competencies, modernizing facilities, and improving ES&H and management performance require that the Laboratory and the DOE exercise leadership and implement changes in management and the allocation of resources. The strategy for achieving a vision of excellence will require LBL leadership to develop compelling priorities, strengthen partnerships, and sustain excellent performance in all areas of Laboratory management.

Research Priorities

LBL's strategy for fulfilling its DOE research mission is to target those research areas that promise national benefits from the Laboratory's science and engineering expertise. The National Energy Strategy identifies key areas of energy supply, efficiency, fundamental science, and education where the Laboratory is directing its research efforts. In concert with national reviews conducted by advisory bodies such as the Basic Energy Sciences Advisory Committee, the High Energy Physics Advisory Panel, and the Nuclear Science Advisory Committee, LBL advances research to strengthen national programs. LBL will participate actively in DOE's strategic planning efforts to define critical new directions and establish a framework for more fully utilizing and focusing the national laboratory competencies.

For the Office of Basic Energy Sciences, the ALS enables the Laboratory to focus its efforts on research priorities directly related to the NES, including the Combustion Dynamics Initiative, and the implementation of user facilities. Other initiatives of a smaller scale complement these priorities, including upgrade of the National Center for Electron Microscopy, and advanced materials and computing research.

Research in the biosciences is becoming increasingly synergistic with energy sciences and general sciences. Facilities such as the ALS have outstanding promise for structural biology through x-ray crystallography, microscopy, and spectroscopy. The Human Genome Center directly benefits from the engineering and computer science expertise originally developed for data-intensive physical sciences. The biosciences offer promise for solving significant problems in molecular medicine, environmental remediation, materials synthesis, and energy conversion. The Laboratory's priorities will continue to emphasize the potential for national impact of these programs beyond traditional biomedical disciplines.

The Laboratory supports initiatives in the general sciences and fusion energy through established long-range planning processes. The Laboratory couples its initiatives in these areas, such as the SDC-SSC collaboration, the STAR Experiment at RHIC, and ILSE for inertial fusion energy to the national framework for large-scale scientific experiments planned for these fields.

Technology research is an emerging direction for DOE and LBL. Critical technologies research opportunities that serve the national interests are in areas such as advanced materials and processing; biotechnology; computing and information science; and energy and environmental research. The Laboratory will work with the Office of Energy Research, the Assistant Secretary for Conservation and Renewable Energy, and other program secretarial offices to support priorities for fundamental and applied research and technology transfer vital to U.S. long-term competitiveness. The Laboratory's programs in energy efficiency and storage have a strong record of effective technology transfer to industry, and support the research strategy of DOE's Conservation and Renewable Energy programs.

Partnerships

The Laboratory will aggressively develop research initiatives and collaborative research opportunities in concert with industrial, academic, and government partners. The success of key LBL initiatives, including the Combustion Dynamics Initiative, Induction Linac Systems Experiments, and B factory at PEP will be increasingly dependent on the strengths of LBL's relationships with its collaborating partners at other national laboratories, maximizing payoffs from DOE investments without duplication.

Collaborations with industry will be essential to develop the technology research role of the multiprogram laboratories. LBL maintains a vision of leadership in becoming a model laboratory to broaden the mission of the national laboratories in response to the need for critical technologies research. The Office of Energy Research has begun support for a technology research program involving CRADAs with LBL's industrial partners. LBL's role in contributing to national initiatives in advanced materials, biotechnology, and computing will depend on strong relationships with industrial partners. LBL's effort in establishing the California Institute for Energy Efficiency, formalized as a CRADA, provides a role model for a successful collaboration among energy utilities, national laboratories, the Office of Conservation and Renewable Energy, and education institutions.

Partnerships with other national laboratories, government agencies, and state governments will contribute to successful strategic planning for the national laboratories. LBL's programs supporting the DOE/NASA Civil Space Mission will be greatly facilitated by formal agreements to strengthen this partnership. LBL's research in structural biology, molecular genetics, and research medicine will greatly strengthen national programs supported by both the Office of Health and Environmental Research and the National Institutes of Health. LBL's alliances with other national laboratories, including the LLNL, ORNL, and SLAC, offer promise to DOE for efficiently and effectively utilizing the expertise of the national laboratory system.

Performance

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

The Laboratory is accountable for program performance based on the strengths, quality, and commitment of LBL's scientific and management efforts. The Laboratory's focus on innovative solutions for national research programs is based on the valued contributions of all Laboratory staff, from principal investigators and program leaders through all the technical and administrative support staff. The Laboratory's success relies on the efforts of multidisciplinary teams, where knowledgeable and capable individuals work together with common goals. The Laboratory seeks the best professional program reviews and maintains nationally recognized high standards for performance and recognition. The DOE review framework, from initial field task proposal through validation and program performance reviews, is an important measure for program performance.

LBL undertook a culture change during 1991 that emphasizes excellence in ES&H performance at all levels of the Laboratory. The Laboratory seeks to strengthen management relationships with DOE so that the Laboratory has both the accountability and the resources to support modern requirements for worker safety and health, waste minimization and management, and environmental protection.

The Laboratory is responsible for maintaining the infrastructure for effective financial and administrative performance. LBL is committed to best business practices in all areas of administration, including human resource development and training, finance and contractual relations, materials management and procurement, facilities maintenance and engineering, and other management and planning practices. The Laboratory will emphasize the application of performance measures. LBL is committed to working with DOE as a partner for continuous performance improvement for national research institutions.

4 INITIATIVES

The Laboratory's initiatives have goals appropriate to a DOE national laboratory and are capable of significant new scientific and technological achievement. Expanded research program activity of a smaller scale is summarized in Section 5, Scientific and Technical Programs. Environment, safety, and health initiatives that support the Laboratory's services and support programs are described in Section 6. The proposed initiatives encompass the five-year planning period and span DOE's research program areas appropriate to this multiprogram national laboratory. Inclusion of the initiatives does not imply that they have been adopted by DOE or that they will be funded at the levels requested. Estimates of the approximate resource requirements for these initiatives include the incremental operating costs (with equipment) and construction costs over the period of the plan.

Basic Energy Sciences

- Combustion Dynamics Initiative
- Advanced Light Source Beamline Initiative
- Atomic Scale Synthesis of Advanced Materials
- Advanced Transmission Electron Microscopes
- High Performance Computing and Communications

High-Energy and Nuclear Physics

- PEP-II, An Asymmetric B Factory
- SSC Solenoidal Detector Collaboration
- Relativistic Heavy-Ion Collider Program

Health and Environmental Research

- Human Genome Laboratory
- Structural Biology Initiative
- Global Change Research Program

Conservation and Renewable Energy

- Advanced Energy Design and Operation Technologies

Domestic and Energy Policy

- Assisting Deployment of Energy Practices and Technologies

Fusion Energy

- Induction Linac Systems Experiments
- Accelerator Test Facility for ITER

Environmental Restoration and Waste Management

- Environmental Restoration Research and Development

Space Research Office

- Civil Space Mission

Work for Others

- Advanced Lithography Initiative

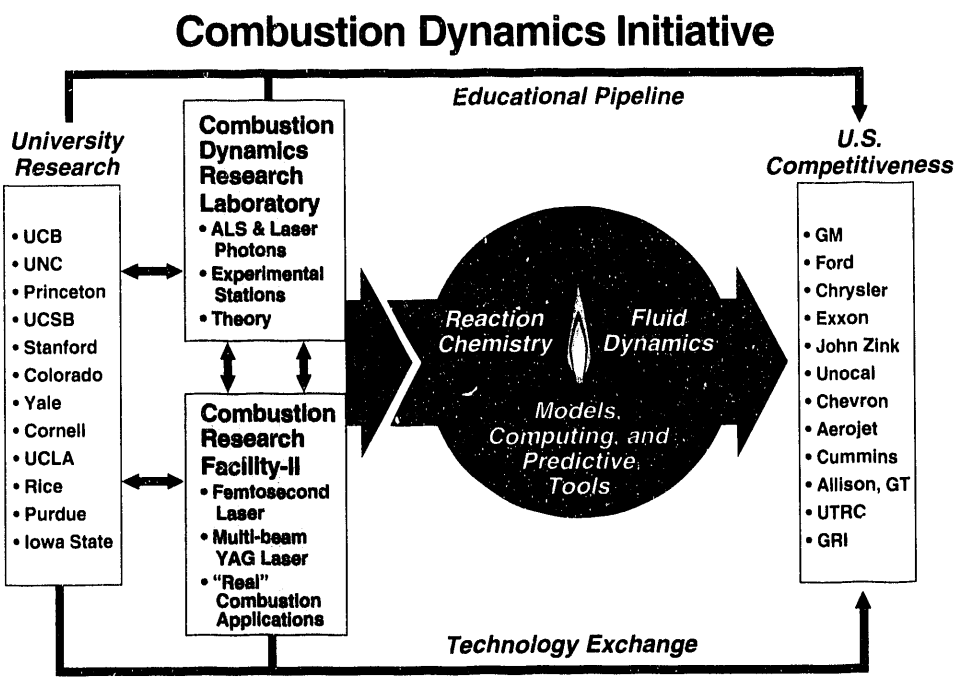
BASIC ENERGY SCIENCES

Combustion Dynamics Initiative

In support of DOE's national role in combustion research and chemical science, LBL and the Sandia National Laboratories (SNL) have proposed a Combustion Dynamics Initiative. This initiative advances DOE's energy sciences mission by providing the knowledge and technology base needed to help solve the nation's combustion-related problems of the 21st century. DOE's Basic Energy Sciences Advisory Committee (BESAC) reviewed the initiative in depth in 1991 and gave its strong endorsement to facility construction, saying, "The Combustion Dynamics Research Laboratory (CDRL) at Berkeley, which along with the Combustion Research Facility, Phase II, comprise the facilities portion of the Combustion Dynamics Initiative, should be initiated. The CDRL will enable research at the heart of the OBES and DOE mission in support of energy development and efficiency, while making use of the special capabilities of the ALS."

The CDRL will provide unparalleled experimental resources for national users to enable new investigations of fundamental and applied combustion processes. At LBL, new lasers, experimental stations, and dedicated chemical physics beamlines from the Advanced Light Source (ALS) will be made available for dynamic, spectroscopic, and structural studies of many types of highly reactive molecules, radicals, clusters, and

The Chemical Dynamics Research Laboratory at LBL and the Combustion Research Facility II at Sandia National Laboratory will be important new resources for the understanding of combustion chemistry and fluid dynamics. Working in partnership with industry and universities, the Combustion Dynamics Initiative will play a significant role in technology development and transfer to industry as well as support for the DOE mission in energy development and efficiency.



unusual transient species. A rigorous molecular-level understanding of combustion reactions, the structure and dynamics of highly excited molecular species and reactive intermediates, and molecular energy-flow processes can provide basic new knowledge that underlies scientific and technological leadership in internationally competitive energy-related industries. Application of this basic chemical knowledge will be accelerated by the partnership with SNL through complementary experimental resources for applied research and linkages to combustion researchers in industry and universities.

The CDRL's purpose is to achieve this new understanding by an intense experimental and theoretical effort, developing and applying infrared radiation sources, and ultrahigh resolution and picosecond lasers in the VUV region, as well as molecular-beam apparatus for these investigations. The proposed facilities include:

- Tunable high-power infrared solid state laser optimized in the 3- to 10-μm wavelength region for chemical reaction research;
- Advanced lasers, molecular-beam machines, fully equipped experimental stations, ALS chemical physics beamlines, and computer-based modeling and control systems; and
- A laboratory facility to support and provide utilities, safety systems, and necessary space to conduct studies.

The solid state laser will, for example, allow scientists to excite the internal modes of molecular species in a way that simulates the combustion environment and, with high intensities and uniquely broad tunability, will allow the unprecedented capability of selective multiphoton excitation. The research facilities would be assembled by combining the various photon sources with molecular-beam and ultrahigh-vacuum surface apparatus. The high-intensity photons from the ALS VUV undulator and the successful development of a high-resolution VUV laser at LBL will expand the potential

scope of experiments substantially, making it possible to monitor many spectroscopic and reactive-scattering processes that were not possible to observe in the past. The facility will allow, for the first time ever, the integrated and simultaneous use of high-power IR laser and ALS beamlines for pump-probe experiments with crossed molecular beams.

Possible new pump-probe experiments include the high-resolution infrared spectroscopy of intermediates in molecular beams and the probing of reaction-product state distributions. The short pulse durations and synchronization of the VUV photon sources will make possible fast-timing experiments, such as the measurements of intramolecular relaxation and rearrangement rates, and unprecedented high-resolution photoelectron spectroscopy experiments. The facility's scope also allows for the flexible management and arrangement of experimental apparatus, for safe transfer of chemicals and gases, and for modular instrumentation and computer interface systems.

Research results from the CDRL will be incorporated into powerful predictive computer codes under development in the Advanced Combustion Modeling Environment (ACME) initiative. These computer codes will enable a broad range of manufacturers to design clean, efficient combustion systems. Combustion modeling and ACME is discussed further in the section on High Performance Computing and Communications.

The CDRL will host visiting scientists, and its facilities will be made available to all qualified collaborating investigators. A Program Review Panel, reporting to the highest levels of management, will recommend allocations of resources and review all proposals for use of the experimental stations. LBL's outstanding graduate student and science education programs will contribute to full utilization of the facility in support of national science education goals. The majority of research at the CDRL will be conducted by graduate students and postdocs from participating universities. A Steering Committee of predominantly external advisors will be appointed to provide advice on policy issues and to ensure maximal scientific and technical productivity of the facilities to achieve national scientific purposes. Collaborations of external users and in-house research personnel will be supported by a dedicated scientific and technical staff. A Fellows Program will attract outstanding scientists to the CDRL. The planning of this initiative has included rigorous safety, health, and environmental considerations to ensure that the project will be conducted in full compliance with DOE Orders, NEPA and CEQA documentation, and other Federal, state, and local regulations.

Combustion Dynamics Initiative Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	0.0	1.0	2.0	2.0	2.0	3.0	*10.0*[b]
Construction	0.0	6.9	16.2	15.2	10.5	5.4	*54.2*

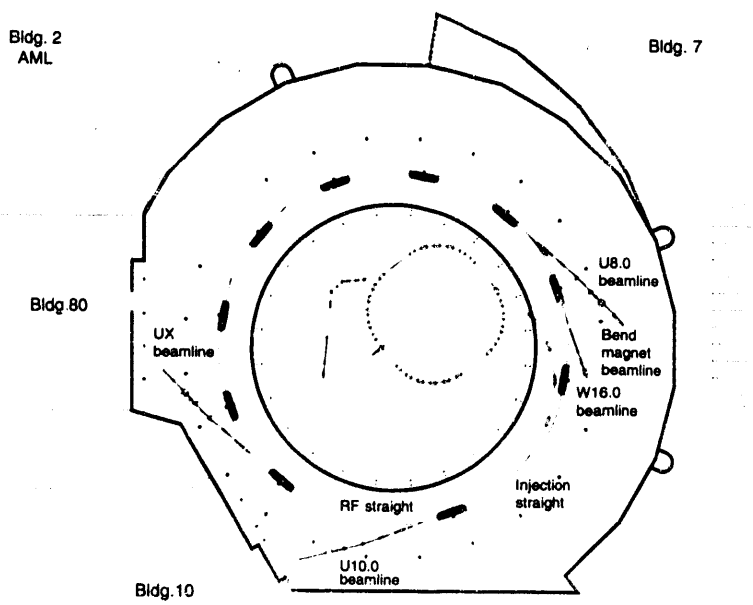
[a] Estimates of actual-year Budgetary Authority for construction and related project costs for the Chemical Dynamics Research Laboratory (B&R code KC).

[b] Does not include $0.3M R&D conducted in FY 1992.

Advanced Light Source Beamlines Initiative

In order to realize the full scientific potential of the Advanced Light Source (ALS) for both fundamental and applied research, LBL is proposing a Beamlines Initiative for experimental facilities needed to address new forefront scientific and technological opportunities identified by the nation's research communities. Applications of the ultrahigh-brightness ultraviolet and soft x-ray radiation from the ALS cover diverse areas, including atomic and molecular physics; biology and medicine; chemical dynamics; materials, interface, and surface science; and industrial research and technology:

- Several of the most exciting applications of the ALS lie in the field of *materials, interface, and surface science.* Enhanced spatial resolution is a significant consequence of the high brightness of the ALS. The impacts of spectromicroscopy are expected to be broad because of the decreasing size of the physical and biological systems to be analyzed or fabricated.
- Use of novel two photon techniques will make it possible to do real-time measurements of *dynamical phenomena in materials.*
- The pulsed time structure of the ALS is crucial to the area of *chemical dynamics,* which encompasses all phenomena in which molecules undergo energetic or chemical transformations, both in the gas phase and on solid surfaces.
- In *all fields,* the extra degree of freedom associated with circular polarization lends a precision and specificity to photon-based techniques that is otherwise lacking. The use of circularly polarized synchrotron radiation is now at the cutting edge of research on properties, such as magnetism, that are dependent on electron spin.



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A plan view of the Advanced Light Source, now under construction at LBL. The ALS Beamlines Initiative will add the insertion-device beamlines indicated in the figure to the initial complement of beamlines now under way, as well as support labs and offices within the ALS building.

Full utilization of the ALS to exploit emerging needs of ALS users from industry, academia, and government laboratories requires insertion devices (undulators and wigglers) and beamlines to carry the light from insertion devices and bend magnets to the experimental end stations, together with completion of the 2,341 gm^2 (25,200 gsf) of office, light laboratory, and support space for users in the unfinished second floor of the ALS building. Projects costs include all safety systems necessary for full compliance with applicable regulations, orders, NEPA/CEQA documentation,and ALS design specifications.

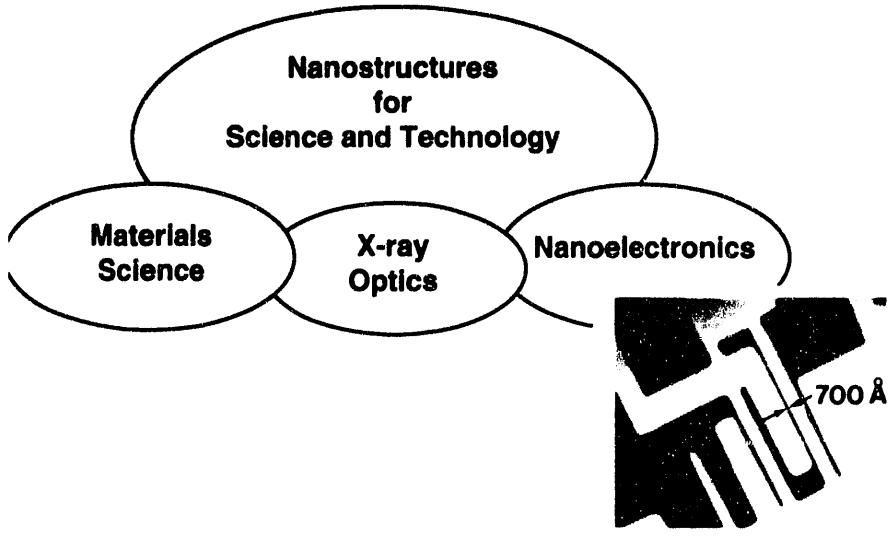
Advanced Light Source Beamline Initiative Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*
Construction	0.0	9.5	13.7	13.0	6.3	0.0	*42.5*

[a] Preliminary estimate of actual-year LBL Budgetary Authority (B&R code KC).

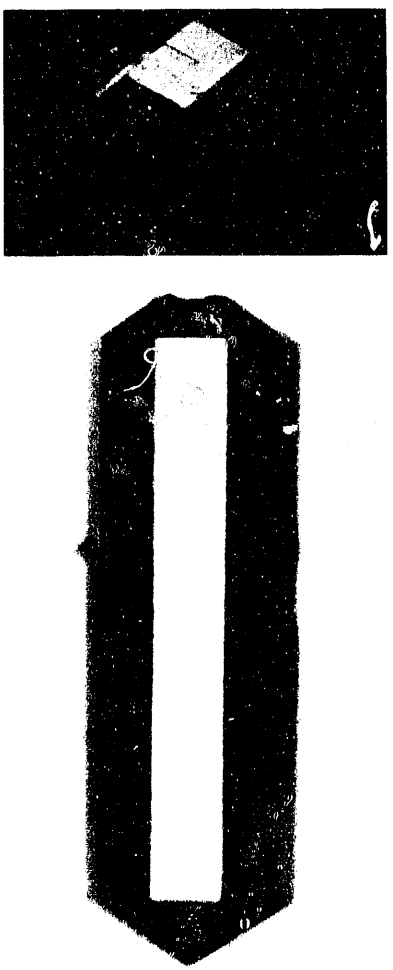
Atomic Scale Synthesis of Advanced Materials

In support of DOE's materials science research programs, LBL is proposing the establishment of a new program to develop techniques for the synthesis, processing, and characterization of materials at the atomic scale. Atomic scale synthesis will enable highly efficient, finely controlled processing and fabrication for the development of a new realm of materials. In addition, atomic scale processing can enhance the properties and synthesis techniques for existing thin films and their use in conjunction with bulk materials. The effort will strengthen DOE's mission in basic research that supports advanced energy technology, enabling more effective development of energy sources and more efficient processing technology. Atomic scale control will enable a new generation of materials technology in support of the National Energy Strategy to improve energy efficiency, environmental research, and economic competitiveness:



The Atomic Scale Synthesis of Advanced Materials is an initiative involving industrial partners in the development of new materials and critical technologies, in support of the National Energy Strategy.

- New superconductors and semiconductor structures (energy storage, photovoltaics, sensors, computing, and automation)
- High-energy-product magnets and magnetic films (motors and memories)
- Control of friction (energy dissipation)
- Hard and/or soft coatings (wearing)
- Stronger and lighter structural materials (transport)
- Materials with better heat resistance (energy dissipation)
- Catalysis (coal gasification and liquefaction; environmental cleanup).



Crystals of the superconductor C-60 "Buckeyball" are grown to allow intense study of their unusual properties. Understanding of such new materials is necessary before industrial applications can be undertaken.

The program will extend beyond the current generation of thin films, interfaces, and bulk materials research. These next-generation studies can enable atomically tailored materials optimized for energy storage, energy transfer, and optical, mechanical, electronic, surface (lubricative, adhesive, hardness), and magnetic properties. Optimized characteristics can be achieved through manipulation and deposition of atoms, clusters, and films using novel inorganic and organic synthesis, molecular and ion manipulation, and other techniques, resulting in unique "zero" dimensional structures or quantum dots (points at conventional scales), molecular wires, tubes of one dimension (length), and two-dimensional films of atomic or molecular thickness. These unique building blocks can be assembled into novel structures with advanced performance capabilities, such as near-zero noise, unprecedented spectral resolution, and temporal response that goes beyond conventional materials into the femtosecond domain.

The program includes the development of low-dimensional building blocks, utilizing organic/biological methods and inorganic synthesis. A wide range of techniques will be employed, including solution chemistry for the preparation of "zero-dimensional" crystallites of cluster compounds, the preparation of polymeric molecular wires sheathed in nonconducting molecules, and the use of organic linkers to attach dots and wires to surfaces. Powerful characterization methods are available at LBL, including the Atomic Resolution Microscope (see below), advanced laser spectroscopy, and the ALS. The initiative complements the ALS, which will be invaluable for studies of structure (e.g., with glancing-incidence x-ray scattering) and other properties. Structural characterization will also be performed by LBL's scanning tunneling microscopes and atomic force microscopes to characterize hardness, adhesion, and other properties. The research will be conducted under rigorous safety, health, and environmental controls and reviews to ensure compliance with DOE Orders and OSHA regulations. Collaborations with industry will be encouraged, and an industrial visitors program will be established.

Atomic Scale Synthesis of Advanced Materials Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	4.9	5.2	5.2	5.2	5.2	5.2	*25.7*
Equipment	3.0	3.0	2.0	2.0	2.0	2.0	*14.0*

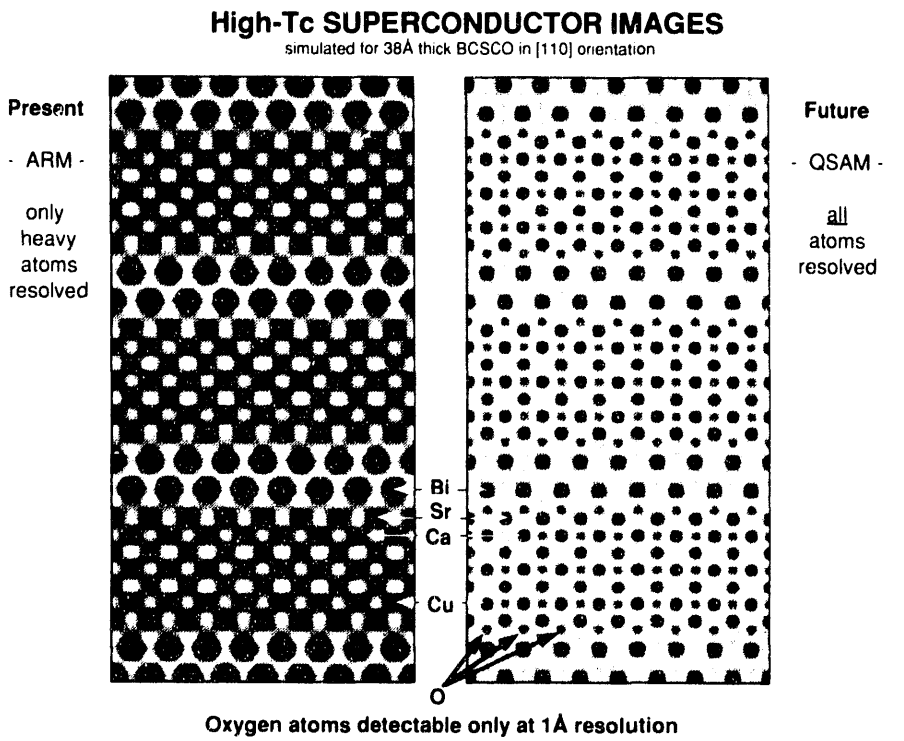
[a]Estimate of actual year Budgetary Authority (B&R code KC).

Advanced Transmission Electron Microscopes

In support of the national research program in materials science, LBL is proposing a major upgrade expansion of its National Center for Electron Microscopy (NCEM). This national user facility has kept DOE programs at the leading edge of transmission electron microscopy during the decade of the 1980s, particularly in high resolution, where the Atomic Resolution Microscope has been in the vanguard of the world effort. Two new forefront instruments are proposed to strengthen and complement existing capabilities:

- **A Quantitative Sub-Angstrom Microscope with point-to-point resolution near 1 Å (a 50% improvement) and the ability to record an exact count of the electron distribution in a microscope image for digital storage and analysis.**
- **A Magnetic Materials Microscope for imaging magnetic materials in field-free space at high spatial resolution with a differential phase-contrast detector, equipped with a field emission gun, ultrahigh vacuum specimen chamber, 5-Å probe, and high performance spectrometers for advanced analytical capabilities.**

NCEM's existing comprehensive computational capability will be expanded and integrated with the new microscopes, allowing on-line image analysis, processing, and simulation. This initiative complements related materials science programs at LBL and supports a range of programs funded by the Office of Basic Energy Sciences (OBES), such as those in metallurgy, ceramics, high-temperature superconductors, geosciences, and chemistry, as well as other Office of Energy Research programs, including the life sciences. It enables these DOE programs to maintain their lead in this highly competitive field through the next decade. The facility is being planned in conformance with DOE Orders and OSHA regulations.



The increased resolution of the proposed Quantitative Sub-Angstrom Microscope will allow detailed understanding of the atomic structure of a variety of important materials.

Advanced Transmission Electron Microscopes
Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	0.0	3.5	6.8	11.3	4.1	2.2	*27.9*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of actual-year LBL Budgetary Authority (B&R code KC).

High Performance Computing and Communications

The primary goal of the High Performance Computing and Communications initiative is to enhance national research and domestic economic development through high-speed, advanced computation, and data communications capabilities. This initiative responds to the Office of Science and Technology Policy (OSTP) report *A Research and Development Strategy for High Performance Computing.* This OSTP document addresses the critical relationship between successful Federal scientific research and enabling high performance computing and communications. Further, the initiative stresses the importance of the U.S. computer industry to the national economy.

The DOE and LBL programs place emphasis on the major scientific initiatives or Grand Challenges, including the development of software tools, new computational capabilities, and gigabit data transmission network applications. As part of the DOE program, LBL has an R&D strategy based on developing an integrated, distributed computing environment, including advanced workstation capability, computer servers, database servers, and a high-speed network integrated through a software bus environment.

LBL is developing key technologies as a part of its high performance computing research program, including high-speed networking, advances in the software bus, developing scientific databases, and imaging and visualization tools for multimedia capability. These tools are being applied to Grand Challenges, including combustion modeling research, resolution-limited imaging (in the areas of medicine, structural biology, geology, and ALS imaging systems), global climate modeling, human genome research, and development of the next generation of detectors for nuclear physics and the Superconducting Super Collider (SSC).

An important part of the effort is focused on the problem of building high-speed distributed computing applications over heterogeneous networks. The fundamental limit is the overhead in inter-process communication mechanisms, network protocols, and routing algorithms that limit performance to a small fraction of the theoretical bandwidth. The research program utilizes existing testbed networks to improve performance limits for problems of interest to the scientific and engineering community. In order to determine these performance limits, the Information and Computing Sciences Division is currently working with the XUNet collaboration and with the T3 networks to model and measure network characteristics and develop enhancements to existing protocols and inter-process communication mechanisms. The program will also utilize the Bay Area Gigabit Network to improve network performance for distributed computing and multimedia applications.

An area of special emphasis will be new capabilities in combustion modeling. The National Energy Strategy calls for the next generation of combustion devices with minimal emissions and maximal fuel efficiency. The common theme of the modeling efforts is to understand the combustion chemistry and the interaction of chemistry with fluid flow. This understanding will allow scientists to follow the development of pollutants in combustion devices and minimize them, while at the same time maximizing fuel efficiency. Both stationary and mobile combustors will be studied, including both gas and diesel engines, industrial burners and furnaces, and gas turbines. ACME will address the relationship among combustion problems and combustion modeling approaches that can contribute to solutions for engine/combustor design needs.

High Performance Computing and Communications
Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	3.0	5.0	5.0	5.0	5.0	5.0	*28.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL actual year Budgetary Authority (B&R code KC).

HIGH-ENERGY AND NUCLEAR PHYSICS

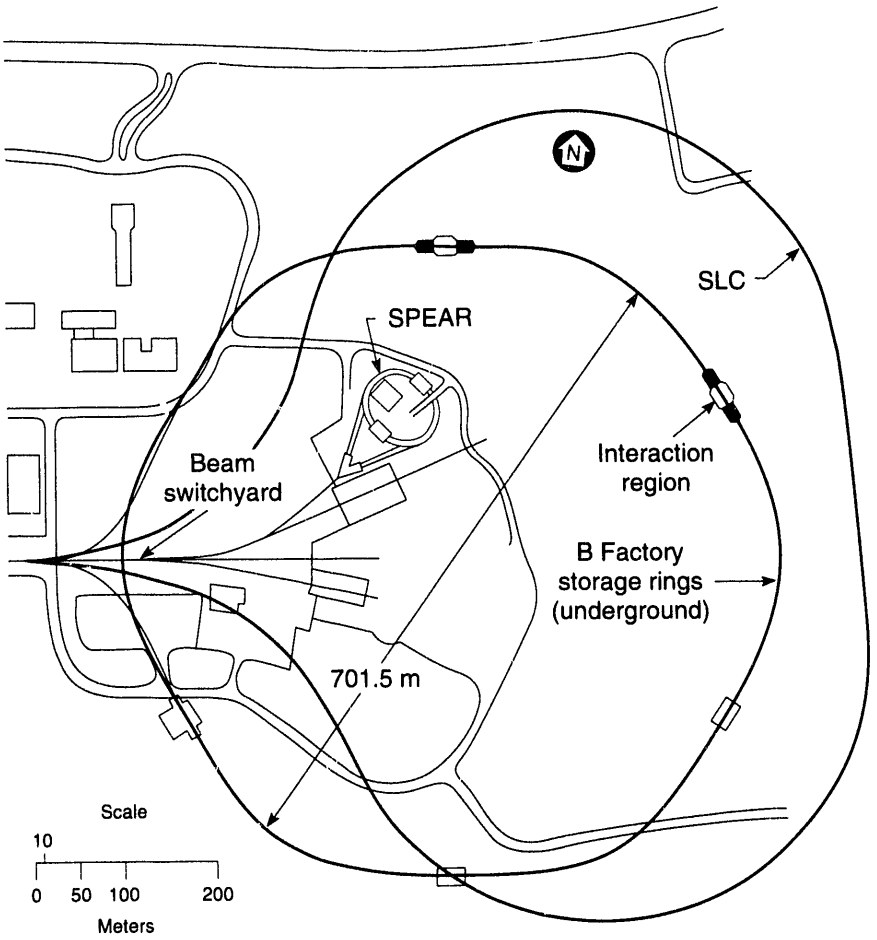
PEP-II, An Asymmetric B Factory at PEP

The study of B-meson decays will be one of the key elements of the worldwide high-energy physics program for many years to come. These studies are limited today by the relatively low rate of events produced at e^+e^- storage rings such as the Cornell Electron Storage Ring. An increase in the event rate by a factor of 10 or more is required for the study of the most interesting processes within the standard model, both rare decays and, even more important, the study of charge-parity (CP) violation.

The concept of using asymmetric collisions of storage-ring beams with a center-of-mass energy at the Upsilon (4S) resonance was originally suggested at LBL. The Upsilon (4S) decays into two B mesons nearly at rest in the center of mass. Since the center of mass would be moving because of the different beam energies of the two rings, the two B mesons move along the direction of the higher momentum, and their decays are separated in time (or, equivalently, space). This separation permits the reconstruction of individual B mesons and the study of the time evolution of their decays. The use of asymmetric collisions is equivalent to an additional factor of approximately 10 in luminosity for the study of the most interesting channels for CP violation.

LBL, in collaboration with the Stanford Linear Accelerator Center (SLAC) and LLNL, has evaluated the use of the Positron Electron Project (PEP) storage ring in conjunction with a new low-energy storage ring. A

A plan view of the proposed asymmetric B-Factory, PEP-II. It would be built in the Positron-Electron Project tunnel at SLAC and would use a substantial amount of the existing hardware for the PEP collider.



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B factory based on PEP (a high-energy, 9-GeV ring), with the addition of a new low-energy (3-GeV) ring, is attractive both scientifically and fiscally. A conceptual design prepared in conjunction with SLAC and LLNL has shown that such an asymmetric B-factory scenario is entirely feasible with state-of-the-art technology; and all environment, safety, and health requirements are included in the project.

The construction of the PEP-based B factory (PEP-II) would be carried out as a collaboration among SLAC, LBL, and LLNL. LBL would play a lead role in major aspects of the accelerator construction project. Studies are also presently under way to design a new detector to exploit fully the opportunities made possible with PEP-II. The detector construction and operation would be carried out in collaboration with universities and other national laboratories. LBL physicists would participate in the detector design and construction, and would play an important role in the excellent scientific program to be carried out at the facility. In the event that new construction funds were not available for PEP-II in the near term, SLAC has proposed applying a portion of its annual operating funds toward the construction of PEP-II for a 5-year period. With this approach, the LBL role in the project construction would be more limited, but still a crucial one involving key management positions that influence the project significantly.

PEP-II Asymmetric B Factory Resource Requirements ($M)[a,b]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	3.2	1.6	1.0	1.6	6.5	—	*29.3* [c]
Construction	—	44.2	68.1	57.0	12.1	—	*181.4*

[a] Includes SLAC/LBL/LLNL costs. Preliminary estimate of actual-year Budgetary Authority (B&R code KA).

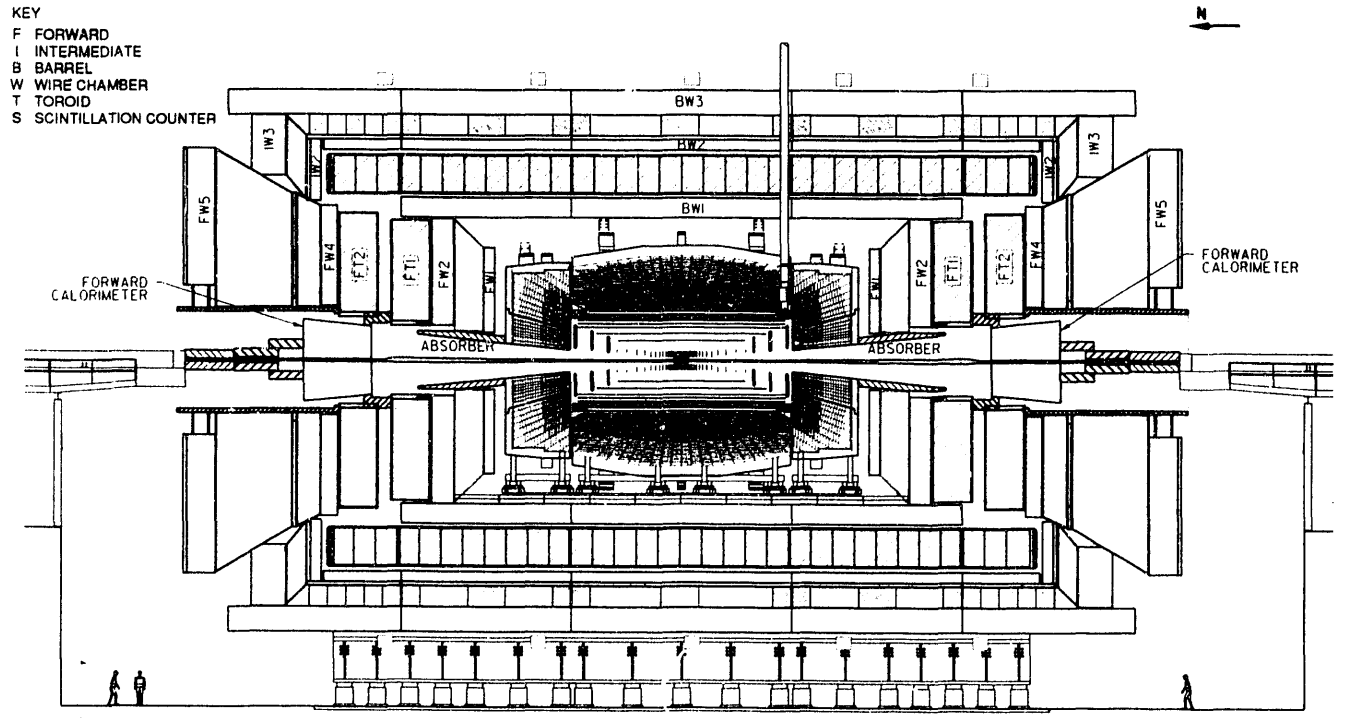
[b] The possibility of a 1994 construction start with funding taken from the SLAC operations budget is also under discussion.

[c] Includes $15.4 M R&D funds from prior fiscal years.

SSC Solenoidal Detector Collaboration

The international collaboration on a solenoidal detector system for the SSC is directed toward exploring the rich domain of high-energy physics to be opened by the SSC. The initial goals include the discovery of new heavy bosons and critical elements of the standard model, including the Higgs particle and the top quark; investigating electroweak symmetry breaking and supersymmetry; and exploring quark and lepton substructure and other new phenomena. The requirements of a detector system to achieve these goals include efficient lepton identification, isolation, and energy resolution; reconstruction of jet fragmentation; and determination of missing transverse energy. A solenoidal detector system with high-resolution vertex measurement, outstanding tracking, well-understood calorimetry, and good calibration and monitoring can meet these requirements and achieve the physics goals.

Elevation view of the SDC detector. The dark structure near the center is the silicon tracking system. The labels BW, IV and FW refer to various muon tracking systems, and BS, IS, FS to muon scintillation counter systems.



The Laboratory has emerged as a leading voice of the Solenoidal Detector Collaboration as an outgrowth of involvement in the detectors worldwide, hosting the SSC Central Design Group, participation in workshops on SSC detector systems, and in developing the challenging technologies required for the high-rate environment of the SSC. This collaboration now comprises more than 900 scientists representing more than 100 institutions from throughout the world. The collaboration spokesperson is at LBL, and the deputy spokespersons are from Fermilab, KEK in Japan, and the University of Pisa in Italy. The technical organization and design activities have begun for calorimetry design; computing and analysis software; electronics, data acquisition, and triggering systems; muon systems; superconducting magnets; and tracking systems; as well as overall detector integration and physics performance. A detailed design report was issued April 1, 1992.

LBL has the established physics base to carry out its leadership and technical management role. Additional administrative and engineering resources are required to design the detector modules, to perform the necessary subsystems prototyping, and to achieve the necessary infrastructure to complete the design for a construction start in FY 1993. Complementing this effort are broadly based LBL detector initiatives supporting the SSC program, including warm liquid calorimetry, liquid argon calorimetry, electronics data acquisition, wire and silicon tracking research and development, and physics and detector simulation. The cost profile identified below is an estimate of LBL's component of the SSC detector efforts including all required ES&H costs.

SSC Solenoidal Detector Collaboration Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	3.0	3.0	3.0	3.0	3.0	3.0	*18.0*
Construction[b]	0.0	5.0	8.0	8.0	8.0	8.0	*37.0*

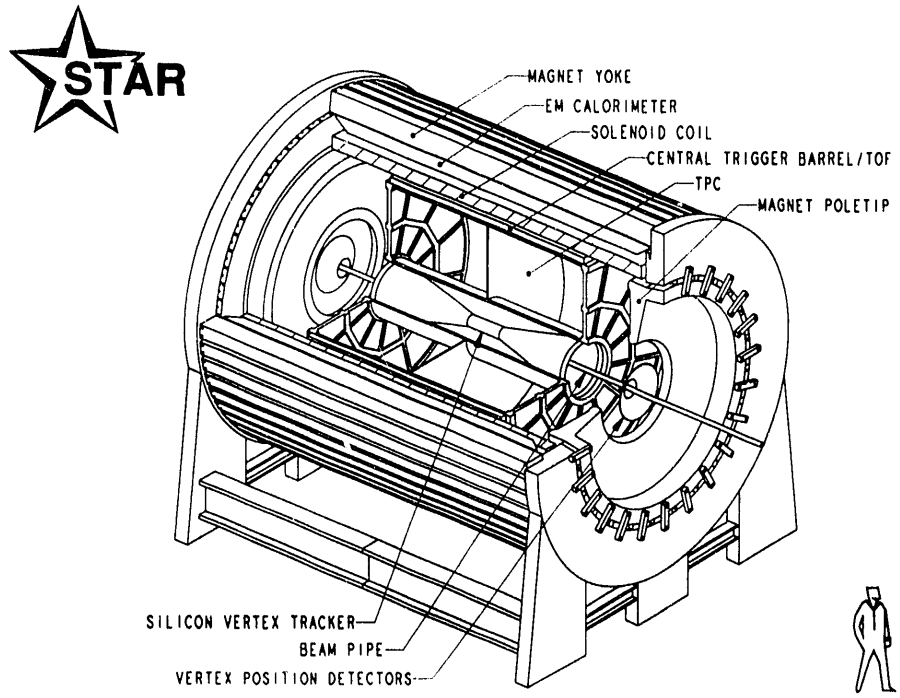
[a] Preliminary estimate of LBL Budgetary Authority (FY 1990 dollars); (B&R code KS).
[b] Resources are for detector fabrication.

Relativistic Heavy-Ion Collider Program

LBL has played a seminal role in defining the forefront of relativistic heavy-ion physics since the field's inception and continues to maintain its leadership role. The Relativistic Heavy-Ion Collider (RHIC) is now under construction at Brookhaven National Laboratory (BNL), and LBL is the lead Laboratory for the approved STAR experiment. LBL's Relativistic Nuclear Collisions Group is providing a focus for these RHIC activities. With a plan to have 30 LBL physicists and technicians working on this experiment, the group has developed the STAR collaboration, now consisting of 140 physicists from 23 institutions.

The experimental goal is to study particle production and high transverse momentum (p_t) jet production at midrapidity to identify the phase transition from normal nuclear matter to quark matter. Since hard-scattered partons, the precursors of jets, are predicted to be sensitive to the medium

STAR is an experiment to study particle and jet production in high energy heavy-ion collisions for identifying the phase transition from normal nuclear matter to quark matter. Shown here is a perspective view of the STAR experimental configuration showing the detector subsystems.



through which they propagate and since hard-scattering and the production of jets at high p_t are directly calculable in quantum chromodynamics, the study of high-p_t jets as a function of energy and mass of the colliding system may be a very attractive experimental approach to identify the presence of quark matter. Furthermore, a measurement of the produced particles at midrapidity provides the opportunity to select on events with extreme values of temperature (particle spectrum), flavor (strangeness content), shape (particle momenta), and size (two-particle correlations). The experiment will contain a Time Projection Chamber (TPC) located inside a superconducting solenoidal magnet for tracking, momentum analysis, and particle identification. Segmented electromagnetic calorimeters will be implemented in an azimuthally symmetric geometry outside the magnetic field for jet identification and triggering. Time-of-flight detectors surrounding the TPC will extend particle identification to higher momenta, and a silicon vertex tracker near the interaction region will distinguish primary and secondary vertices, and improve the tracking and momentum resolutions of the experiment.

A detector R&D program is currently underway to provide the detector and data acquisition developments required to support the experiment. Projects now receiving support from RHIC detector R&D funds administered by BNL include feasibility and performance studies for use of a TPC at RHIC energies, integrated electronics for advanced detectors, and studies of a silicon vertex tracker. These projects and the proposed STAR program are being developed in compliance with DOE Orders and all other applicable ES&H requirements. LBL expects this R&D effort and the detector engineering to expand significantly in the next few years.

Relativistic Heavy-Ion Collider Program Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	0.5	1.5	2.5	4.0	5.0	6.5	*20.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

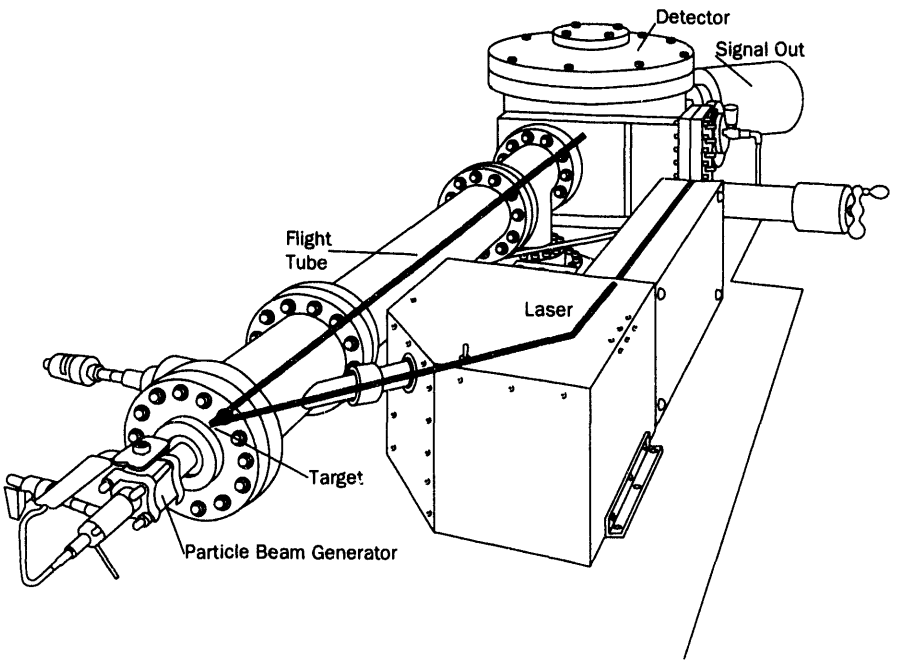
[a] Preliminary estimate of LBL Budgetary Authority (FY 1992 dollars), including equipment (B&R code KB).

OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH

Human Genome Laboratory

LBL was designated by the Secretary of Energy as a center for human genome studies as part of DOE's important role in the national effort to physically map and sequence the human genome. This national program will contribute significantly to understanding, diagnosing, and preventing hereditary and environmental diseases. LBL's Human Genome Center now requires the necessary laboratory facilities to conduct the research and development needed to map and sequence the human genome and to analyze the resultant complex genomic data. Programmatic elements to be conducted at the Laboratory would include:

- Mapping, cloning, and sequencing—develop new methods that will accelerate the speed of constructing large-scale restriction maps, ordered libraries, and completed DNA sequences of large regions of the genome. Immediate goals are to use the polymerase chain reaction



Drawing of a mass spectrometer test stand for studying adaptation of mass spectrometry for determining the size distribution of DNA. One mass-spectrometry method being tested employs a pulsed laser; another uses a particle-beam approach.

to automate many of the steps required in DNA mapping and sequencing and to test new schemes where a set of dispersed segments of DNA sequence substitutes for the need for a continuous DNA map;

- Information systems—develop computational tools needed to analyze the mapping, cloning, and sequencing data generated from genome research at LBL and throughout the scientific community and to provide computational foundations for the Human Genome Project. Develop novel data-management techniques needed for map and sequence data and laboratory information management. Investigate and implement methods for DNA fragment overlap detection, map assembly, and sequence and pattern matching;
- Instrumentation—develop innovative techniques in instrumentation and automation to accommodate the size and complexity of the experimental procedures. In addition to improving existing methods, emphasis will be placed on developing advanced techniques for handling large numbers of samples, e.g., large numbers of polymerase chain reactions, large numbers of oligonucleotides, etc. Methods for direct imaging of electrophoresis gels using modern detectors or optical and ultraviolet imaging systems, including those based on chemiluminescence and fluorescence, will be explored, as will methods of manipulating, dissecting, and sequencing individual DNA molecules; and
- Structural and functional interpretation—interpret DNA sequence to identify transcriptional promoters and terminators, splice sites, reading frames, and protein binding sites; perform structural analyses to predict unusual DNA structures relating to DNA regulation and RNA transcription; and relate these structural and functional elements to biological functions.

The program plans are being developed with close review and guidance from the Office of Health and Environmental Research (OHER), with other national laboratories, and with the life sciences and computer sciences departments at UC Berkeley and other UC campuses. LBL expects the research and development efforts to grow significantly during the next several years. The major experimental activities at that time will be conducted in an essential new facility, the Human Genome Laboratory, to be constructed in the Life Sciences Functional Area of the Laboratory. This new laboratory will consist of 3850 gm^2 (41,500 gsf) of light-laboratory space with functions dedicated to the conduct of mapping, cloning, and sequencing activities along with integrated instrumentation, computation, and all required ES&H support facilities and building design elements. A plan for recommended NEPA/CEQA documentation and operational safety procedures has been developed. As more is learned about the map of the human genome, the efforts will be integrated with fundamental studies in molecular genetics and gene expression.

Human Genome Laboratory Resource Requirements ($M)[a]

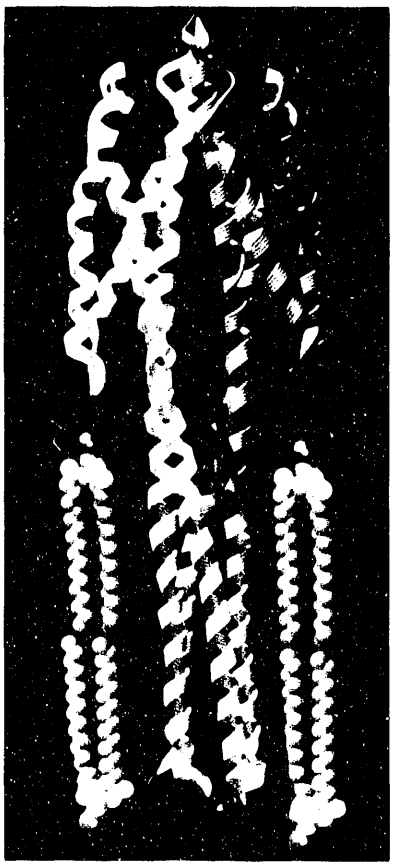
Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	7.0	11.0	12.0	12.0	12.0	12.0	*66.0*
Construction	0.0	2.2	15.6	5.9	1.0	0.0	*24.7*

[a] Preliminary estimate of actual-year LBL Budgetary Authority (B&R code KP).

Structural Biology Initiative

New applications of advanced imaging, diffraction, and spectroscopy techniques will greatly strengthen DOE's emerging national program in structural biology. A structural biology research program is being formulated at LBL to develop the potential structural biology resources at the Advanced Light Source. The ALS will offer major new resource opportunities for life sciences research supporting several facilities in emerging areas of scientific emphasis:

- X-ray microscopy—to investigate tissues, cells, and organelles in near-native states at a resolution that may approach macromolecular dimensions. Among the benefits of x-ray microscopy at the ALS will be element-specific imaging and the possibility of three-dimensional imaging.
- Crystallography—to conduct static and dynamic analysis of macromolecular architecture with precise wavelength tuning and controlled polarization. The facility addresses the high demand for beam time with a multiuser configuration and user-friendly design and operation.
- X-ray spectroscopy—to determine biochemical properties at high spatial and temporal resolution within cells and organelles.



Computer-generated image showing the 3-D backbone structure of the aspartate chemotaxis receptor of a bacterium. Studies done by scientists in LBL's Structural Biology program on such receptors may be the key to how living cells and microorganisms sense and respond to their environment.

The structural biology programs at the ALS will be focused on experimental stations, initially at the ends of the two beamlines. The first beamline, from an undulator source of ultrabright soft x-rays, will illuminate two x-ray microscope stations, one available for biological microscopy and the other for developing advanced microscopy techniques. The second beamline, from a wiggler source of both soft and hard x-rays, will branch into separate experimental areas for spectroscopy and diffraction research. The majority of the operating (and equipment) funds identified below will be for fabrication and development of these beamlines. The beamline and equipment components will include all safety systems, interlocks, and biohazards controls in compliance with DOE Orders and regulations; and appropriate safety procedures and manuals will be prepared prior to final design or operation. The supporting laboratories will be constructed in the second floor of Building 6, as part of the ALS Structural Biology Support Facilities.

These ALS projects will be coupled to other structural biology expertise at LBL to initiate new collaborations and to participate in the national scientific program. Strengths at LBL include x-ray microscopy, spectroscopy, and crystallography, as well as other relevant techniques such as electron crystallography, high-voltage electron microscopy, NMR spectroscopy, and scanning tunneling microscopy. Among these, the new, largely DOE-developed microimaging technologies offer unprecedented opportunities for collaborative research investigating subcellular architecture. Another example is the use of an interdisciplinary approach toward chemical biology and computational biology proposed for the Center of Biomolecular Design. This will merge a detailed understanding of biological systems with the ability to analyze and manipulate chemical structures.

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

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	10.0	8.0	5.5	4.5	4.1	4.1	*36.2*
Construction	0.0	0.6	4.7	2.6	0.0	0.0	*7.9*

[a] Preliminary estimate of actual-year LBL Budgetary Authority (B&R code KP).

Global Change Research Program

OHER is participating in national and international efforts to understand complex and interdependent global environmental processes, including global climate change and its potential consequences. LBL scientists, through laboratory, field, and theoretical research, have contributed to the existing concepts on global and regional atmospheric phenomena and are participating in DOE's planning processes.

LBL is developing an interdisciplinary program to investigate the processes that lead to changes in the physical and chemical characteristics of the atmosphere, to provide the information to global climate modelers, for example, on cloud properties and other characterizations, and to assess potential regional ecosystem changes. The effort involves collaborations with several divisions at LBL, various UC campuses, and Lawrence Livermore National Laboratory (LLNL) to use most effectively a breadth of research capabilities. The effort will benefit from instrumentational and computational capabilities developed at LBL and LLNL, such as the Cloud Chamber Facility at LBL. The effort is being developed in close conjunction with LBL's national and international policy-related studies on greenhouse gas issues sponsored by DOE's Office of Policy, Planning and Analysis. Areas of initial interdisciplinary research include:

- Laboratory, chamber, and field studies of atmospheric radiation properties including the physics and chemistry of cloud processes, such as the effect of natural and anthropogenic nucleating particles on cloud optical characteristics;
- Atmospheric-ecosystem interactions, such as CO_2 buildup and temperature increases, that play a potential role in the modification of ecosystems principally at the landscape level, with a focus on the western U.S. region, primarily forests and semi-arid areas; and
- Quantitative understanding of the sinks of CO_2 in the oceans, including primary production, ocean mixing, transport of heat and carbon, and isotopic composition of ocean sediments.

The effort is coordinated by LBL's Center for Atmospheric and Biospheric Effects of Technology. Resource requirements, with necessary ES&H operational and equipment needs projected for the program, follow.

Global Change Research Program Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	2.0	2.5	3.0	3.5	3.5	3.5	*18.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

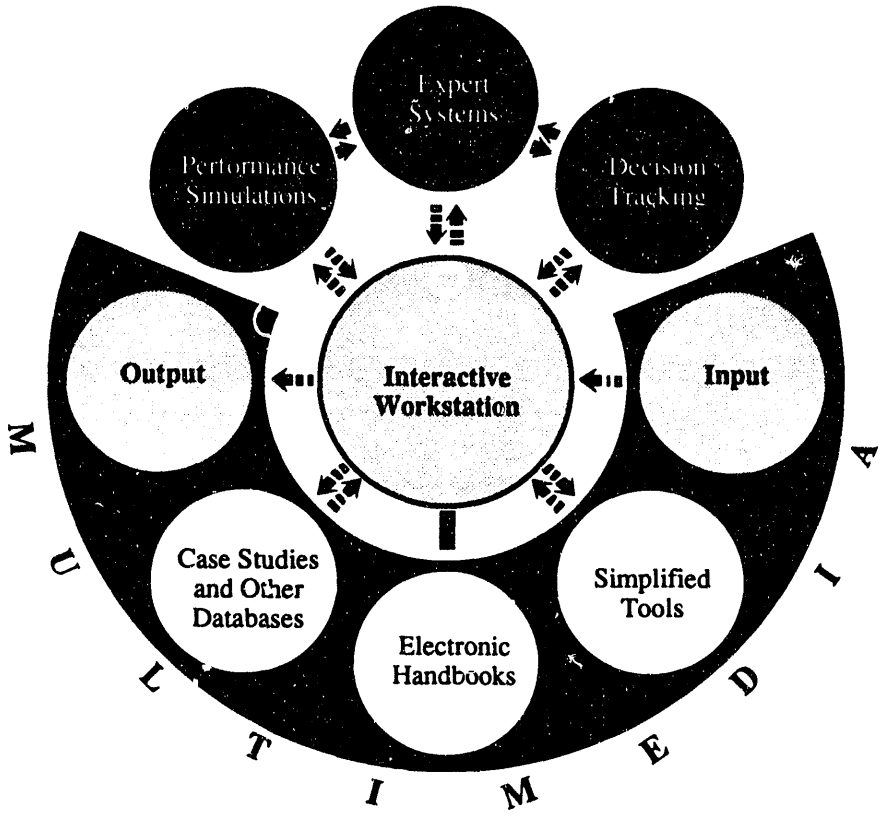
[a] Preliminary estimate of LBL actual year Budgetary Authority (B&R code KP).

CONSERVATION AND RENEWABLE ENERGY

Advanced Energy Design and Operation Technologies

LBL and other DOE national laboratories are engaged in a continuing research effort to improve energy efficiency in buildings. The LBL Advanced Energy Design and Operation Technologies (AEDOT) initiative would develop innovative methods to incorporate advanced energy-efficiency concepts directly into building design and operation. These concepts can provide an additional energy savings of approximately 50% beyond the efficiencies already achieved. The design system would integrate new computer-aided design (CAD) systems with sophisticated graphics, expert systems, and new energy-simulation models. Activities underway at LBL coupled to the initiative include:

- The DOE-3, the next-generation whole-building energy-simulation program;
- Computer-generated visualization of interior lighting and daylighting;



The components and structure of a computer-based Building Design Support Environment. LBL is one of the premier institutions in the study of advanced energy design and operation.

- Studies of innovative building technology and systems such as windows, lighting, ventilation, and indoor air quality;
- User-friendly interfaces, CAD/CAM systems, and large databases; and
- Exploratory research on expert systems for building design and operation.

AEDOT software would link energy and nonenergy issues in buildings—to integrate quantitative (e.g., energy consumption) and qualitative (e.g., aesthetics) aspects of design, including considerations of occupant productivity. The initiative is intended to incorporate energy efficiency, building structure, and other design elements directly into architectural systems. Advanced simulation and imaging technology would provide engineering accuracy and visual realism. The complete building cycle would be addressed, providing novel feedback to integrate design, construction, occupancy, maintenance, and economics.

An ongoing challenge is the transfer of building research results to the building industry, since energy efficiency is often treated as separate from the architectural design. The envisioned system would become a vehicle for the transfer of technology for almost all of DOE's research products to the design and construction industry. Resource requirements include ES&H and distributed data management costs.

Advanced Energy Design and Operation Technologies
Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	1.0	2.0	2.0	2.0	2.0	2.0	*11.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL actual year Budgetary Authority (FY 1992 dollars); (B&R code EC).

DOMESTIC AND ENERGY POLICY

Assisting Development of Energy Practices and Technologies

The Assisting Development of Energy Practices and Technologies (ADEPT) initiative establishes a new program at DOE that provides assistance to developing and transitional countries in their choice and application of energy technologies. The program supports technology choices that—when compared with typical current technology—produce or use energy more efficiently, cause reduced levels of emissions of pollutants and greenhouse gases, and are economically competitive or superior on a life-cycle cost basis.

The new program consists of seven elements: (1) energy technology adaptation, (2) demonstrations, (3) key country programs (including China and India), (4) one-stop shopping network, (5) graining, (6) applied R&D,

and (7) institution building in developing countries and Eastern Europe. Initial work on the program has begun within the Office of Domestic and Energy Policy during FY 1992.

ADEPT will be especially valuable in responding to developing country needs for technical assistance for limiting greenhouse gas emissions in a highly cost-effective manner. It will also provide important benefits in reducing future global oil demand and in helping to establish international markets for U.S. energy technology. This program is an important United States contribution to support recommendations made by the Intergovernmental Panel on Climate Change and the United Nations Conference on Environment and Development. The program will be conducted consistent with applicable DOE orders and regulations. The resources indicated below are for LBL's activities for the national DOE program.

Assisting Deployment of Energy Practices and Technologies
Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	0.5	1.5	2.0	3.0	3.5	3.5	15.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL actual year Budgetary Authority (B&R code PE).

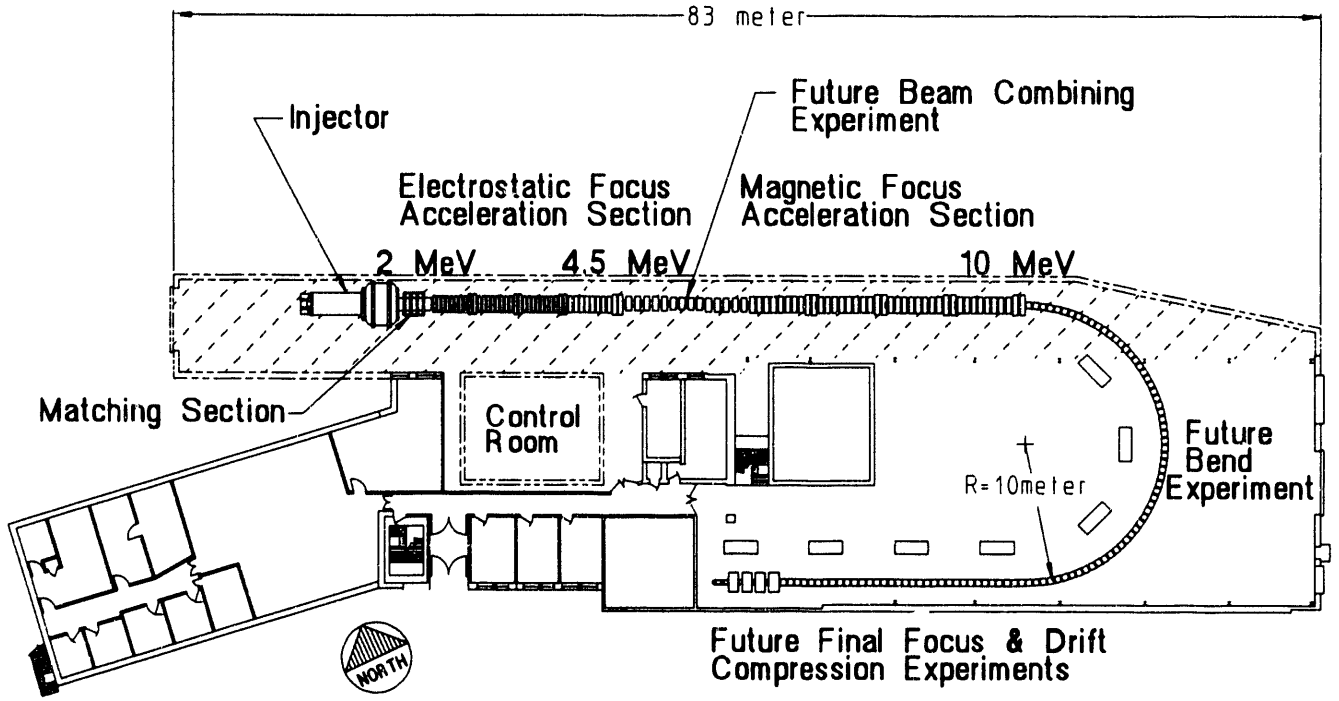
FUSION ENERGY

Induction Linac Systems Experiments

The U.S. Heavy-Ion Fusion Accelerator Research (HIFAR) program is building the research database to assess and develop heavy-ion accelerators as drivers for an inertial-fusion energy source for commercial power generation. The results of the successful Single-Beam Transport Experiment and the LBL Multiple-Beam Experiment provide encouragement and justification to conduct larger, more complex experiments; however, these experiments do not demonstrate all features of a full-scale fusion driver.

Yet to be demonstrated are beam merging with minimal phase-space density dilution, transition from electrostatic to magnetic focusing, transport in bending and focusing magnets, drift compression, and focusing onto a small target. To demonstrate these important beam manipulations, LBL proposes to build a new accelerator known as ILSE (Induction Linac System Experiments).

The ILSE Program has two parts, an accelerator construction project and a series of experiments to be performed with the accelerator. The ILSE accelerator and the associated experiments are designed to test nearly all the features of a fusion driver. Using a 2-MeV injector, ILSE will accelerate ions such as Ne^+ or K^+ to 10 MeV, after which they will be transported and focused to a small spot. To minimize cost, the ILSE accelerator is shorter and has fewer beams than a full-scale driver, but the beams will have the same diameter and line charge density as driver beams. ILSE will therefore test much of the important driver physics at full scale. Incremental costs of



A plan view of ILSE located in the expanded LBL Building 64. The accelerator construction project consists of the injector, the electrostatic and magnetic focus sections of the accelerator, and the building addition (dashed). Future experiments to be performed with the accelerator are also shown.

ILSE hardware above the base HIFAR program are indicated in the following table, which assumes a construction project start in FY 1994. Additionally, the base program will support ILSE research and development associated with construction in FY 1992 and FY 1993 and experiment design and development beyond FY 1997. These costs include all required protective systems for ES&H hazards, which are similar to those of the existing HIFAR program. The Conceptual Design Report addresses necessary ES&H requirements and NEPA/CEQA documentation.

Induction Linac Systems Experiments Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	3.3	0.8	0.7	0.8	0.7	0.8	*7.1*
Construction	0.0	8.3	13.1	14.0	13.5	12.1	*61.0*

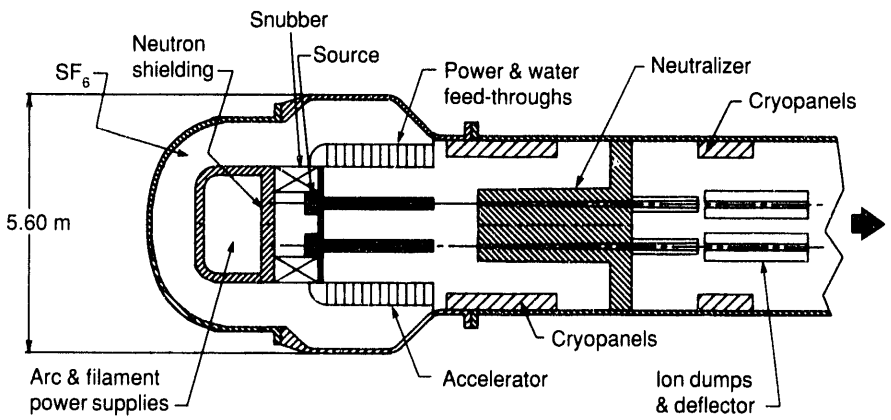
[a] Preliminary estimate of LBL Budgetary Authority (B&R code AT).

Accelerator Test Facility for ITER

Most proposals for future magnetic-fusion projects involve injection of energetic neutral beams at high currents; the beams play a significant role in heating the plasma and in driving the toroidal current noninductively in the steady state. LBL has traditionally been a leading center for design and development of these neutral-beam injection systems, including the standardized Common Long-Pulse Source that has been incorporated into all major U.S. fusion experiments.

The International Thermonuclear Experimental Reactor (ITER), a proposed next-generation tokamak to be built by a multinational collaboration, may need neutral-beam systems of higher power and energy (a total of 75 MW of D^0 at 1.3 MeV from 9 injectors) capable of operating continuously for periods as long as two weeks. Significant design challenges, many of which are already being addressed in the Magnetic Fusion Energy program at LBL, include negative-ion sources, accelerators, neutralizers, and a suitable test facility.

LBL's role in ITER has been to participate in a conceptual design for a neutral-beam system agreeable to all four participants (the U.S., Europe, Japan, and the U.S.S.R.) and to conduct supporting research and development in the areas of D^- ion sources and high-voltage dc accelerators. LBL is now proposing a major ITER neutral-beam development project, including a new accelerator test facility for conducting a proof-of-principle accelerator demonstration. The resource requirements indicated below are the incremental fabrication and operating costs for the proposed facility. These costs include all protective systems for ES&H compliance.



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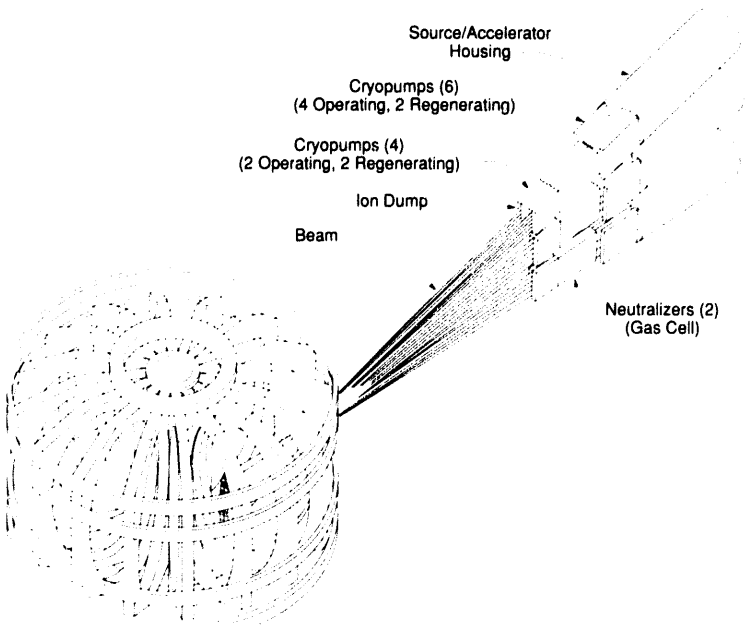


The ITER conceptual design (left) calls for three stacks of three 1.3 MeV neutral-beam injector modules providing a total of 75 MW. Each injector (top) can provide 10 MW, so ITER can continue to operate if one of them is down for repair or modification.

XBL 908-5558

Accelerator Test Facility for ITER Resource Projections ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating	5.6	7.9	3.0	2.0	2.0	2.0	*22.5*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL Budgetary Authority, including equipment (B&R code AT).

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

Environmental Restoration Research and Development

In support of the Office of Technology Development in DOE's Environmental Restoration and Waste Management program, and to facilitate the development of underlying science conducted in the Offices of Basic Energy Sciences and Health and Environmental Research, LBL is developing a multidisciplinary research and development program directed to improving the effectiveness and cost/risk benefits of environmental restoration technologies. The program has three components:

- Improved characterization of subsurface environments, including better measurement of their biological, chemical, and physical properties and the better definition of the associated contaminant transport processes;
- Development of methods for assured containment and control of subsurface biological, chemical, and radiological contaminations;
- Development of advanced remediation technologies including methods appropriate to complex and heterogeneous subsurface environments.

The methodologies used in the program will include: field testing and tracking contaminant fronts; developing descriptive and predictive mathematical models; characterizing heterogeneous underground systems; designing, demonstrating, and testing containment and cleanup systems at specific contaminant sites; and determining the underlying chemical, biological, and thermodynamic properties involved in mixed contamination.

Environmental Restoration Research and Development Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating[b]	2.0	3.0	4.0	5.0	5.0	5.0	*24.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL Budgetary Authority (B&R code EX).

SPACE RESEARCH OFFICE

Civil Space Mission

The Department of Energy's national laboratories have unique and valuable expertise, capabilities, and facilities that can significantly contribute to the National Aeronautics and Space Administration (NASA) Civil Space Mission. The DOE efforts, coordinated through Secretary of Energy James Watkins in close conjunction with the NASA Administrator program, will strongly support the scientific exploration of the solar system, provide beneficial advanced technology, and improve the environment through an understanding of global processes. LBL has been actively participating in the joint DOE/NASA planning, including the technical areas of radiation effects on health, environmental sensing, materials research, advanced technologies, and high-performance computing. LBL's education program is participating in the development of outreach programs to provide opportunities for a diversity of students.

LBL's support of the health and life sciences program can help establish the technical basis of radiation risk to astronauts through the development of radiobiological response data. LBL's Bevalac accelerator can uniquely provide a ground-based experimental program that simulates the heavy-ion particles characteristic of the cosmic-ray environment in space. The Bevalac's ability to readily provide these ions (H through Fe in a range of energies up to 2 GeV/amu) and its well-developed experimental facilities are coupled with the extensive experience of its staff in the conduct and support of the type of research required of the Civil Space Mission. The final decision whether to continue Bevalac operations in FY 1993 is pending joint DOE/NASA review.

LBL's environmental and materials science research also strongly supports the NASA/DOE effort. LBL's experience with space-based and surface-based sensing systems is ideal for monitoring space, the earth, and other planetary environments. Radiation-sensor-systems expertise ranges from infrared radiation to the highest energy photons and charged particles. In-situ surface and subsurface monitoring also ranges from the scale of ultrasensitive, low-noise magnetic field detectors to in-situ sensors for high-energy seismic waves. Research is being done on regenerative fuel cells and high performance rechargeable batteries for use in renewable energy systems which could be used in space applications. LBL materials research is also directed to aerospace needs, including the development of light alloys and ceramics that are high performance, lightweight, and temperature resistant.

Civil Space Mission Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	*Total*
Operating[b]	4.0	4.0	5.0	5.0	5.0	5.0	*28.0*
Construction	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL Budgetary Authority .

[b]Includes NASA and DOE Space Office funding.

WORK FOR OTHERS

Advanced Lithography Initiative

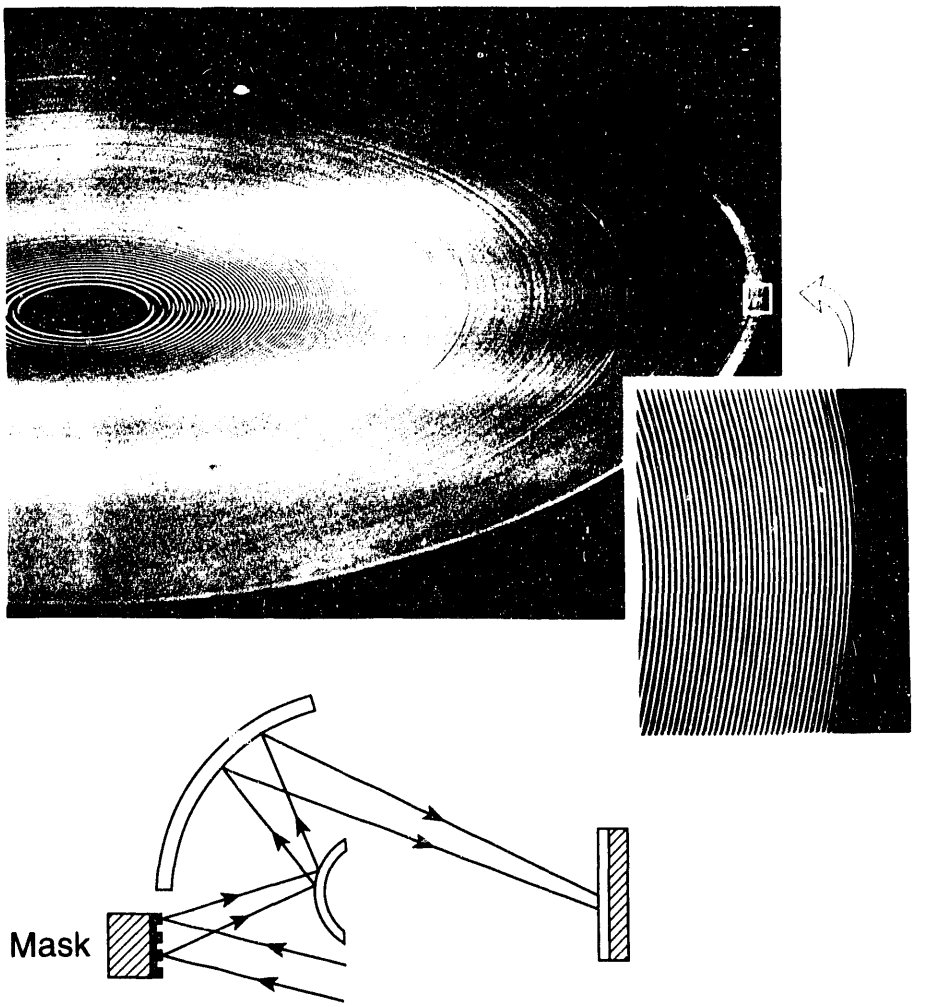
Since the creation of the first integrated circuit in 1960, there has been an ever increasing density of devices manufactured on semiconductor substrates. The VLSI (very large scale integration) era from the mid-70s to the present has seen chip densities increase from 100,000 transistors per chip to over 1 million per chip. The increasing device count was accompanied by a shrinking minimum feature size from 2 μm in the late 70s to less than 0.75 μm in current 4 megabit DRAMs. The challenge to continued US industrial competitiveness in microelectronics is the development of techniques of lithography and pattern transfer at minimum feature sizes less than 0.25 μm. This will lead to chip densities of over 10^9 transistors per chip. The advanced lithography program at LBL's Center for X-Ray Optics (CXRO) focuses on the enabling technology's essential for extreme ultraviolet (EUV) and soft x-ray (SXR) optical imaging systems. Imaging systems will be required for 0.1 μm features, and 1 Gbit DRAM's by the year 2000. CXRO's lithography program will concentrate on the development of EUV/SXR interferometry for at-wavelength (130 Å) testing of optics, nanofabrication facilities for zone plates and reflective masks, general x-ray metrology and the necessary processing for pattern transfer.

LBL's initiative responds to programmatic needs established by the Department of Defense to provide collaborative support for this emerging area of science, which supports essential U.S. technological capabilities. A successful program requires an integrated consortium of industrial, university, and national laboratory scientists to break new scientific and technical ground well in advance of the competition and to train a new generation of scientists to carry the project to fruition in the 21st century. The consortium will require dedicated laboratory research facilities with modern high-brightness partially coherent x-ray sources, expertise in relevant x-ray optical techniques, an active student research program, and state-of-the-art equipment for the fabrication of nanometer-scale structures and the synthesis of new materials whose structures are controlled at the atomic level. Strong participation of a consortium of local microelectronics companies will ensure quick and effective transfer of all relevant technologies.

The ALS synchrotron storage ring will be a unique national resource to be utilized by the collaboration. Additional laboratory equipment dedicated to advanced lithographic research for microelectronics applications will be required. These facilities will include insertion devices, bend magnets, and beamline components; metrology stations to test all optical surfaces and coatings; and advanced EUV/SXR interferometers for testing optical surfaces and integrated optical systems and equipment that will support the fabrication of nanostructures and the synthesis of artificially structured materials. Specific initial elements are to include:

- High-brightness coherent undulator beamline for at-wavelength interferometry
- Electron beam "nanowriter" for mask writing and diffractive optics
- Component and system interferometry
- EUV/SXR metrology bending magnet beamline

A high-resolution fresnel zone-plate is shown (top) during processing. The smallest zone width is 300 Å. This is the enabling technology for the construction of x-ray microscopes. The optical technology of the projection lithography process, represented by the schematic (below), will be advanced by the unique capabilities of the ALS.



A continued investment of $10 million in FY 1993 would further the consortium efforts and lead to improved American competitiveness in this critical technological area. Costs include operational procedures and equipment design in compliance with DOE ES&H orders and regulations.

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

Category	1992	1993	1994	1995	1996	*Total*
Operating[b]	9.7	10.0	14.0	12.0	11.3	*57.0*
Construction	0.0	0.0	0.0	0.0	0.0	*0.0*

[a] Preliminary estimate of LBL actual year Budgetary Authority from DOD.

[b] Costs are primarily for equipment.

5 SCIENTIFIC AND TECHNICAL PROGRAMS

Lawrence Berkeley Laboratory research programs fortify the foundations of energy and environmental technology and will continue to be supported primarily from the Office of Energy Research (OER) and the Assistant Secretarial Offices of Conservation and Renewable Energy, Civilian Radioactive Waste Management, and Fossil Energy. The Assistant Secretary for Environmental Restoration and Waste Management will be increasingly important to support site-specific environmental restoration projects. In addition, other DOE offices, and the Nuclear Regulatory Commission, will support LBL programs. Work for Others (WFO) supports about one-sixth of the Laboratory's programs. This section summarizes current LBL research programs, including anticipated program trends. LBL's scientific and technical programs are conducted under strengthened environment, safety, and health guidelines for conduct of operations. Research facilities and programs are conducted to ensure the safety of all employees and the public, with environmental and safety management programs developed in close working relationships with OER.

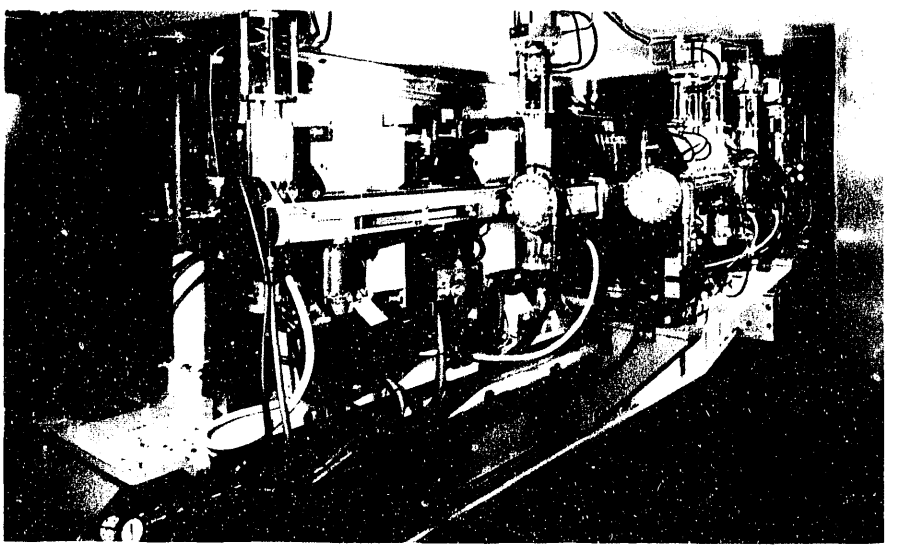
Laboratory Funding Summary
(Fiscal Year Operating and Capital Budgetary Authority, $M)

Major Program/Office	1991	1992	1993	1994
Office of Energy Research	170.6	178.8	171.5	178.9
Conservation & Renewable Energy	16.5	16.1	18.2	19.4
Fossil Energy	2.1	2.2	2.2	2.2
Environmental Restoration & Waste Mgt.	7.4	14.2	9.3	15.0
Environment, Safety, and Health	1.7	1.7	1.7	1.8
Other DOE	25.1	22.8	24.9	26.1
Work for Others	34.3	45.2	48.3	49.6
Total	*257.7*	*281.0*	*276.1*	*293.0*

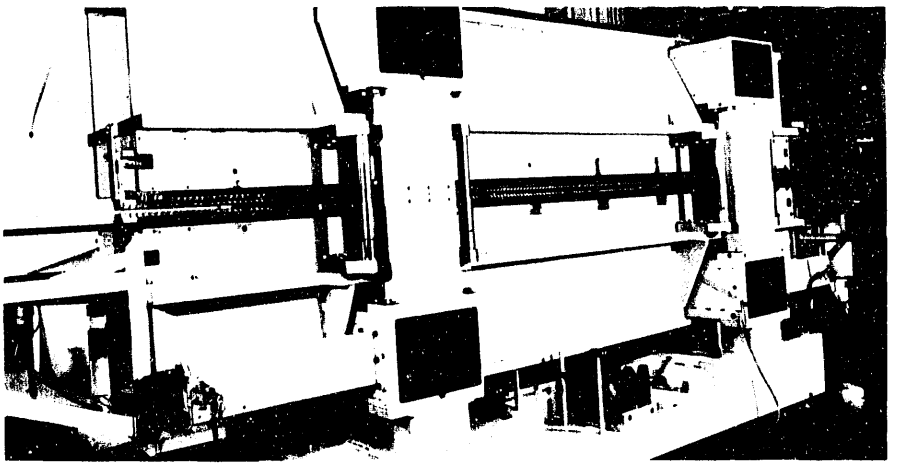
OFFICE OF ENERGY RESEARCH

During the plan period, OER will continue to be the focus of fundamental science and engineering research activities at the Laboratory, implementing the initiatives described in Section 4 and growing in selected areas of the Basic Energy Sciences and Life Sciences. Many of these programs will be conducted in cooperation with industrial and academic research communities.

- For FY 1993 the Laboratory's contribution to national efforts in the Basic Energy Sciences (BES) includes completion and startup of the Advanced Light Source (ALS) and developing advanced user facilities to support scientists in chemistry, biology, materials research, physics, and other fields.
- The 88-Inch Cyclotron with its new Advanced Electron Cyclotron Resonance (AECR) ion source provides the highest flux of heavy ions of any low-energy accelerator in the U.S. The Gammasphere detector, located at the Cyclotron, will open up new research opportunities in nuclear structure. The Bevalac will complete its pioneering studies of nuclear matter and advances in atomic physics, biomedical research, and related fields. The nuclear physics program at the Bevalac is projected to close in FY 1993, completing 40 years of world-leading high-energy and nuclear physics accomplishments. The relativistic heavy-ion research program will be pursued with the STAR experiment at the Relativistic Heavy-Ion Collider (RHIC) and with lead beams at CERN (NA49).
- High-energy physics research will continue to make major advances in detector systems with a sophisticated new detector for the SSC and plans for a B-factory detector. LBL contributes to the operation of current forefront facilities, including the D-Zero and Collider Detector Facility (CDF) at Fermilab.



This view faces the synchrotron radiation ports (covered circular openings) of an arc sector in the ALS storage ring. The rearmost port will deliver radiation from an undulator soon to occupy the straight section behind the arc sector. The other ports are outlets for radiation from the bending magnets in the arc sector.



The first ALS undulator stands on the ALS floor assembled except for its vacuum system. The photo shows the 4.55-meter magnetic structure installed in the support structure. Also shown is the drive system for changing the gap between the upper and lower rows of magnets to alter the output photon energy.

- In the context of an advancing national program in health and environmental research, LBL's human genome, structural biology, and cell and molecular biology programs will continue to provide the technical capabilities to improve the understanding of environmental and genetic control of diseases and normal functions. The biomedical program will improve diagnostic imaging systems and elucidate the metabolic basis of disease.
- In support of the national fusion research goals, LBL's programs in heavy-ion fusion accelerator research for inertial-confinement fusion and in neutral-beam development for magnetic-confinement fusion may expand significantly. These programs build on expertise in induction-linac systems and ion-source development.
- The Center for Advanced Materials (CAM) will continue to pursue Laboratory goals for conducting longer-term research responsive to industrial needs and the transfer of the results of the work to industry. Expanded program activity in CAM is anticipated in thin-film research, studies of wear and mechanical properties of surfaces, atomic scale synthesis of materials, and enzymatic synthesis of materials.
- The National Center for Electron Microscopy (NCEM) will continue to provide forefront research facilities for metallurgy, ceramics, and other materials research. Advanced microscopes for quantitative atomic resolution and analytical studies and studies of magnetic materials are proposed to maintain the nation's research leadership (see Section 4).

LBL will continue providing OER programs with the most advanced engineering research for instrumentation, such as magnet technology devices and advanced control systems. Program activity for OER is summarized in the table below.

Office of Energy Research Funding Summary
(Fiscal Year Operating and Capital Budgetary Authority $M)

Major Program (BR Code)	1991	1992	1993	1994
Basic Energy Sciences (KC)	68.4	63.7	65.2	69.3
Nuclear Physics (KB)	43.0	46.8	36.5	25.1
High-Energy Physics (KA)	21.7	22.6	20.6	21.3
Superconducting Super Collider (KS)	2.5	0.4	0.0	0.0
Biological & Environmental Research (KP)	16.9	20.6	22.7	24.5
Fusion Energy (AT)	7.9	9.1	10.6	11.1
University and Science Education (KT)	2.5	2.5	2.9	3.0
General Purpose Facilities (KG)	7.7	11.0	10.7	21.3
Laboratory Technology Transfer (KU)	0.0	2.1	2.3	3.3
Total	*170.6*	*178.8*	*171.5*	*178.9*
Percent of LBL Total	*66.2*	*63.6*	*62.1*	*61.1*

Basic Energy Sciences

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

Materials Sciences

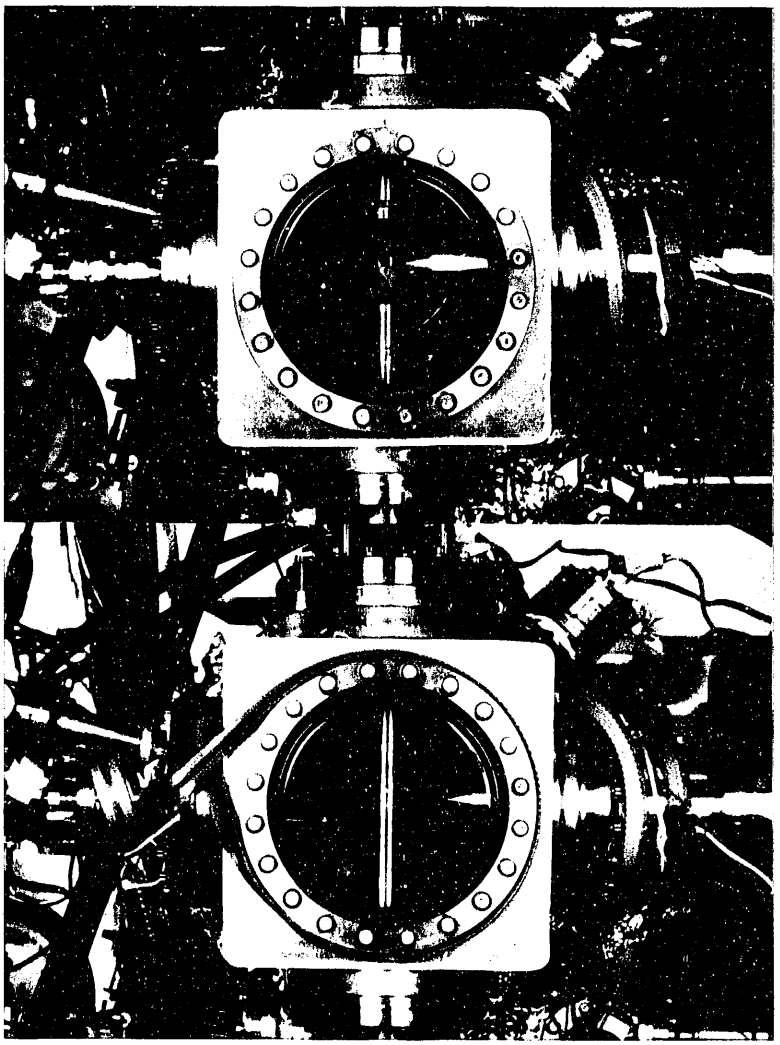
BES programs in Materials Sciences will emphasize new and forefront research projects for the synthesis, processing, and characterization of advanced materials. Expanded areas include design and construction of synchrotron-radiation instrumentation and advanced materials synthesis and fabrication technologies, especially at the atomic scale. Leading programs continue in x-ray optics, electron microscopy, solid-state physics, surface science, catalysis, polymers, metallurgy and ceramics, and materials chemistry. Beginning in FY 1993, the ALS, a third-generation synchrotron-radiation facility, will produce the world's brightest beams of ultraviolet and soft x-ray radiation. The commissioning of the injector has been completed, and booster-ring commissioning is on schedule. The ALS, CAM, Center for X-Ray Optics (CXRO), and NCEM are organized interdisciplinary research centers that bring DOE resources to bear on scientific challenges of national importance.

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

CAM will continue major research efforts that are vital to U.S. industrial strength. The research focus evolves with new discoveries and with the

changing needs of U.S. industry for fundamental research to underlie its development and commercialization activities.

- The Surface Science and Catalysis Program focuses on studies of advanced catalysts for clean fuels, pollutant reduction and methanol synthesis, and the atomic scale surface structure and chemical and mechanical properties of solids and adsorbed monolayers. Advanced surface instrumentation includes nonlinear optical techniques, scanning tunneling and atomic force microscopies, and advanced Raman spectroscopy.
- The Electronic Materials Program focuses on theoretical and experimental studies of basic materials problems pertinent to the development of advanced electronic and optical materials. Semiconductor thin-film crystal growth and characterization, and comprehensive investigations of structural properties of heterointerfaces are pursued.
- The Polymers and Composites Program pursues polymer synthesis and studies of the relationships between polymer processing and microstructure, focusing on anisotropic materials, and surface interactions between polymer liquids and metals.



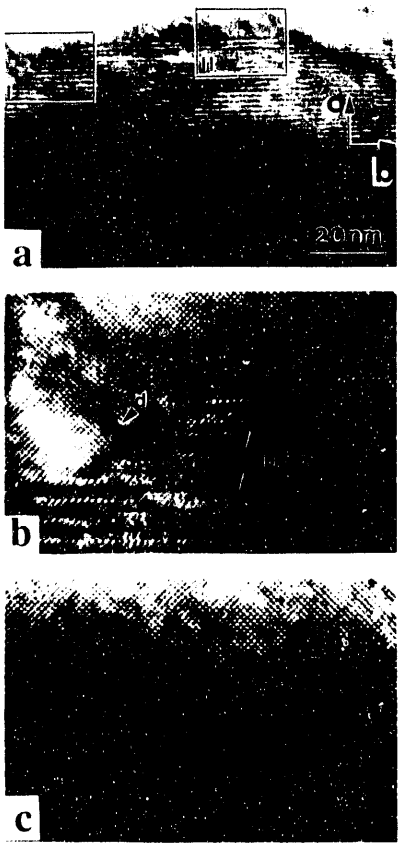
The apparatus used by scientists in the Surface Science and Catalysis Program in low-energy electron diffraction (LEED) surface studies. It includes an ultrahigh vacuum chamber and a high-pressure cell, which holds a single crystal of a catalyst.

- The High-Performance Metals Program addresses the mechanisms of structural failure, including fatigue and fracture in metals and intermetallics, and is concerned with the theoretical and experimental studies of the properties and development of metal alloys, formable steels, advanced intermetallics, and materials for high-field superconducting magnets.
- The Ceramics Science Program supports research on the development of predictive, quantitative theories of densification and microstructure development, the application of these theories to produce and evaluate advanced structural ceramics with improved high-temperature performance, and new understanding of fatigue and other failure mechanisms in ceramics.
- The Enzymatic Synthesis of Materials Program explores the application of recent advances in biochemistry, molecular biology, and bioorganic chemistry to the synthesis of novel materials. Emphasis is on the use of natural and genetically engineered enzyme and self-assembling thin films to control surface properties and form the basis of sensors.
- The High-T_c Superconductivity Program focuses on basic science, including theory, synthesis, and characterization of new materials; and thin films and their applications, including devices such as SQUIDs and bolometers.

CXRO continued its two complementary roles: developing state of the art x-ray optics and demonstrating their utility for new science and technology in the extreme ultraviolet (EUV) and soft x-ray (SXR) regions of the electromagnetic spectrum. High resolution x-ray microscopy continues to be prominent among our activities, with applications directed at both the physical and life sciences. For example, our SXR microscopy based on fresnel zone-plate lenses has produced images of features as small as 300 Å. These microscopes are widely used for biological microscopy and surface science at synchrotron radiation laboratories around the world. Other efforts include an SXR photoelectron microscopy beamline, based on multilayer-coated reflective optics, for material and surface science at the University of Wisconsin Synchrotron Radiation Center. In the hard x-ray regime our microprobe has achieved 2-μm spatial resolution at the National Synchrotron Light Source (NSLS) and has been used in a large number of applications. New efforts include projects in SXR projection lithography (Section 4) and in development of a national resource center for biological microscopy at the ALS.

NCEM, a national user facility, is supported by the DOE Metallurgy and Ceramics Program but contributes substantially to research in other fields, such as biology and geology. The heart of NCEM consists of two microscopes: (1) the High-Voltage Electron Microscope, the most powerful microscope of its kind in the U.S., and (2) the Atomic Resolution Microscope, with a resolution of 1.5 Å, currently the highest resolution in the world. Enhancement of the center through the design and acquisition of new state-of-the-art microscopes is being proposed to maintain U.S. leadership in electron microscopy (see Section 4).

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



The NCEM scientists study epitaxial growth using high resolution transmission electron microscopy. Seen in the first picture is a lattice fringe image of $SrTiO_3$ grown on YBCO. The second picture is a detail of a stepped interface, showing an edge dislocation labeled "d", in which an associated extra half plane is normal to the interface. The last picture is a detail of a completely flat interface.

boundaries and the relationship between structure and properties at the interface.

In response to a Presidential Initiative, LBL participates in the DOE, Division of Materials Sciences, Center of Excellence in Synthesis and Processing of Advanced Materials. Research focuses on control at the atomic level and includes synthesis of lower toxicity single molecule precursors for MOCVD, high-T_c superlattices, high-resolution electron beam lithography, and wet chemical approaches to atomic level structure control, including synthesis of 0-dimensional clusters, one-dimensional "wires," two-dimensional films, and networks of these materials with controlled structures. Center programs also include a theoretical component, and a characterization component including work at the ALS.

In addition to the research conducted in focused centers described above, LBL conducts materials research in further support of DOE's Metallurgy and Ceramics program, Solid-State Physics program, and Materials Chemistry program, as described below.

In Metallurgy, LBL projects involve the development, characterization, and understanding of advanced alloys and intermetallics for energy needs. The principal objective is to understand the mechanisms of behavior at the microstructural level and to use that understanding to develop superior materials and better predictive theories of material performance. Current mechanistic studies address the mechanisms of fatigue, fracture, friction and wear, including behavior in extreme environments and in high magnetic fields, microstructural instabilities that affect alloy properties, including phase transformations and precipitate reconfigurations under load or in electromagnetic fields, and the role of elastic stress in solid-state phase transformations. This research is directed toward new structural steels with exceptional toughness for advanced energy needs, cryogenic structural steels and weldments for high-field superconducting magnets, formable steels for efficient manufacturing, reliable conductors and interconnections for microelectronic packaging, wear-resistant alloys, and hard magnetic materials.

In Ceramics, the LBL program is again focused on developing advanced materials, both monolithic and composite, with superior mechanical properties. Several projects are centered on the processing of improved compositions, both by special coating techniques applied to reinforcement phases for composite materials, and by modification of grain-boundary phases in monolithic materials. Mechanical property evaluation is concerned primarily with the mechanisms of toughness, oxidation, and creep behavior and the performance of ceramics under cyclic fatigue conditions, with particular emphasis on elevated-temperature behavior. In addition, the joining of ceramics to metals and other ceramics is being examined using novel techniques, such as transient liquid-phase bonding.

A new research program is planned to characterize the mechanical properties of advanced materials at extreme temperatures. An integral part of this program will be evaluating the deformation and fracture properties of advanced ceramics and intermetallics at temperatures up to 1600°C and above.

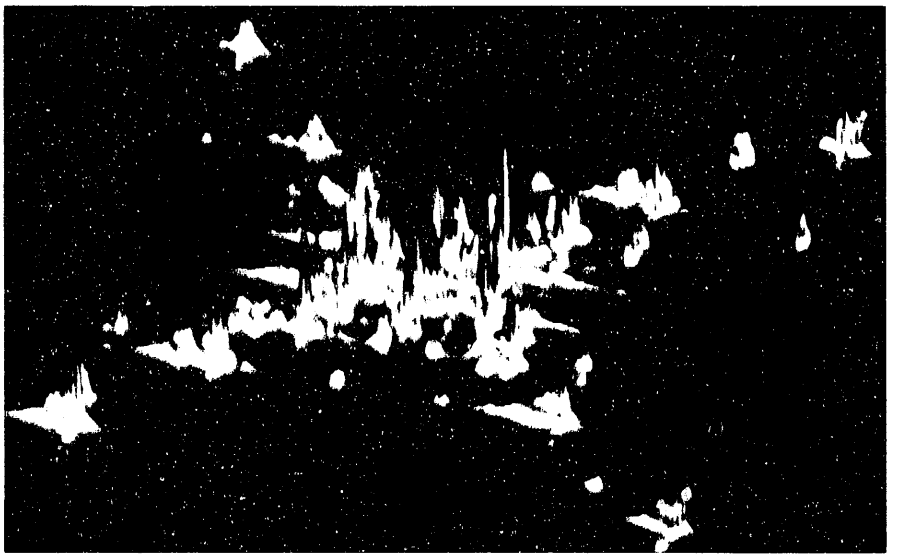
In Electronic Materials, LBL research focuses on an improved understanding of the materials science of artificially structured semiconductor and semiconductor-metal systems. Basic studies concentrate on the relationships between synthesis and processing conditions and the properties of semiconductor materials, as modified by the resulting structural and electronic imperfections. Projects include the synthesis and study of

heterointerfaces between highly dissimilar materials in order to understand mechanisms of interface formation and the defect structures resulting from lattice mismatch and differences in ionicity and electrochemical potential. The structure and stability of defects and interfaces are studied by advanced characterization techniques. Atomic resolution microscopes at the National Center for Electron Microscopy and advanced x-ray techniques utilizing synchrotron radiation provide structural information. Optical spectroscopies ranging from the near UV to the far-infrared region of the electromagnetic spectrum, electron paramagnetic resonance spectroscopy and electrical transport measurements reveal complementary electronic properties. Theoretical and experimental work on the effects of atomic scale diffusion and the differences between solid solubility limits of dopants and the maximum concentration of free carriers is pursued. Novel types of processing methods including annealing under large hydrostatic pressures and with tunable synchrotron radiation, to increase the electrically active fraction of dopants, are explored. Progress in this area is applicable to design of advanced photovoltaic energy conversion devices and of a large variety of sensors used in energy conversion processes.

Solid-State Physics research at LBL will continue with strong programs in both experimental and theoretical physics. Experimental research includes new far-infrared spectroscopy systems, including those using high-critical-temperature superconducting films. Studies on nonlinear phenomena and other spectroscopies further the understanding of surface, bulk, and interface systems. Studies of materials are pursued with an ultrashort timescale and at ultrasmall dimensions. The properties of materials under pressure and structural phase transitions are studied using diamond-anvil techniques. Theoretical research has focused on applications on quantum-mechanical theory to study the properties of solids, clusters, and molecules.

In Materials Chemistry, LBL will continue its strong contributions, including studies of polymers and composites, enzymatic synthesis, low-temperature properties of materials, synthesis of novel transition-metal solids, high-temperature thermodynamics, and the chemistry of interfaces. In one major project, solid-state and surface reactions are studied, with emphasis on the kinetics and mechanisms of catalytic surface reactions. In another project, the chemistry of materials is being studied with nuclear magnetic resonance (NMR). Advances in NMR include zero-field NMR for determination of proton positions in polycrystalline material, and double-rotation NMR for high resolution in solids.

An important new program on growth mechanisms at heterointerfaces studies the formation and properties of complex thin films. Systems chosen for initial study include growth of the polar semiconductor InP on single-crystal Pt using various techniques; epitaxial synthesis of silicide-fluoride heterostructures; and formation of interfaces between boron nitride and materials of high electron density. LBL's powerful complement of facilities available and under development, including the ALS, will be used extensively. Other new programs include atomic scale studies of tribology — friction, lubrication, wear — using advanced surface spectroscopy and microscopy; and synthetic and characterization studies of fullerenes and related new materials.

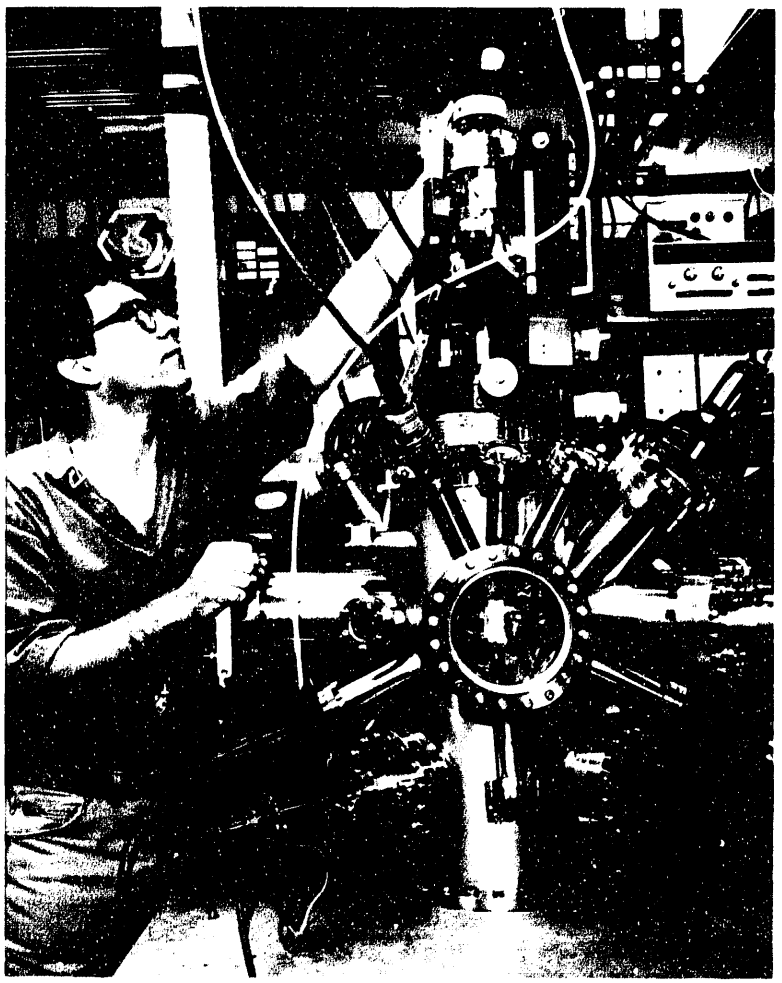


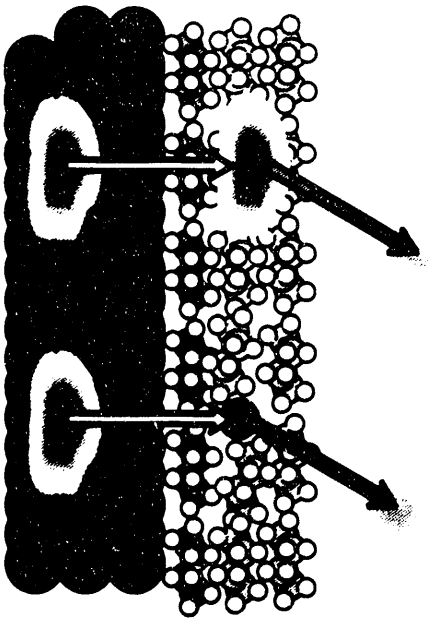
A two-dimensional spectrum of hexane in a liquid crystal matrix, done by nuclear magnetic resonance (NMR). The peaks indicate spatial correlation between the atoms on the molecule. From the analysis of such spectra, the structure and dynamics of the molecule may be studied.

Chemical Sciences

DOE's Chemical Sciences program supports focused research in several LBL divisions. Efforts in the Chemical Sciences Division (CSD) emphasize chemical physics, dynamics and mechanisms of chemical reactions and combustion processes, catalysis, electron spectroscopy, atomic physics, photochemistry, theoretical chemistry, and chemistry of the actinide elements. Programs in the Energy and Environment Division focus on advanced combustion and the mechanisms for minimizing emissions and improving fuel efficiency. In the Structural Biology Division, programs in photochemistry and the chemistry of electronically excited molecules are conducted. In the Nuclear Science Division, a study of the chemical properties of the heaviest elements is being conducted.

In CSD, the extensive chemical-physics research includes several major programs. One has focused on a study of the spectroscopy and structures of reactive intermediates. Laser-induced fluorescence, multiphoton ionization, and negative-ion photodetachment have been used to study reactive molecules such as free radicals and cluster ions that may be important in combustion processes, reactive plasmas, and high-technology manufacturing processes. Techniques such as the use of crossed molecular beams are used for advanced and novel studies of the dynamics of important reactions with the goal of understanding elementary chemical reactions through single collision conditions or laser excitation. The program in reactivity at surfaces and interfaces will involve molecular studies of interfacial phenomena using new techniques in laser spectroscopy and x-ray scattering. The program is designed to gain an understanding of chemical reactivity in key areas of energy science, including nearly all catalytic reaction systems, solar-energy conversion technologies, light-assisted chemical syntheses, electrochemical-energy-conversion technologies, and corrosion phenomena.





By measuring the angle and energy of photoemitted electrons at an interface (above), LBL researchers have developed a general and very sensitive method to understand the properties the electrons have as function of the structure and molecular composition at the interface. The method uses very high-repetition rate, ultrashort-pulsed laser to achieve the high sensitivity necessary for these measurements. The equipment is shown (left) with a UC Berkeley postdoctoral student.

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

The research programs in theoretical chemistry have the goal of accurately predicting chemical reaction dynamics, especially those that are too complicated to be solved experimentally. The program on photochemical and radiation sciences includes research into the photochemistry of materials in the stratosphere (with applications to the role of trace gases in the "greenhouse effect").

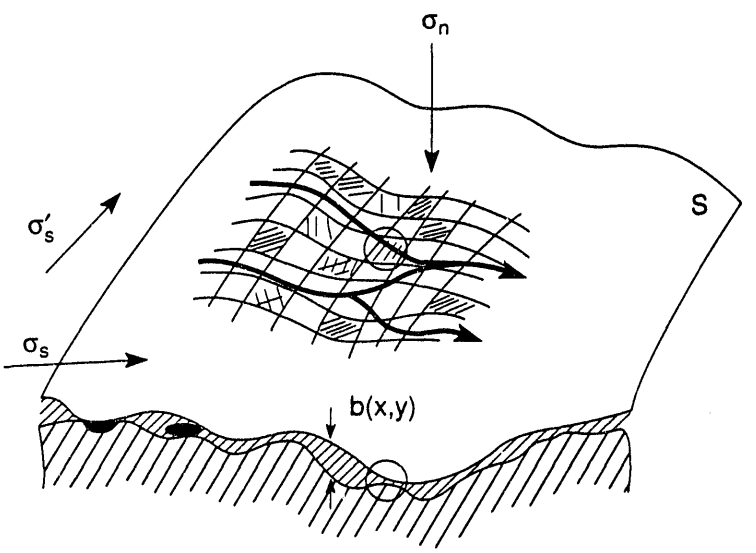
Research in the actinide chemistry program in CSD focuses on two thrusts, design and synthesis of sequestering agents for treatment of actinide poisoning and for possible application to spent reactor fuels, and the preparation and study of new compounds incorporating actinides. A program to investigate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

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

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

Engineering and Geosciences

The Geosciences Program at LBL is strengthening its multidisciplinary effort to expand the scientific basis of many energy-related technologies, including safe disposal of radioactive and toxic chemical wastes, exploitation of geothermal energy, and development of petroleum and strategic-mineral resources. Earth sciences researchers at LBL are among the leading investigators in the areas of subsurface imaging of the structure and dynamics of the earth's deep crust and the mechanisms by which lithospheric processes influence energy resources; in chemistry and physics of geological materials at high temperatures and pressures; and in coupled processes occurring in fractured rock formations.



Schematic diagram illustrating the coupling of flow and transport with normal and shear stresses across a variable-aperture rock fracture.

LBL is a key participant in the multiagency Continental Scientific Drilling Program (CSDP), with studies, either completed or underway, at the Valles caldera in New Mexico, the Salton trough, the Cajon Pass in southern California, and the Long Valley caldera in eastern California. Research at these sites has led to conceptual models of their structure and hydrothermal systems.

Geohydrology research at LBL includes studies of the physical behavior of fluid-saturated rock, the dynamics of subsurface reservoirs, and the mechanisms associated with chemical transport and fracture-flow phenomena. Multiphase flow in fractured porous media is being studied through the use of numerical models, as well as novel laboratory techniques such as positron emission tomography.

Geophysicists, supported by LBL's Geophysical Measurements Facility and the Center for Computational Seismology, are developing methodologies and instruments to define deep crustal structure, to measure elastic anisotropy in geological formations, and to track the movement of toxic chemical contaminant plumes in underground aquifers. Other geophysical research employs new computational codes to measure fracture properties in subsurface reservoirs and to map hydrofractures at well sites. At a laboratory scale, new approaches are employed to understand fracture processes and wave propagation in fluid-filled fractured media. The need for technology to image structures and processes correctly in the earth's complex heterogeneous crust is being addressed. Key projects include development of electromagnetic methods for high-resolution mapping, borehole seismic source development, and new methods for signal processing.

Geochemical studies focus on the properties of magmas and electrolytes, the generation and migration of petroleum compounds, and the interactions between minerals and groundwaters. Analytical capabilities of the Center for Isotope Geochemistry provide a powerful means of characterizing natural systems. This Center is an important new element in many of the multidisciplinary investigations at LBL.

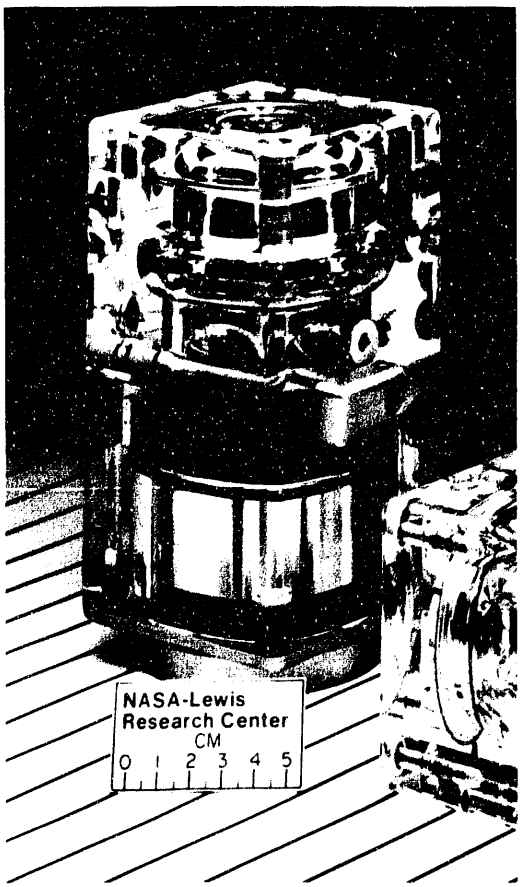
Energy Biosciences

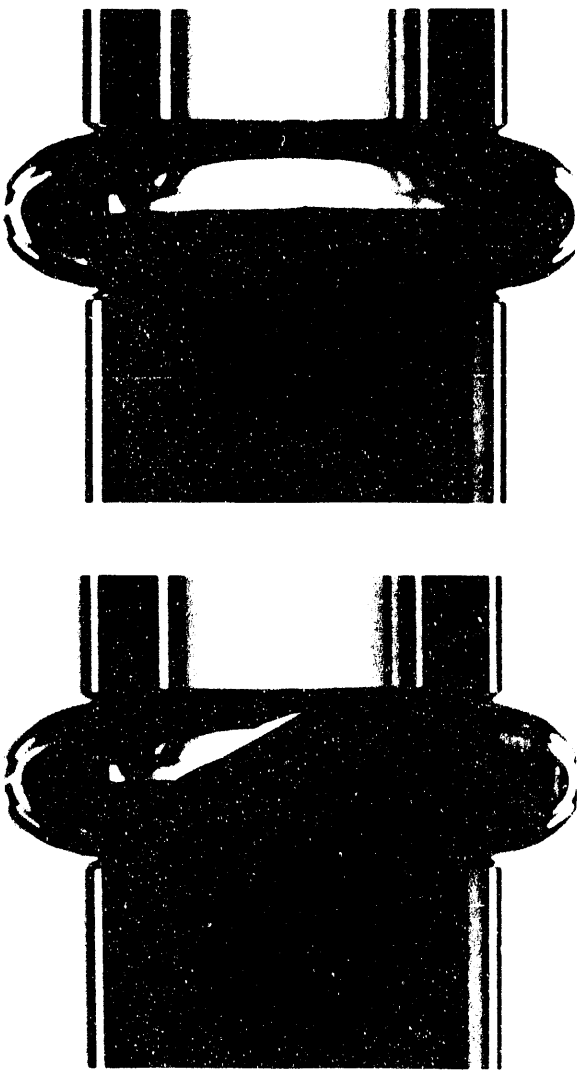
LBL's program continues to improve understanding of the unique features of photosynthetic organisms for collecting light energy and storing it as chemical energy. One project uses spectroscopic techniques to map the components and the kinetics of the light reactions. The genetics of the photosynthetic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

Applied Mathematics and Computer Science

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

The three most active areas are particle and vortex methods, free-surface problems, and parallel processing. In the first area, recent successes include an analysis of superfluid turbulence by vortex methods, a model of the turbulent boundary layer, vortex renormalization, rapid implementation of particle methods, and numerical studies of engineering flows and of suspensions. In the second area, new algorithms based on Hamilton-Jacobi methodology, new surface-integral techniques, and other methods are being developed for free-surface problems; these techniques will be used for studying applications in differential geometry, combustion, flow in porous media, solidification, relativity, fluid instability, and capillarity. In the third area, software is being developed on a massively parallel processor for solving two-dimensional, viscous, incompressible fluid flow in arbitrary geometries and for scientific visualization. Other continuing areas of activity in mathematics include numerical linear algebra, finite-difference methods in fluid mechanics, Monte Carlo methods, and labor-partitioning schemes for multiprocessors.





In the absence of gravity, fluid reorients spontaneously. Predicting fluid behavior has been the focus of this mathematical study. The pictures confirm the predictions that fluid goes from a symmetric (top right) to a nonsymmetric (bottom right) configuration when gravity is removed during a drop-tower text. More complete testing was done subsequently in modules (above) flown on a NASA Space Shuttle.

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

The Supercomputing Access Tools Program addresses the problems of scientific computing in distributed environments, with the goal of developing techniques that will partition the computational requirement optimally across distributed resources. The research on a software bus system will result in an ability to generate *interoperable*, and therefore reusable and replaceable, software. This will greatly enhance the computing environment available to energy-research scientists. Visualization and imaging tools compatible with this innovative architecture will be developed.

Nuclear Physics

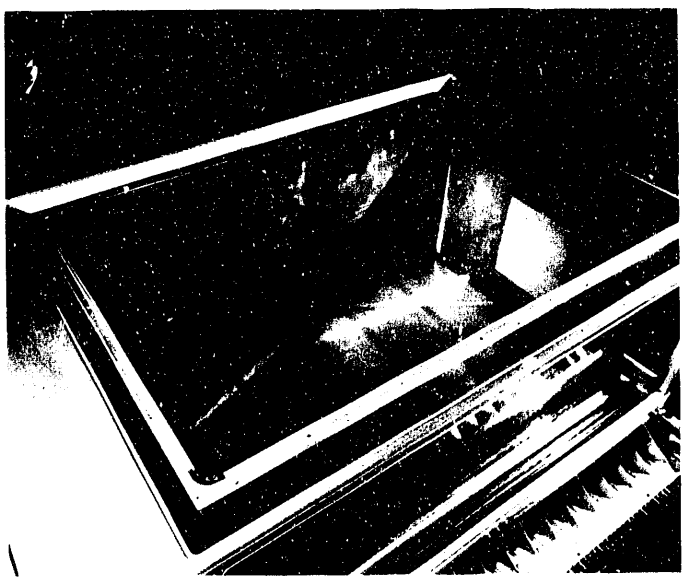
Nuclear physics research at LBL will continue to focus on the experimental and theoretical investigation of nuclei under extreme conditions. The comprehensive research program and the unique facilities and instrumentation available at LBL are summarized below.

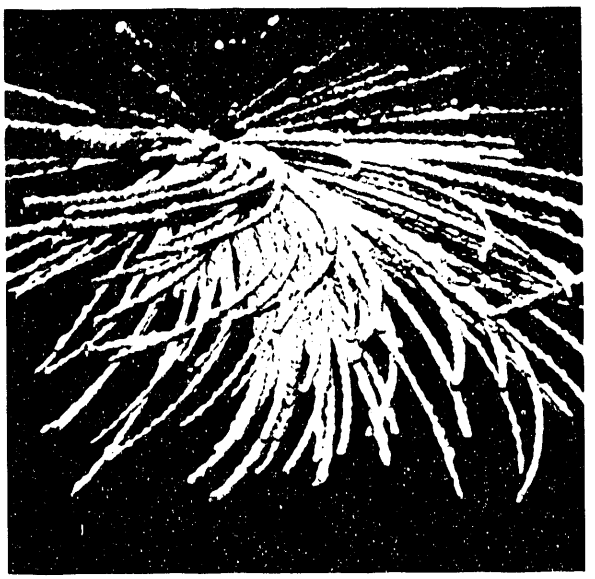
Relativistic Heavy-Ion Physics

The EOS Time Projection Chamber (TPC), now installed at the Bevalac, will be utilized to extend LBL's studies of the equation of state of nuclear matter. This next-generation 4π detector will provide new capabilities for complete event analysis of central collisions between the heaviest nuclei. Also at the Bevalac, dileptons (e^+e^- pairs) continue to be studied as a fundamental probe of extreme conditions. Due to their relatively weak interaction with matter, leptons are used to probe the hot, dense stage of the collision process. Understanding the reaction dynamics and the nuclear matter equation of state is fundamental and essential to the interpretation of neutron stars and supernova explosions. At higher energies (AGS, CERN), a complete description of the reaction dynamics is much more difficult since the basic nucleon-nucleon process becomes much more complex. Thus, the comprehension of dense nuclear matter at Bevalac energies is of great importance for the investigations at higher energies. With the closure of the Bevalac for nuclear science now projected to be in FY 1993, emphasis continues to be placed on those experiments (EOS and DLS) that will provide the deepest insights into the nuclear matter equation of state.

LBL is also pursuing the study of heavy-ion collisions at even higher energies at the Super Proton Synchrotron (SPS) at CERN. The emphasis of the present program of 200 GeV/nucleon ^{32}S-induced reactions is to explore the possibilities of producing a phase transition from hadronic matter to a quark-gluon plasma in central collisions of heavy ions at these energies. In the past year, NA49, the major experiment to be carried out at CERN with lead beams was approved. Building on the EOS and NA35 electronics developments, LBL will make major contributions to the integrated electronics for the 1994 NA49 experiment.

At the AGS, LBL is participating in a search for rare negative particle production in Si + Au collisions. During the past year, approval was won





The Equation at State Time Projection Chamber (EOS TPC) has been installed at the Bevalac to analyze most of the 200 or so particles produced when heavy nuclei collide. Here part of the apparatus is shown (left) with a computer-modeled result (right) of a simulated 800-MeV Au+Au central collision.

for construction of STAR (Solenoidal Tracker at RHIC), one of the two major experiments to be conducted at the Brookhaven RHIC. LBL is the lead institution in the STAR collaboration that has now grown to 140 scientists from 23 institutions. STAR is an experiment to study particle production and high transverse momentum jet production at mid-rapidity to identify the phase transition from normal nuclear matter to quark matter (see Section 4). After the closure of the Bevalac, STAR and NA49 will be the focus of LBL's relativistic activities through the end of the century.

Low-Energy Nuclear Physics

The broad and diversified low-energy nuclear physics research program will continue at the 88-Inch Cyclotron. At the 88-Inch Cyclotron, new research opportunities have been made possible by the electron cyclotron Resonance (ECR) ion sources; both heavy-ion and light-ion beams are used to study nuclear structure, nuclear reaction mechanisms, exotic nuclei, and nuclear astrophysics.

Nuclear-structure studies at the 88-Inch Cyclotron are aimed mainly at understanding nuclei with large angular momenta (high spin). Results from the 21-element Compton-suppressed Ge gamma-ray High-Energy Resolution Array (HERA), have been particularly rewarding. Over half of the 27 superdeformed (SD) bands found in the mass 190 region during the past two years were discovered or co-discovered at HERA by a collaboration of LBL and LLNL groups.

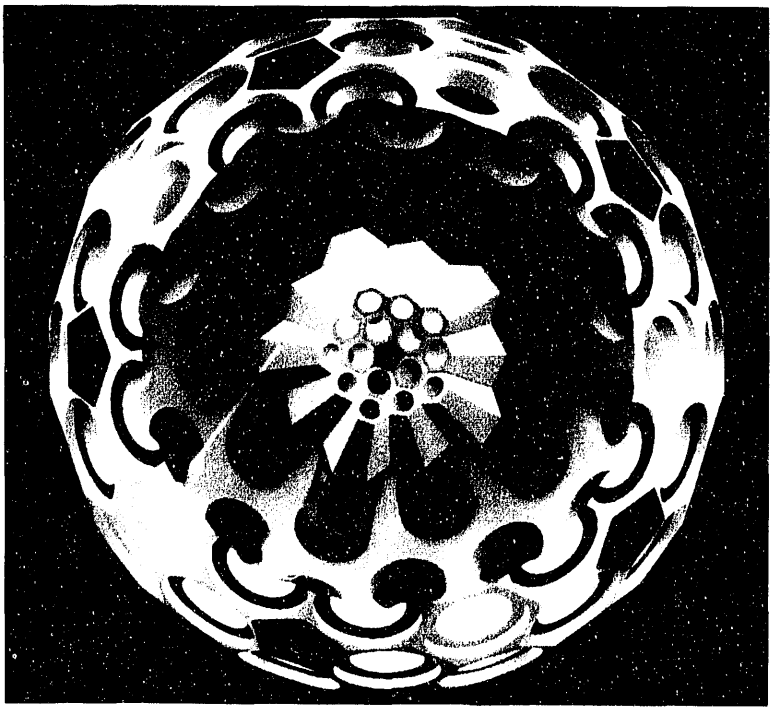
Gammasphere, the major initiative of the nuclear structure community, is under construction at LBL, and will operate initially at the 88-Inch Cyclotron. Construction began early in 1991 following the selection of LBL as the initial site. Gammasphere consists of an array of 110 large Compton-suppressed Ge detectors that will have an efficiency for detecting 1-MeV gamma rays six times larger than any array currently existing. It will be possible to use five-fold coincidence events with Gammasphere, and these events will provide a resolving power that is around 100 times higher than that obtained from any of the arrays in use today. A broad range of nuclear

physics can be addressed with such an instrument. Some examples include nuclear shapes (superdeformation, coexistence), warm nuclei (damping, giant resonance), symmetries in nuclei (Coulomb excitation), new regions of nuclei (secondary beams), and astrophysics (proton and alpha-particle capture cross sections).

Current schedules call for Gammasphere to begin initial operation in January of 1993 with about 30 detector systems, first phase operation to begin a year later with about 80 detectors, and completion in October 1994. After it is fully operational, Gammasphere research is expected to occupy about one-half of the 88-Inch Cyclotron's total beam time. Gammasphere will be operated by LBL as a national user facility, with active participation by groups at ANL, ORNL, and about 20 other U.S. national laboratory and university research groups that joined in the proposal.

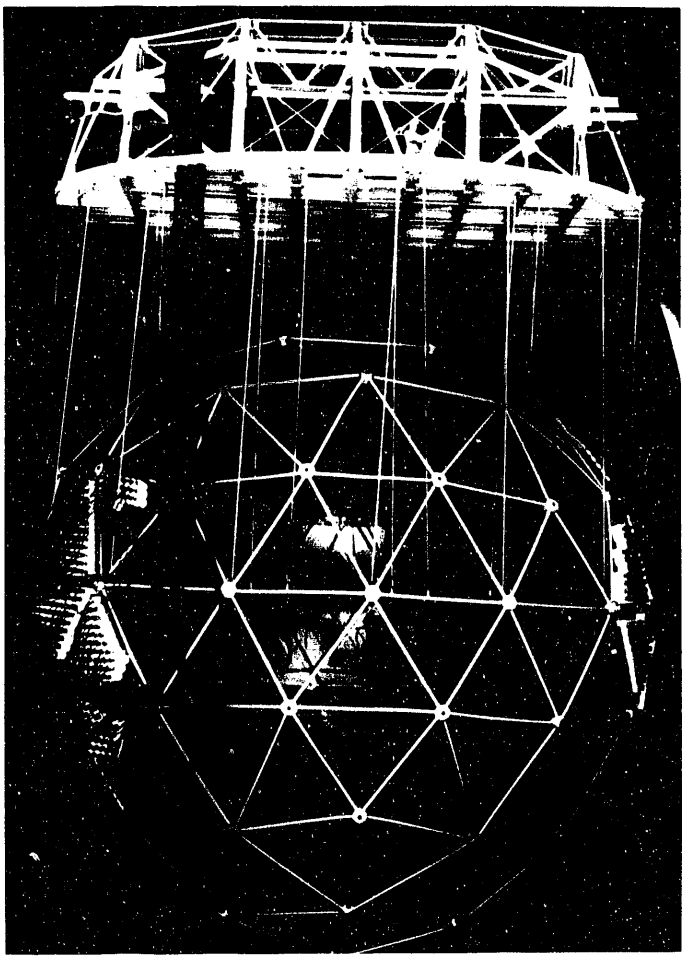
Heavy-ion reaction-mechanism studies in the intermediate-energy region (5–100 MeV/ nucleon) will be advanced by continued upgrading of detector systems and by use of higher-energy beams from the new advanced ECR source. As part of a new program in weak interactions, the beta-decay asymmetry of ^{21}Na will be measured using a laser trapping technique. The 88-Inch Cyclotron is also one of the leading laboratories in the world for the production and study of transuranic nuclei. The goals of this research effort are to explore the limits of the Periodic Table and to determine the factors that govern nuclear stability for the heaviest nuclei, as well as to train students in modern nuclear and radiochemical techniques.

The nuclear astrophysics group is participating in the Sudbury (Ontario, Canada) Neutrino Observatory collaboration to detect solar and supernova



A computer-assisted design drawing of Gammasphere showing the major components of the detector now under construction. Gammasphere will be the premier U.S. nuclear structure facility for the 1990s.

At SNO, an acrylic tank containing heavy water (deuterium oxide) will be suspended in ordinary, ultraclean water. The tank will be surrounded by an array of photomultiplier tubes, the framework of which is shown in the picture, that will measure the brief bursts of light produced when neutrinos interact with deuterium nuclei.



neutrinos using a large D_2O detector. In particular, the LBL group has assumed responsibility for the design and construction of the support structure to hold the ~10,000 photomultiplier tubes required. Installation of the support structure in Sudbury will begin in 1993. In experiments performed at LBL, this group has found confirming evidence for the existence of a neutrino with a mass of 17 keV. More definitive experiments are underway.

The idea of a high-intensity Radioactive Nuclear Beam (RNB) facility in the U.S., first suggested in 1989 during the development of the NSAC Long Range Plan for Nuclear Science, has found broad national and international support. A steering committee was formed to develop the idea; it recently issued a White Paper in which the scientific case for an RNB facility (tentatively given the name IsoSpin Laboratory) is made and design goals are put forth. LBL is represented on the steering committee, is conducting R&D to answer key design questions, and is exploring a preliminary proposal to build such a facility.

Nuclear Theory

The goal of the nuclear theory program at LBL is to develop precise theoretical tools and methods necessary for the proper analysis and interpretation of experiments involving atomic nuclei. These include nuclear reactions at low to ultrarelativistic energies and lepton-nucleus and hadron-nucleus reactions. In addition, the program aims at adding breadth to the Nuclear Science Division's overall nuclear research program by concentrated effort also in nuclear astrophysics, macroscopic nuclear models, QCD, and hadrodynamic theories of ultra-dense matter and phase transitions, order-to-chaos transition in nuclei and selected DOE research and development projects such as neurocomputing methods for pattern recognition.

Data Evaluation

The Isotopes Project of the Nuclear Science Division will continue to provide evaluated nuclear-structure and decay data for the world nuclear physics community. In addition to its mass-chain evaluation activities, the group produced the *Table of Radioactive Isotopes*, a comprehensive reference intended primarily for applied users of nuclear data and techniques. The group will also produce both electronic and hard-copy versions of the next (8th) edition of the *Table of Isotopes*. On-line access to the databases is provided to the scientific community, and "electronic publishing" is being developed as a regular means of disseminating up-to-date data.

Accelerator Improvements

The 88-Inch Cyclotron is being upgraded to optimize its performance for heavy-ion beams needed for the scientific research planned with the Gammasphere detector. Improvements in the cyclotron vacuum system will increase the intensity for heavy-ions above mass 100 and a beam pulse reduction system will improve beam timing. An upgrade is planned for the Advanced ECR Ion Source at the cyclotron to increase the energy and intensity of heavy-ion beams available. In addition to improving the cyclotron's performance, the planned upgrade will advance ECR technology.

Aimed at optimizing the Bevalac's scientific productivity prior to closing the nuclear physics program, the accelerator improvement program has as its near-term goals improvements in beam spill quality and duty factor for EOS experiments. New controls are being installed to help assure the desired beam emittance and cleanliness, and main guide-field power supply improvements have provided for quieter spills and extended flattop and duty factor.

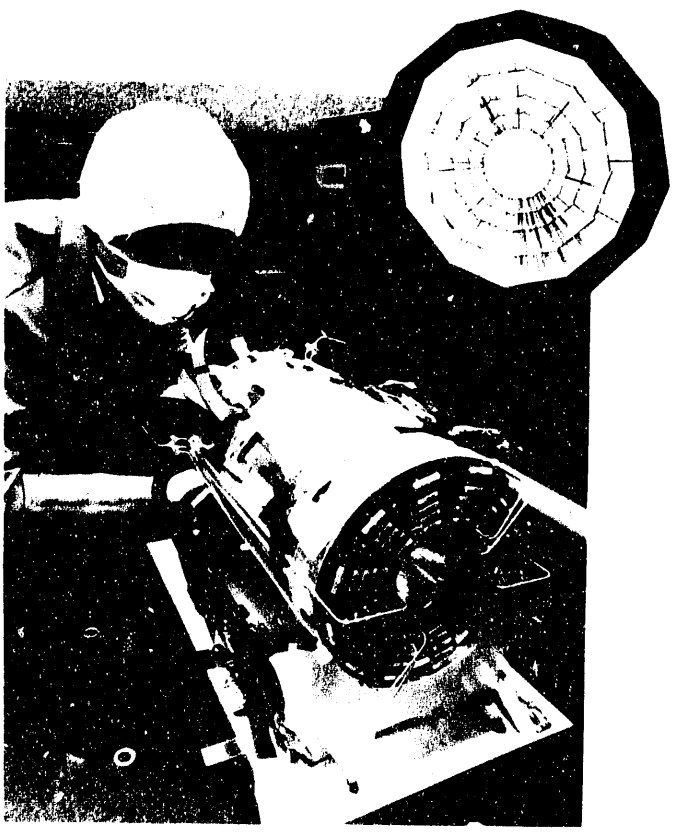
High-Energy Physics

In high-energy physics, the Laboratory continues its strong and diverse program of experimental and theoretical research, including the development and operation of innovative detectors and research on advanced accelerator components and concepts. LBL is actively participating in the national effort to design future facilities — the SSC detector and accelerator components and an asymmetric B factory at the Positron Electron Project (PEP).

Experimental Programs

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

At Fermilab, LBL is involved in both of the major experiments being prepared for the new proton-antiproton collider (Tevatron I). Part of the hadron calorimeter for the Collider Detector at Fermilab (CDF) was built at LBL and assembled at the CDF facility. Collaborative work between the LBL Instrumentation Group and the high-energy physicists on development and fabrication of important parts of the electronics for the CDF is also complete. LBL has major responsibilities in the D-Zero detector collaboration, also at the Tevatron I. These include coordination of the design and fabrication of the central part of the detector and fabrication of a microvertex tracking chamber, as well as the design and development of a sophisticated calorimeter. LBL physicists are major participants in fixed-target experiments at Fermilab. In addition to these large detector programs, there are smaller ongoing experimental efforts in both high-energy physics and selected areas of astrophysics.



LBL designed and built the Silicon Vertex Detector for the Collider Detector at Fermilab (CDF). Here the actual detector is shown with one of the early results after installation in the CDF.

At SLAC, LBL is involved in the development of the polarimeter to detect the left-right asymmetry A_{LR} in collisions at the Z^0, an important test of the Standard Model. LBL continues its pioneering role in particle astrophysics through several experimental programs in collaboration with the Center for Particle Astrophysics (CFPA).

Theoretical Programs and Data Compilation

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

The Particle Data Group performs a service to the world's high-energy physics community through its compilations of particle properties. Its recent strengthening includes making databases more accessible through computer links.

Detector Research and Development

Advanced detector development is aimed at long-range research in detector problems relevant to proposed hadron colliders (see SSC below and Section 4). The program emphasizes the development of radiation-hardened devices, pixel devices, monolithic amplifier arrays, and data-acquisition electronics.

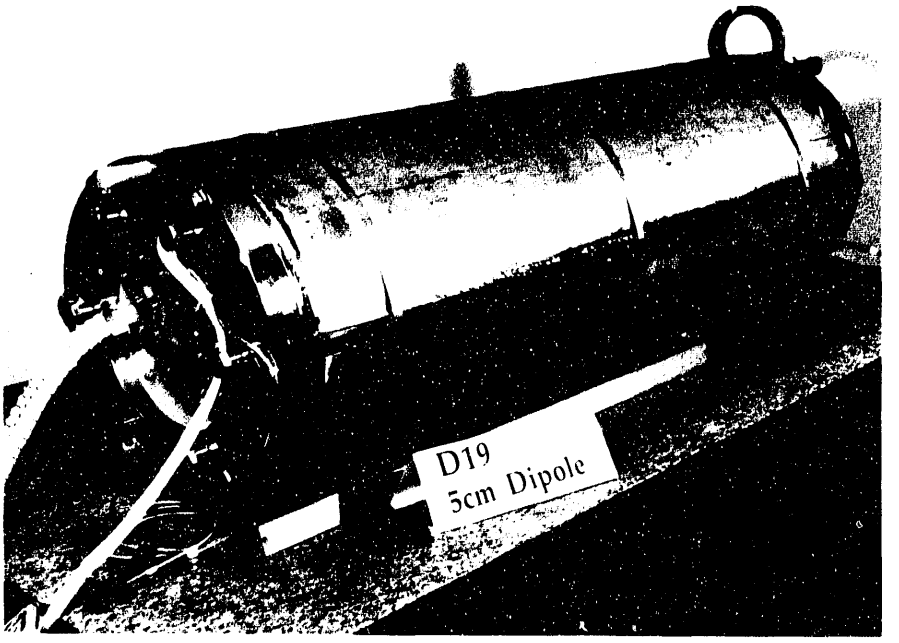
In addition, technology development efforts are directed toward ongoing detector construction and upgrade projects. For example, ultrahigh-resolution vertex detectors for MARK II at the SLC and D-Zero at the Tevatron I were fabricated to provide spatial resolution on the order of tens of micrometers to detect the decays of very-short-lived particles. Another example is the development of ultrahigh-resolution solid-state detectors to search for neutrinoless double beta decay to measure a finite neutrino mass.

Accelerator Physics and Design

LBL accelerator physicists have long played a leading role in research and development for high-energy physics facilities. In the recent past, for example, their experience with beam cooling resulted in successful systems at the Tevatron I. Most recently they have turned their attention to high-luminosity lepton colliders such as B-meson factories, and have been using their combination of analytical and practical expertise to solve a variety of problems, such as beam-beam instabilities and damping of higher-order modes.

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

LBL scientists and engineers designed and built a world record setting 10-Tesla accelerator-type magnet using NbSn superconductor material.



Other activities include accelerator design studies for an energy-asymmetric B factory (see Section 4). Based on an LBL concept, it would use e^+e^- collisions at different energies to produce B mesons in a way that spreads out the collisions over space-time so that they are easier to study for evidence of CP-violating decays.

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

Superconducting Super Collider

LBL is conducting advanced detector development in detector problems directed specifically toward SSC physics. The program emphasizes the development of radiation-hardened devices, new pixel devices for two-dimensional high-resolution detectors, and low-noise, high-speed monolithic amplifier arrays. Specific efforts are directed toward a silicon tracker, scintillation calorimetry, and front end electronics for the SSC. Cooperative efforts between LBL engineers and high-energy physicists are developing designs for improved data-acquisition electronics suitable for experiments at high-luminosity hadron colliders as a part of LBL's major Solenoidal Detector Collaboration initiative (see Section 4). The design, fabrication, and testing of SSC quadrupole magnets with a Nb-Ti superconductor continues at LBL.

Mechanical technicians are shown winding the cable onto the first of six prototype quadrupole magnets for the SSC.

Office of Health and Environmental Research

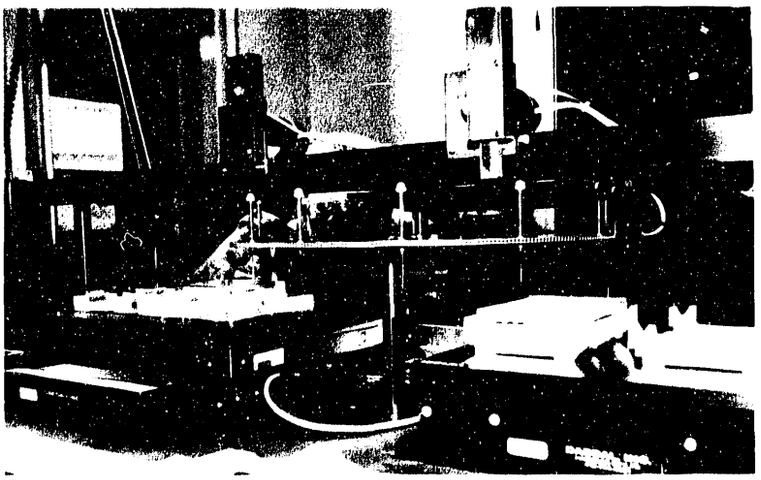
Life-sciences-related research activities include six research program areas: gene expression and genome mapping; structural biology; nuclear medicine and functional imaging; carcinogenesis, mutagenesis, and radiation biology; environmental and health-effects research; and measurement technology. These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

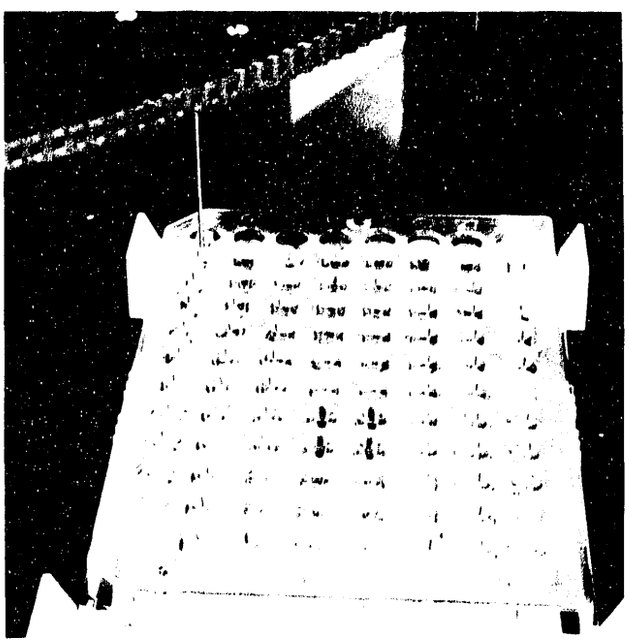
Gene Expression and Genome Mapping

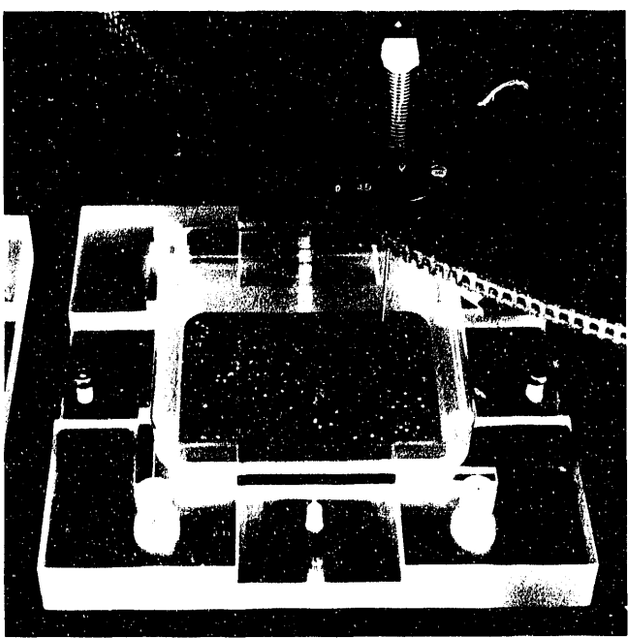
Important research growth areas for LBL are studies on human genome structure and regulation of gene expression. Research at the Human Genome Center includes generation of physical and genetic maps at several levels of resolution (20 kb to 100 kb), identification and localization of all of the expressed genes on human chromosome 21, and development of techniques and automation for efficient sequencing of human DNA. Expressed genes and cDNAs are also being mapped throughout the *Drosophila* genome, in collaboration with UC Berkeley and Harvard University. Identification and mapping of groups of genes involved in the control of development and in the generation of personality traits are also part of the Center's program.

LBL's Life Sciences Division conducts several related research programs on gene expression within mammary-gland and blood-forming systems. The highly secretory mammary epithelial cells provide excellent models for gene

Automatic instrumentation is a significant requirement, especially for cost savings, for the mapping of the human genome. Some of the laboratory equipment developed at LBL include a colony picker (right). This moves a robotic needle to sample a Petrie dish (lower right) with colonies of yeast or bacteria cells containing cloned human DNA. The carousel rotates and deposits the cells in the correct well of a microtiter plate (lower left).



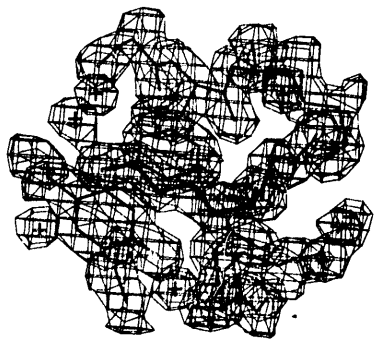




expression and chemical- and radiation-induced carcinogenesis and are now also providing vehicles for production of genetically engineered foreign genes. LBL has identified hematopoietic research for expansion. Blood-forming cells are important targets of radiation-induced damage and are versatile models of stem-cell differentiation and regulation of gene expression.

Structural Biology

One thrust of LBL's structural biology program is directed toward x-ray based research at the ALS, as described in Section 4. Research on advanced techniques in x-ray microholography focuses on subcellular structures at the level of organelles. X-ray crystallography and NMR spectroscopy focus on protein and nucleic acid structures. Several studies are aimed at determining how proteins regulate the expression of genes by examining the structure of the protein-nucleic acid complexes. These latter studies will make use of



Electron density around the bound lysine in the bacterial lysine-arginine-orthnithine (LAO) receptor. The grids outline a contour of constant electron density, while the spacing between parallel grid lines indicates the frequency of data measurements. Such maps enable study of the detailed interactions between the lysine and the receptor protein. These studies are done to understand how cells detect and absorb surrounding nutrients.

advanced imaging techniques made possible by the ALS such as x-ray diffraction and scanning tunneling microscopy.

Studies based on high-resolution electron crystallographic structure analysis are also elucidating the structure of specific membrane proteins that are involved in transmembrane signaling. Using unique techniques for electron diffraction and imaging of crystalline sheets of membrane proteins, structural studies will be pursued on such membrane bound proteins as growth-factor receptors, chemotaxis receptors, and receptors for extracellular matrices. LBL's new intermediate-voltage electron microscope, which allows viewing of much thicker specimens than can be examined with conventional electron microscopes, is enabling researchers to study complex structures, including that of the isolated mitotic spindle, which can be prepared as a frozen, hydrated specimen. Related work will exploit circular-dichroism microscopy, electron microscopy, and novel microscopic-imaging capabilities from the UV and SXR beams of the ALS.

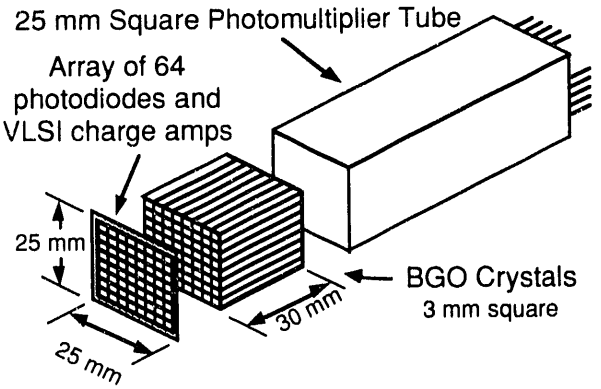
Nuclear Medicine and Functional Imaging

Research in nuclear medicine will include studies involving molecular biology while continuing studies on both basic science and therapeutic applications of radiation sources and instrumentation developed at LBL. A systematic search for new, ultrafast heavy-atom scintillators will continue, as well as the development of solid-state photodetectors for multilayer high-resolution positron-emission tomography. A new multilayer, high-resolution tomograph design is planned for use in medical studies of the human brain and heart, as well as for studies in laboratory animals. This work includes studies of the causes of atherosclerosis and of the physiological basis of brain disorders, including Alzheimer's disease, using nuclear and organic chemistry, tomographic imaging procedures, autoradiography, and advanced computer kinetic modeling. High-resolution *in vivo* microscopy and *in vivo* carbohydrate metabolic studies are also being furthered through the development of advanced NMR instrumentation.

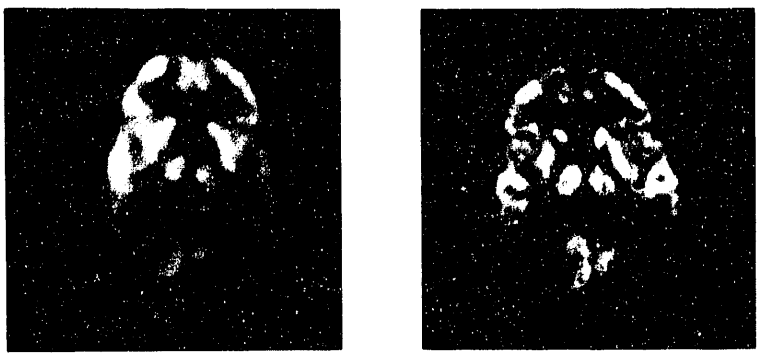
Methods for the production of radioisotopes and for the labeling of biochemical substrates to be used in noninvasive imaging have contributed to the effective use of these diagnostic-imaging tools. Newly developed radioisotope generators give greater flexibility to the application of short-lived, positron-emitting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

A new Biomedical Isotope Facility that will provide isotopes for use by LBL scientists and other qualified users is scheduled for completion in 1993. The capability for using the short-lived light-element tracers from a minicyclotron that is the heart of the facility will be especially appropriate to a range of metabolic studies. The primary isotopes produced would be ^{15}O, ^{11}C, ^{13}N, and ^{18}F for brain and heart positron-emission tomography studies. The two LBL positron tomographs, one with the highest spatial and temporal resolution in the world, will be utilized effectively with these short-lived positron-emitting tracers.

Basic studies of the biological effects of heavy-ion beams from the Bevalac have been coupled with research on optimum methods for heavy-ion radiosurgery. Research on the treatment of arteriovenous malformations (AVMs) in the brain has built on the established clinical research successes and on basic biological studies of the effects of heavy ions. Tracer studies with radioactive beams have established the basis of placing the radiation dose in the tumor or target volume with high accuracy.



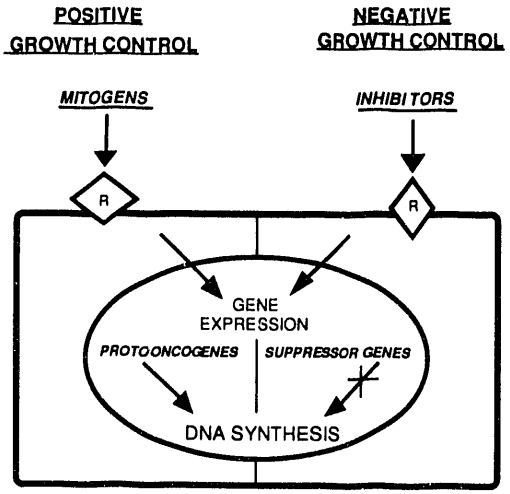
LBL scientists have developed a refined positron-emission tomography (PET) detector (top) that improves maximum data rate by a factor of 4 and spatial resolution by almost a factor of 2. Better images are now available for the understanding of the brain (right).



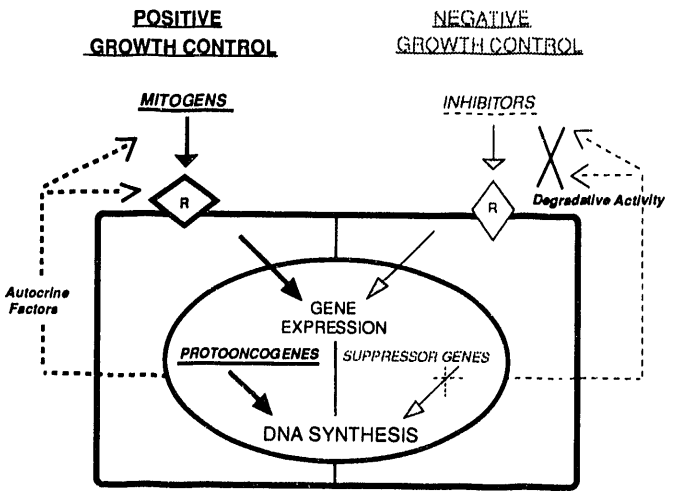
OLD NEW

Carcinogenesis, Mutagenesis, and Radiation Biology

LBL plans increased research emphasis on the role of oncogenes and tumor suppressor genes in cancer induction and embryogenesis, as well as on an integrated program in cancer initiation, promotion, and progression. Activities in the area of DNA damage and repair include cloning of human genes by complementation of the defects, research on how structural constraints and organization of the cell's genome affect repair processes, studies of inducible responses to DNA damage, and cell culture studies of replication of damaged DNA templates. Studies using rodent and human epithelial and blood-forming cells in culture and *in vivo* are directed toward a better understanding of their differentiation and malignant transformation. Researchers are examining how the cells communicate with their environment to regulate gene expression, growth, and differentiation. Using viral and cellular genes, they are studying critical features of oncogene expression, including the influence of both environmental variables and cellular growth factors. Another area of research is directed at understanding how protooncogenes (which, through mutation, become oncogenes) and tumor suppressor genes (which become inactivated during carcinogenesis) function in normal, terminally differentiated, and neoplastic cells. Finally, researchers are intensively studying the process of hematopoiesis—the differentiation of blood cells from a multipotential stem cell—both because of its intrinsic significance and relationship to diseases of the blood and because it provides an excellent model for the processes that take place during embryogenesis.



NORMAL CELL PROLIFERATION



ABNORMAL PROLIFERATION

LBL researchers are studying the fundamental processes that regulate cell division (left), and the mechanisms by which these processes go awry in carcinogesis (right). These include studies on the interactions of growth factors, growth inhibitors, and other extracellular molecules with their receptors. They are also studying the processes by which these bound receptors communicate with the cell nucleus. In the nucleus are the genes that are critical regulators of cell proliferation — the protooncogenes and the tumor suppressor genes.

LBL researchers are using electromagnetic radiation (x-rays and gamma rays) and accelerated ions as probes to answer specific questions regarding the cellular and molecular effects of various types of radiation. The approach to determining the risks associated with ionizing radiation is based on understanding and characterizing basic cellular and molecular phenomena. This fundamental radiobiological research focuses on such processes as the molecular basis of radiation damage and radiation-induced cancer, as well as physical phenomena such as the fragmentation of ions into particles of lower charge and mass. Such work will enable continued progress in radiation medicine and the assessment of radiation hazards. The influence of the extracellular environment, including hormones and the extracellular matrix, will be included in models of the relationship between exposure dose and tumorigenicity.

Applied studies of the interactions of heavy ions with normal tissue aim at defining tolerance limits and the risks of carcinogenesis associated with exposure to these particles. Studies with tumor tissue are directed toward determining optimal strategies for tumor treatment, including dose, particle type, and treatment interval. Another major effort is directed toward understanding how the responses of human cells differ from those of animal cells, both *in vitro* and *in vivo*.

Because of the importance of measuring the consequences of low-dose exposure, emphasis will be given to these types of measurements. The studies will attempt to separate the process of lesion formation in DNA from the processes of enzymatic repair. These studies will contribute to understanding the risks associated with accidental exposure to neutrons, space radiation, other occupational hazards, and exposure from medical diagnostic investigations.

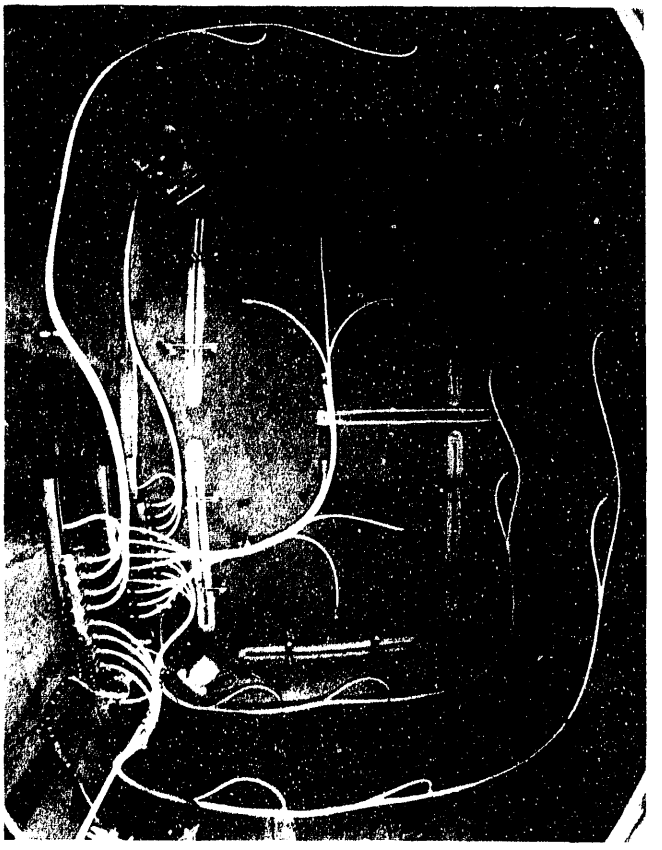
Environmental and Health-Effects Research

Environmental research at LBL comprises multidisciplinary efforts on global, regional, and local environmental problems such as subsurface contamination, indoor air quality, and high-magnetic-field environments.

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

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

Research at LBL on radon migration through soils and into buildings and the indoor behavior of radon and its radioactive decay products are important components of the national radon research effort sponsored by OHER. The LBL program includes unique experimental facilities for studying radon movement in soil and into buildings under controlled conditions, which will allow comparisons with detailed numerical simulation models. In addition, the radon research program examines the effects of other parameters, including other indoor air pollutants, building construction and operation, and climate conditions, on the resulting indoor radon concentrations and, ultimately, on the radiation doses to the building occupants from these indoor exposures.



A small basement structure has been used by LBL researchers to study how radon enters buildings. The structure is equipped with numerous probes to measure pressure differences and radon concentrations.

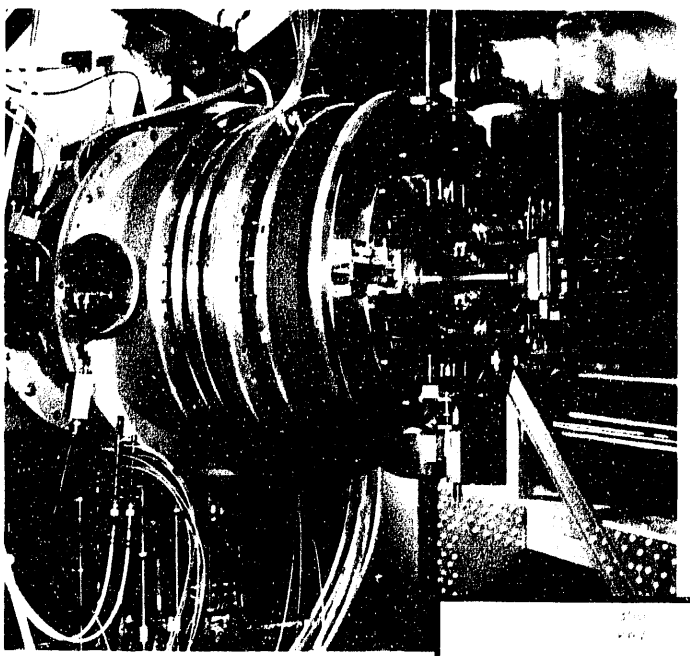
Magnetic-field interactions are being evaluated in experimental-animal systems and in tissue and cellular systems potentially sensitive to this nonionizing radiation. This program will develop theoretical models of magnetic-field interactions with biological systems and provide essential data for assessing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

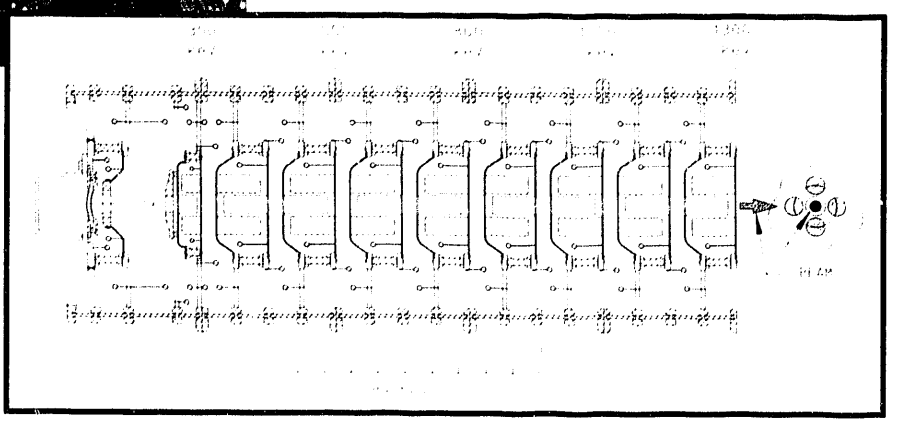
Measurement Technology

Excellence in measurement technology is key to the success of OHER programs. Refinements in sensors and analytical techniques have been developed at LBL for a number of years. Improvements in radiation detectors and materials for detectors, and the development of increasingly sensitive and specific x-ray and atomic-absorption analytical methods are the major thrusts. Research and development of the associated electronic signal-processing techniques complement this work. OHER support for x-ray detectors at the ALS and other synchrotron sources will utilize LBL expertise and provide significant advances in image resolution and chemical characterization of biological materials.

Office of Fusion Energy

Fusion energy research at LBL focuses on accelerator systems supporting the nation's inertial confinement and magnetic fusion energy programs. The LBL Heavy-Ion Fusion Accelerator Research (HIFAR) Group has focused its attention on exploring the physics and technology of induction acceleration as the means for producing high-current heavy-ion beams as a driver for inertial-confinement fusion systems. In comparison with other possible inertial-fusion drivers (e.g., lasers), beams of heavy ions offer important advantages for practical applications, including high efficiency from the "wall plug" to the beam, good potential for beam-to-pellet energy coupling, and high repetition rates. LBL's current efforts have resulted in successful completion of the multiple-beam experiment to examine the





The accelerator that would be used for the ITER proof-of-principle test is a constant current variable voltage (CCVV) accelerator with electrostatic quadrupole (ESQ) focusing (right). It is a scaled-up version of one that LBL has been working with since 1987 (top). The quadrupole units of the later version will be approximately 2.5 times larger in length and diameter.

initial accelerator components for space-charge-dominated beams undergoing current amplification. Current efforts are directed toward design and development of the next set of studies, the Induction Linac Systems Experiments (ILSE), as described in Section 4.

LBL contributes to the magnetic-confinement fusion program through the development of neutral beams for heating, refueling, and confining reactor plasmas. LBL's work on positive-ion-based neutral beams has been coupled with the research efforts at the Tokamak Fusion Test Reactor at Princeton and the DIII-D at General Atomics in La Jolla. Studies for an Engineering Test Reactor, specifically the International Thermonuclear Experimental Reactor (ITER), have identified neutral beams as a leading candidate for driving current in the steady state. The mission of ITER, and the need for neutral beams, will be re-examined during the initial part of the next phase of the project, the Engineering Design Activity. As a result, research and development of high-energy (≥1 MeV) beams for heating and current drive in ITER may increase. These systems will be based on the production and acceleration of negative deuterium ions.

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

University and Science Education Programs

In support of DOE's role in energy-related science education and technology transfer, LBL conducts training and technology-transfer activities with many organizations and institutions as part of the Laboratory's mission to educate and train scientists and engineers and to transfer knowledge and technological innovations to industry. These programs, currently undergoing significant expansion in response to strategic national goals for investment in human resources and long-term economic development, include collaborative technology research projects with industry, an industry-laboratory-personnel exchange program, and science education activities (see Section 7).

CONSERVATION AND RENEWABLE ENERGY

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

Conservation and Renewable Energy Funding Summary[a]
(Fiscal Year Operating and Capital Budgetary Authority, $M)

Major Program (BR Code)	1991	1992	1993	1994
Buildings Sector (EC)	9.8	9.1	11.1	12.0
Electric Energy (AK)	0.6	0.2	0.2	0.2
Geothermal (AM)	1.5	1.6	1.6	1.7
Industrial Sector (ED)	1.2	1.3	1.2	1.2
State & Local Assistance (EF)	0.2	0.1	0.2	0.2
Transportation Sector (EE)	2.8	2.8	3.1	3.2
Utility Sector (EK)	0.4	0.8	0.8	0.8
Total	*16.5*	*15.9*	*18.2*	*19.4*
Percent of LBL Total	*6.4*	*5.7*	*6.6*	*6.6*

[a] Does not reflect DOE-CRE reorganization below pending additional budgetary guidance.

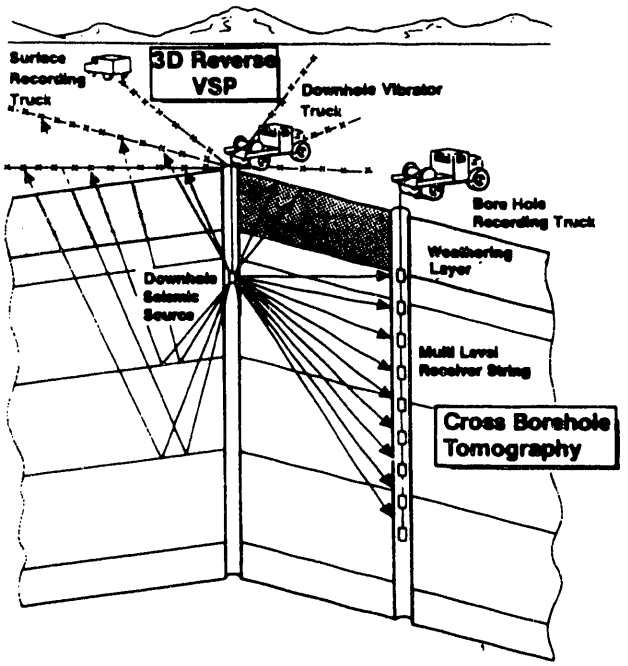
Utility Technologies

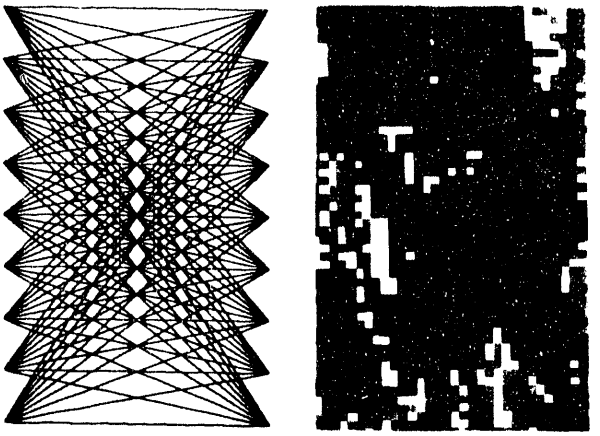
LBL's programs provide assistance to utility planning and renewable energy supply, and research that will yield long-term options for utilities. An expanding effort in Integrated Resource Planning is directed toward providing information and analytic methods for incorporating conservation and renewable options in utility planning on an equivalent basis to conventional supply options. This effort is carried out in close collaboration with the National Association of Regulated Utility Commissioners.

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

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

Reservoir-technology work will lead to more accurate predictions of the responses of a geothermal reservoir to exploitation for optimum management through carefully designed fluid-production and injection operations. Joint field projects with U.S. geothermal developers continue to be highly productive, as do collaborations with organizations in Mexico, Iceland, and Italy. Magma-energy-extraction investigations are directed at the evaluation of candidate sites, where bodies of molten rock (magma) may exist at shallow depths (< 10 km) in the earth's crust. Currently, LBL is investigating the Long Valley caldera in California as part of a multi-institutional collaboration.





Verticle Seismic Profiling (VSP) and cross borehole imaging is an emerging technology that avoids surface effects and increases spatial coverage. It gives subsurface studies the potential for tomography and allows higher frequencies for better definition.

Industry Technologies

This effort focuses on advanced industrial concepts, including energy-efficient chemical separations such as distillation, the opacification of aerogels for high-performance insulation in non-view applications (e.g., refrigeration), and premixed lean-engine combustion, which holds the promise of reduced emissions, improved engine efficiency, and extended fuel tolerance. Work is just underway in two projects on catalysts for industry: theory-assisted design of metal and zeolite catalysts; and chemistry, immunology, and modeling as tools for the rational design of stable, active enzymes.

Transportation Technologies

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

Based on its work for Building Technologies, LBL is developing switchable glazings for automobiles and other vehicles. Optical control to reduce solar heat gain will permit down-sized air conditioners and thus reduced use of CFC refrigerants as well as increased mileage.

Building Technologies

LBL will continue activities related to residential and commercial buildings in a program of laboratory and field research, modeling, and data analysis. This work is a coordinated systems approach to designing building components and whole buildings with improved energy efficiency. Modeling and field measurements verify results on economic costs and benefits of conserving energy. Important aspects of the work include measurements of indoor air quality and possible health effects of proposed conservation measures. The initiative on Advanced Energy Design and Operation Technologies (see Section 4) is an extension of these efforts.

The Laboratory has a lead role in applied research in four areas related to energy efficiency in buildings: windows and daylighting, artificial lighting, computer modeling of building energy use, and infiltration/ventilation and indoor air quality. The general objective of these programs is to develop advanced energy efficient technologies and to develop computational tools and experimental facilities. This will allow evaluation of technologies showing the greatest promise for significant energy savings in buildings while maintaining levels of illumination and air quality adequate for human comfort and health. Specific projects focus on energy-savings opportunities in fluorescent lamps, advanced windows, novel building insulation, analysis of federally assisted housing, residence analysis and performance studies, analysis of appliance energy efficiency, and site-planning studies to minimize summer heat-island effects. These projects are undertaken in close collaboration with the building industry.

Research on building technologies include use of a special Mobile Window Thermal Test Facility (MoWiTT). Inside this facility is a pair of room-size calorimeters to accurately characterize energy performance of windows, especially heat flow, in a real world environment, together with the analytical and recording instrumentation shown. The facility is normally located at the University of Nevada in Reno.

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

OFFICE OF FOSSIL ENERGY

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

A study is underway of the fundamental processes involved in enhancing underground oil recovery by means of foam surfactants used to dislodge trapped oil in nearly depleted reservoirs. This study will determine how such foams are generated and how they flow in porous rock so that better oil-recovery methods can be designed for specific applications. Studies of chemical wastes from subsurface hydrocarbon conversion systems are directed toward developing an improved database and processes for microbial degradation of organic waste materials.

Fossil Energy Funding Summary
(Fiscal Year Operating and Capital Budgetary Authority, $M)

Major Program (BR Code)	1991	1992	1993	1994
Coal (AA)	1.2	1.0	1.0	0.9
Gas (AB)	0.3	0.3	0.3	0.3
Petroleum (AC)	0.6	0.9	0.9	0.9
Total	*2.1*	*2.2*	*2.2*	*2.2*
Percent of LBL Total	*0.8*	*0.8*	*0.8*	*0.7*

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

The Laboratory is implementing site projects for restoration and waste management consistent with DOE's National Environmental Restoration and Waste Management Program. As described in greater detail in Section 6, the existing and budgeted site projects address specific conditions at the Laboratory, including facilities and operating programs for corrective actions, environmental restoration, and waste management. The ERWM program is vital to LBL's Tiger Team Corrective Action Plan.

Environmental Restoration and Waste Management Funding Summary
(Fiscal Year Budgetary Authority, $M)

Major Program (BR Code)	1991	1992	1993	1994
Environmental Management (EX)[a]	7.4	14.2	9.3	15.0
Percent of LBL Total	*2.9*	*5.1*	*3.4*	*5.1*

[a]Includes costs with reference to Section 6.

ENVIRONMENT, SAFETY, AND HEALTH

LBL is continuing its strong programs in analytical methods development and statistical studies of environmental and epidemiological factors supported by the Office of Epidemiology and Health Surveillance. The Population at Risk to Environmental Pollution project focuses on the collection, analysis, and interpretation of data pertaining to relationships between human health and environmental pollution. Computational techniques are developed for the analysis of ecologic data, especially small-area geographic data, to investigate alleged departures from expected disease rates, to generate etiologic hypotheses, and to plan clinical trials or cohort studies. The role of the Comprehensive Epidemiologic Data Resource project is to provide exposure and health data on DOE workers, to research epidemiologists both within and outside DOE.

Environment, Safety and Health Funding Summary
(Fiscal Year Budgetary Authority, $M)

Major Program (BR Code)	1991	1992	1993	1994
Environmental Health & Safety (HA)	1.7	1.7	1.7	1.8
Percent of LBL Funding	*0.7*	*0.6*	*0.6*	*0.6*

OTHER DOE PROGRAMS

LBL maintains active research programs in Civilian Radioactive Waste Management, Policy Planning and Analysis, In-House Energy Management, and in supporting other DOE contractors, such as the Superconducting Super Collider.

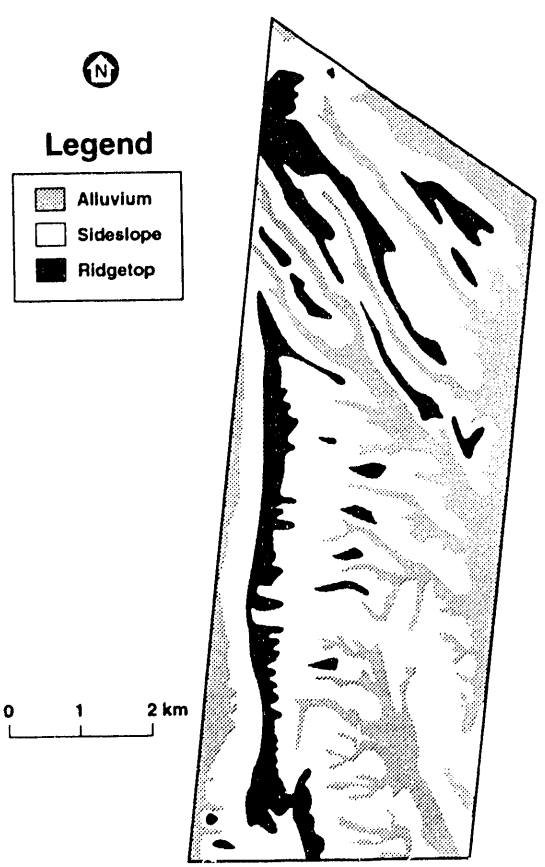
Other DOE Programs Funding Summary
(Fiscal Year Budgetary Authority, $M)

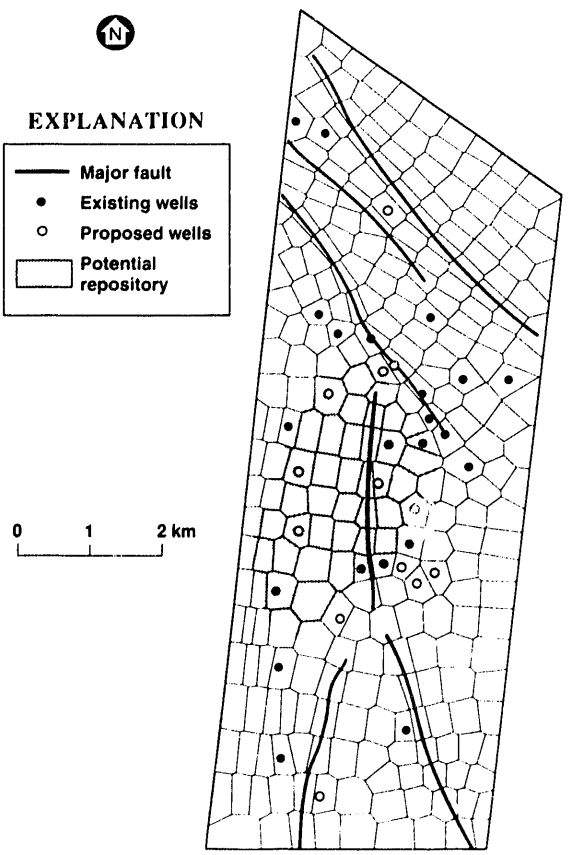
Major Program (BR Code)	1991	1992	1993	1994
Civilian Radioactive Waste Management (DB)	3.3	3.6	4.2	4.4
Policy, Planning, & Analysis (PE)	1.3	1.5	2.2	2.8
Administration and Human Resource Management (WB)	2.3	3.5	2.3	2.3
Other DOE Contractors (WFO)	18.2	14.2	16.2	16.7
Total	*25.1*	*22.8*	*24.9*	*26.1*
Percent of LBL Total	*9.7*	*8.1*	*9.0*	*8.9*

LBL scientists, in collaboration with the USGS, study the infiltration zones in a model area of Yucca Mountain. The different zones are mapped (left) and location of faults and existing and proposed wells laid out (right). Careful understanding of a potential repository site is vital for the safe long-term storage of radioactive waste.

Civilian Radioactive Waste Management

LBL 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, e.g., characterization of deep geologic formations, determination of the physical and chemical processes occurring between waste-repository materials and the surrounding rocks, analysis of hydrologic and chemical transport mechanisms, and





development of predictive techniques for repository performance. Coupled with ongoing basic research, LBL is contributing to technology and applied development research at DOE's Yucca Mountain Project.

Experimental work involves testing rock samples to determine fundamental chemical, mechanical, and hydrologic parameters under a suite of anticipated repository conditions. Complementary research is conducted on the characteristics and processes that control radionuclide transport in host rocks. Related efforts involve development of analytical methods for predicting the response of geologic systems to repository development and the performance of geologic environments for various repository containment designs. These expanding research activities draw upon LBL's expertise in nuclear chemistry, earth science, computing and numerous engineering fields.

Policy, Planning, and Analysis

LBL undertakes analysis activities in support of policy issues of concern to DOE. Recent efforts include analysis of feebates as a policy approach to increase auto fuel economy, combustion pollution exposure that takes place indoors, and assessment of a variety of policies as an input to the National Energy Strategy (NES). An ongoing task related to the NES is to assess the performance of utility demand-side management programs, to gather better cost data for energy conservation measures, and to incorporate this information into forecasts of residential and commercial energy demand.

In support of DOE's interest in developing a comprehensive understanding of factors that influence the release of "greenhouse" gases, LBL is undertaking a series of studies on global energy demand and related issues. Included are: (1) an extensive analysis of China's energy system and an exchange and collaboration program with the Energy Research Institute of the People's Republic of China; (2) an analysis of electricity and overall energy demand growth patterns in the major developing countries; (3) energy demand analysis of Poland; (4) development of technology database for the Intergovernmental Panel on Climate Change; (5) and a review of current knowledge about selected environmental parameters in developing countries. An initial effort to combine this knowledge into a set of global scenarios is under way.

Administration and Human Resource Management

LBL's In-House Energy Management program pursues opportunities to significantly reduce energy costs at LBL. It is estimated that the program will result in over $2 million in annual savings. The program involves surveys and studies of existing conditions, retrofit projects, new construction, and utility management and related operational programs. Recent major projects have improved accelerator efficiency, lighting, and utility systems.

Other DOE Contractors

LBL conducts research and development programs in support of the SSC Laboratory, including magnet systems technology development and research on detectors (see Superconducting Super Collider above). The magnet systems work, now focusing on dipole magnets, is supported through the Universities Research Association, the SSC Laboratory contractor.

LBL contributes to the research programs at other DOE national laboratories and facilities through such activities as laser-material interactions for LLNL, development of specialized object scanning CCD cameras, and the investigation of advanced windows and energy-conservation strategies for the Bonneville Power Administration.

WORK FOR OTHERS

LBL WFO complements DOE research programs and provides unique research resources to other agencies and organizations. Reductions in support from some Federal agencies is being offset by collaborative research with the private sector consistent with national technology transfer goals.

Work for Others Funding Summary
(Fiscal Year Budgetary Authority, $M)

Agency	1991	1992	1993	1994
Department of Defense	3.2	13.2	13.2	13.2
Department of the Interior	0.9	0.7	0.7	0.7
Environmental Protection Agency	1.7	1.7	1.8	1.8
National Aeronautics & Space Adm.	2.0	2.2	2.3	5.3
National Institutes of Health	13.6	14.8	13.4	13.8
Other Federal Agencies	0.4	0.8	1.2	1.4
State and Private	12.5	11.8	12.7	13.4
Total	*34.3*	*45.2*	*48.3*	*49.6*
Percent of LBL Total	*13.3*	*16.1*	*17.5*	*16.9*

Agency for International Development

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

Department of Defense

The Army Strategic Defense Command supports neutral-beam research related to magnetic fusion energy. The Air Force Office of Scientific Research supports x-ray microscopy and high-brightness x-ray studies. The Office of Naval Research supports studies of oxide scales on aluminides, quantum Monte Carlo calculations, thin-film superconductors, zinc cells, and microwave-radiation-stimulated release of drugs. The Navy also sponsors research on efficient lighting for ships and optical properties of the ocean.

The Defense Advanced Projects Research Agency (DARPA) is expanding its support of research in x-ray lithography at the Center for X-ray Optics (CXRO). The projects supported by DARPA are on the critical path for the development of extreme ultraviolet (EUV) and soft x-ray (SXR) pattern transfer technology. The research is in response to unique opportunities for

science, and technology at the Advanced Light Source (ALS). Funding for the design of an undulator beamline has already (FY 1991) been received through LBL's Center for X-ray Optics (CXRO). Funds for undulator, front-end, and beamline fabrication are expected in FY 1992 as an extension of the present LBL/CXRO contract with DARPA.

Department of the Interior

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

Environmental Protection Agency

LBL conducts research on the hydrogeological transport of contaminant plumes from deep underground injection disposal. In the area of global environmental effects, LBL is characterizing the emissions of energy technologies, improving global energy projections, fostering international awareness of global trends, studying effects of tropical deforestation, and gathering information on the potential effect of global climate change on U.S. natural resources.

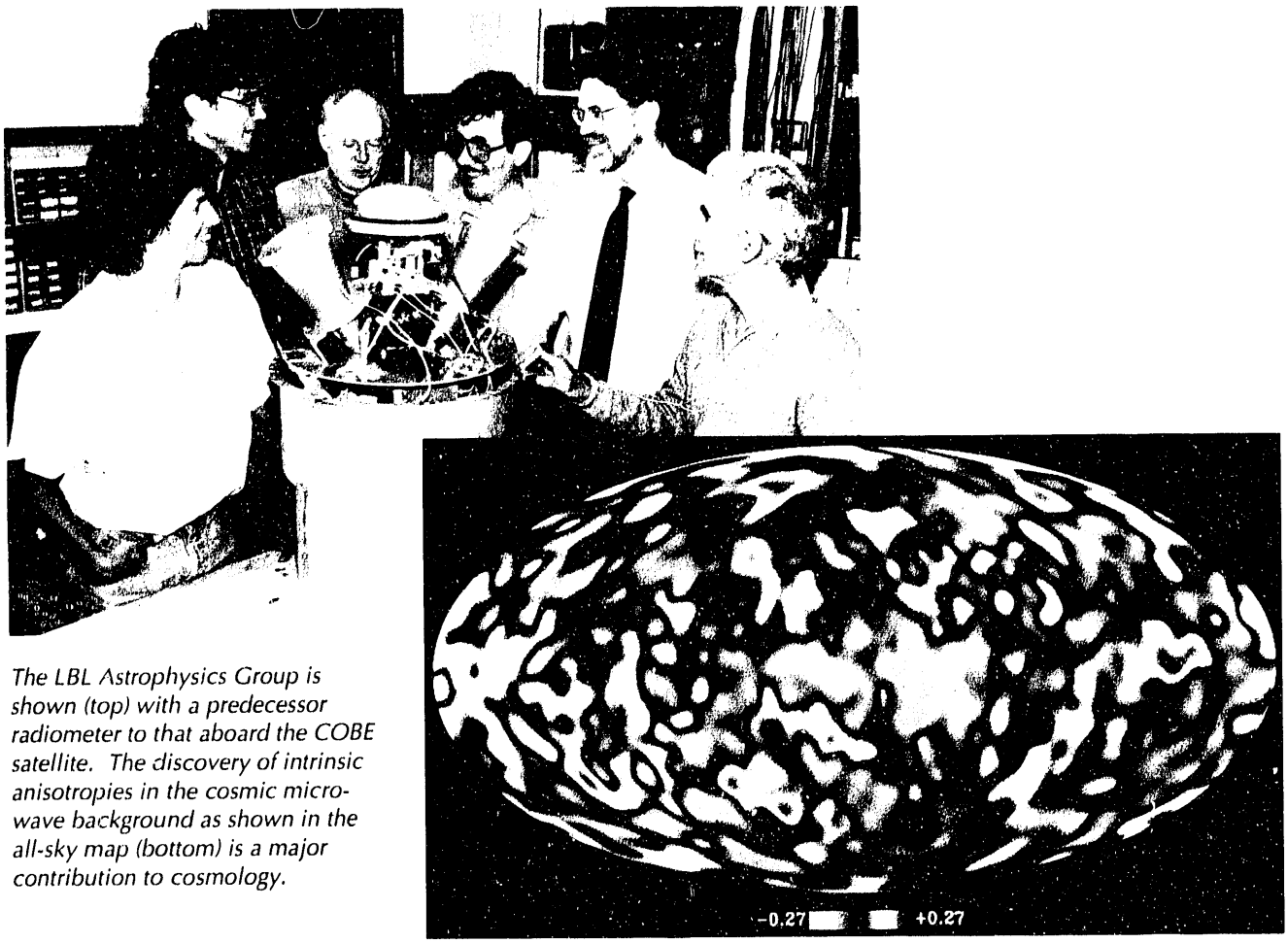
National Aeronautics and Space Administration

LBL is conducting radiation health and instrumentation-development projects for NASA. The carcinogenic and mutagenic hazards to humans in the space-radiation environment are being studied with combinations of high- and low-(linear-energy-transfer) radiation at LBL's Bevalac accelerator. In collaboration with Colorado State University, Fort Collins, LBL is recognized as the NASA Specialized Center for Research and Training (NSCORT) in these areas. LBL also collaborates with various NASA groups to develop gamma and x-ray detector systems for various space applications, such as for the WIND Spacecraft and Nuclear Astrophysics Explorer. LBL scientists are developing a superconducting magnetic spectrometer for the space station to measure cosmic-ray particles and gamma rays in search of exotic matter. Other ongoing research concerns nitrogen recycling in a Closed Ecological Life Support System for long-term space missions (see also the Civil Space Mission, Section 4).

The LBL Astrophysics Group has been instrumental in the development and integration of the Differential Microwave Radiometer installed on the Cosmic Background Explorer (COBE). The satellite was the first instrument to detect intrinsic anisotropies in the cosmic microwave background. Data collection and analysis is continuing, to improve statistics and to refine our understanding of the early universe. These measurements will shed light on the later development of large-scale structures.

National Institutes of Health

The success of DOE life sciences and environmental sciences program at LBL has depended not only on DOE support but also on complementary NIH-supported research that is closely coupled to these programs. Several critical technologies recently identified as being of high priority for advancement by NIH, specifically molecular medicine, biotechnology, and struc-



The LBL Astrophysics Group is shown (top) with a predecessor radiometer to that aboard the COBE satellite. The discovery of intrinsic anisotropies in the cosmic microwave background as shown in the all-sky map (bottom) is a major contribution to cosmology.

tural biology, are all major components of the life sciences program at LBL. These technologies build on the unique facilities and expertise available at LBL, and point toward a growing interaction of DOE and NIH-funded research in pursuing new goals in biology and medicine.

Programs sponsored by NIH include research on medical applications of heavy ions and the treatment of cancer. NIH also supports programs on radionuclides, NMR, diagnostic image reconstruction, and radiopharmaceuticals related to advanced instrumentation. Other major NIH-funded programs involve lipoproteins and their relationship to cardiovascular disease and the intracellular molecular structure of DNA and sickle hemoglobin.

NIH applies LBL's unique resources to investigations of the human genome and in carcinogenesis and mutagenesis. Repair and recombination in yeast and the genetic effect of carcinogens will continue to be major foci. Biological structure analysis by electron-crystallographic methods characterizes cell-membrane proteins and viruses. Cell nuclei are studied by circular dichroism and related techniques. The Laboratory's capability in culturing human mammary epithelial cells is used to study breast cancer.

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

Other Agencies/State and Private

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

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

LBL's expertise in buildings is recognized by the California Energy Commission and the energy utilities. Much of the support is through the California Institute for Energy Efficiency. Projects include the study of efficient systems for thermal distribution in buildings, advanced envelope and lighting technologies, and end-use technology performance data. Southern California Edison supports window studies; Pacific Gas and Electric Company supports a study of end-use energy intensifiers in commercial and residential buildings; and the Sacramento Municipal Utilities District (SMUD) supports energy-savings studies of shade trees and other surfaces.

The LBL-designed Keck 10-m telescope, the world's largest optical instrument, is nearing completion. LBL anticipates funding from UC Santa Cruz/Lick Observatory to perform work in support of the equally large companion Keck II. In the life sciences, research on human lipoprotein function and genetics is supported by the National Dairy Research Board through Children's Hospital in Oakland. The UC California Tobacco Research Institute supports research on carcinogenesis. The California Competitive Technology Program is supporting several LBL-industry collaborative R&D projects in the Center for Advanced Materials, including high-temperature thin-film superconducting device development and self-assembling thin-film sensors.

LABORATORY DIRECTED RESEARCH AND DEVELOPMENT

The Laboratory Directed Research and Development (LDRD) Program was established in 1984 following the issuance of DOE guidance to allocate a portion of LBL's operating budget to explore innovative research opportunities. These allocations are subject to the approval of DOE.

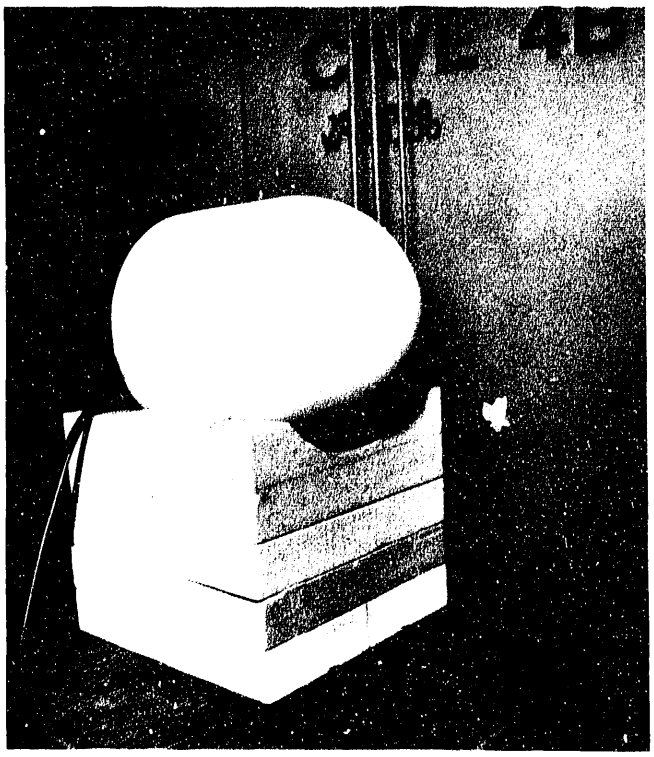
Laboratory Directed Research and Development Program

Category	FY 1989 Actual	FY 1990 Actual	FY 1991 Actual	FY 1992 Projected
Funding ($M)	[illegible]	4.2	3.5	4.9
Projects Approved	46	51	26	46

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

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

Recent achievements sponsored by the LDRD program include novel x-ray crystallographic studies of RNA, analysis of a cell cycle regulatory gene, exploration of the interface between homogeneous and heterogeneous catalysis, studies of ultrafast dynamics of electrons at interfaces, work on flow-pump-probe x-ray absorption and emission, new approaches to assessing oceans as CO2 sinks, development of neutron dose detector, processing of semiconductor materials under high hydrostatic pressure, studies in use of non-toxic precursors in wide-gap II–VI compounds, new understanding of fullerene solids and clusters, new concepts for isospin studies, laser trapping of neutral atoms and research in Si microstrip disk detectors. An *Annual Report on the LBL Laboratory Directed Research and Development Program* is available from the Office for Planning and Development. Annual planning documents are prepared that indicate program directions and projected resources.



The LDRD program is funding the development of new methods for crystallizing RNA and determining the crystal structure. The picture (top) is an x-ray diffraction pattern from crystals of an RNA oligonucleotide. The hexagonal symmetry within the crystal is apparent in the diffraction pattern. LDRD is also funding theoretical studies and concept prototyping for an advanced neutron dose detector (right) with an unprecedented rem response to 1 GeV. Testing is being done using the unique capabilities of the LBL accelerators.

6 ENVIRONMENT, SAFETY, AND HEALTH MANAGEMENT

ES&H GOALS AND OBJECTIVES

As indicated in the Mission Statement, it is the policy of the Lawrence Berkeley Laboratory to integrate environment, safety, and health (ES&H) performance in the conduct of all of its operations to ensure employee and public safety and the protection of the environment. The Laboratory has developed institutional ES&H goals to guide its integrated ES&H program. The ES&H goals are to:

- Develop new, innovative strategies for effective management of environment, safety, and health activities;
- Identify and reduce risks to the environment and to the safety and health of employees and the public;
- Integrate and implement ES&H plans and programs through line management activities;
- Deliver ES&H services in full regulatory compliance with a highly qualified staff;
- Involve and train all employees in strengthening ES&H performance and programs; and
- Achieve an overall reduction in the generation of solid, hazardous, radioactive, and mixed waste.

Underlying these goals is a commitment to ES&H performance through quality management of the Laboratory's programs and in its conduct of operations. LBL's current efforts respond directly to its Corrective Action Plan for Tiger Team Assessment. The Laboratory has also developed a new Safety and Health (S&H) five-year plan and is developing implementation programs for DOE Environmental Restoration and Waste Management five-year plan. These efforts include a renewed commitment to ES&H through an effective Corrective Action Plan.

The Laboratory's ES&H performance indicators are utilized to improve performance and institute a more quantitative framework for LBL's ES&H trends and activities. For employee health and safety, representative indicators include the absolute number and rate of injuries (i.e., frequency) and the number of workdays lost and rate of workdays lost (i.e., severity rate). The Laboratory seeks to establish trends of continuing improvement in ES&H performance for FY 1993 compared with performance in recent years.

Environmental indicators include improving waste management operations and waste minimization, with the goal of managing waste disposal more effectively and efficiently, including significantly reducing the total amount of hazardous waste generated for FY 1993. Waste minimization indicators include the percent of Laboratory office waste recycled and the total number of solid, hazardous, and radioactive waste streams recycled. In addition, the Laboratory is eliminating any excess discharge of heavy metals or toxic chemicals to the sewer system, with no exceedances of standards as the Laboratory's goal.

To facilitate management performance, the Laboratory is developing improved standards for individual employee ES&H responsibility, calling for formally defined responsibilities for each employee as a goal (100 percent confirmed level for 1993). The Laboratory also has the goal of providing OSHA-trained expertise in each division. The Laboratory recognizes that quantitative performance indicators vary due to many conditions, including changes in both the type of operations, external conditions, and employee and management performance.

ES&H Performance Indicators

Indicator	1987	1988	1989	1990	1991	1992 (Projected)
Injuries	62	50	75	78	101	85
Injury Rate[a]	2.6	2.0	3.1	3.2	4.0	3.4
Lost Workdays[b]	592	442	295	810	1409	1693
Lost Workday Rate[a]	25	18	11.1	33	55.7	67
Division OSHA Training (%)[c]	0	0	0	0	66	100
Office Waste Recycled (%)[d]	n.d.	n.d.	n.d.	n.d.	80	82
Recycled Waste Streams[e]	n.d.	n.d.	n.d.	23	26	35
ES&H Responsibilities[f]	5	5	5	5	8	12

[a]Rate is expressed as number per 100 FTEs, approximately 200,000 person hours of work.
[b]System and comprehensiveness of tracking has undergone improvement in recent years.
[c]Percent of divisions with OSHA trained safety staff (estimated).
[d]Percent of employees with defined ES&H responsibilities (estimated).
[e]Number of solid hazardous, and radioactive waste streams recycled; n.d. = not determined.
[f]Percent of LBL employees with defined ES&H responsibilities (estimated).

This Environment, Safety, and Health Management section provides a framework for identifying and integrating long-range programmatic activities with ES&H resource plans. The following sections identify current ES&H operating conditions and trends, management arrangements, and management strategies and initiatives. This framework supports the Office of Energy Research efforts to effectively plan and assess safety and health support, facilities infrastructure needs, and long-range environmental compliance programs, such as National Environmental Policy Act (NEPA) compliance and site restoration programs.

CURRENT CONDITIONS

Programmatic Directions and Potential Hazards

As indicated in Section 5, LBL's scientific and technical programs primarily support DOE's Office of Energy Research (62%). The multiprogram character includes programs in Basic Energy Sciences, Nuclear Physics, High Energy Physics, and Health and Environmental Research. Conservation and Renewable Energy (6%) supports studies in building energy conservation, energy storage, and solar and geothermal energy. Other DOE-sponsored programs (16%) include research supported by the Superconducting Super Collider Laboratory (SSCL), Civilian Radioactive Waste Management, and Fossil Energy. Work for other agencies and institutions (16%) is primarily for the National Institutes of Health (NIH), Department of Defense (DOD), states, and private industry.

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

LBL monitors the air, groundwater, and effluents for both radiation and chemical sources and discharges. Radiological operations include particle accelerators, gamma irradiators, laboratories conducting research using radionuclides and radiopharmaceuticals, and the National Tritium Labeling Facility. Nonradiological sources and discharges include chemicals from research operations, fabrication shops, automotive shops, paint shops, water treatment facilities, and the Hazardous Waste Handling Facility. Current trends in Laboratory activity indicate environmental and safety hazards that must be accommodated:

- ***Chemistry and Materials Research.*** Programs in materials and chemical research, including new hazardous materials management requirements, create demands on many ES&H programs. Examples include managing chemical acquisition and inventories, chemical monitoring systems, fume hood monitoring, laser safety training, respiratory protection programs, and hazards communications.

- ***Biological Research.*** LBL biological research programs have grown recently. LBL's biological hazards control program continues to be expanded. Biological research programs often utilize radiolabeled materials, and the delivery of low-level radioisotopes has increased in the last few years. The radioactive and mixed wastes derived from these operations present a special challenge because of the restrictions on their disposal.
- ***Construction.*** LBL's construction activity has increased during the past decade, resulting in potential additional accident risk. ES&H oversight for construction contractors and tradespersons has become increasingly important, including, but not limited to, the need to ensure the stability of excavations and management of drainage systems.
- ***Nuclear Physics and Nuclear Chemistry.*** The nuclear physics experimental programs at the Bevalac will be curtailed in FY 1993. The SuperHILAC no longer has an independent experimental program. The 88-Inch Cyclotron anticipates expanded research with the Gammasphere detector and supports a more diversified scientific program.
- ***Radiobiology Experimental Programs.*** Some experimental radiobiology programs may be reduced if the Bevalac closes, although the Civil Space Mission may continue the biological experimental programs.

Increasing resources are being provided to serve research program areas with potential hazards, such as those employing toxic chemicals, lasers, new x-ray sources and beamlines, and radiolabeled compounds. New resources are being allocated to meet demands on ES&H field staff. Space for staff and equipment must be provided to meet service demands and logistics needs. Reporting functions are being formalized to optimize use of staff. Automated systems to track chemicals from procurement to disposal are under development.

Response to Regulatory Requirements

LBL ES&H polices and procedures are being developed to fully comply with existing, proposed, and anticipated DOE Orders, Federal laws and regulations, and applicable state and local regulations. For maintaining and improving air quality, LBL addresses requirements of the Federal Clean Air Act and the California Air Resources Act and obtains permits consistent with EPA policies and those of the Bay Area Air Quality Management District, including NESHAPS. The Laboratory conducts its operations and monitors its effluents consistent with its National Pollution Discharge Elimination System (NPDES) permit. For protecting surface water and groundwater, LBL conducts programs consistent with the Federal Clean Water Act, the Safe Drinking Water Act, and the California Oil Pollution Control Act. In addition, the Laboratory complies with the requirements of the California Porter-Cologne Water Quality Act, including programs permitted through the San Francisco Bay Regional Water Quality Control Board and the East Bay Municipal Utility District. LBL further protects and monitors the environment from radiation releases as directed by the Atomic Energy Act and monitors wastes through compliance with the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

In addition, LBL policies, procedures, and operations must fully comply with the Toxic Substances Control Act and the Federal Insecticide, Fungi-

cide and Rodenticide Act to control the storage and disposal of hazardous materials, including polychlorinated biphenyls. Consistent with the Hazardous Materials Transportation Act, LBL provides complete manifests for shipped wastes and packages and labels materials to comply with Department of Transportation Regulations.

LBL safety and health programs also address requirements of the Occupational Safety and Health Act (OSHA), DOE Orders, and a broad range of industry standards on occupational protection. The Laboratory's Conduct of Operations and QA plans are addressing appropriate guidelines of new DOE Orders. Quality assurance for planning, monitoring, testing, controlling, and reporting is being directed to meet the objectives of DOE General Design Criteria, reporting, and environmental protection and safety standards, as well as methods for analysis established by the Environmental Protection Agency.

LBL projects and new proposals are reviewed for conformance with the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA), including the goals to protect the environment and provide safe and healthful surroundings. The Laboratory provides environmental reviews and classifications and performs assessments consistent with NEPA and CEQA guidelines. The Laboratory incorporates procedures and documentation responsive to the Endangered Species Act, the Federal Fish and Wildlife Coordination Act, and the National Historic Preservation Act. These programs are directed toward DOE NEPA orders and the Secretary of Energy Notice (SEN-15) concerning the National Environmental Policy Act. LBL cooperates with the State of California Resources Agency, including the Department of Fish and Game, to identify and protect threatened or endangered species.

LBL also coordinates ES&H activities with the cities of Oakland and Berkeley, including environmental activities and mutual-aid fire-protection programs and traffic management. Examples of this coordination include (1) a hill-area fire-safety program with the University and Berkeley fire departments, (2) an LBL traffic and parking management plan to discourage single-occupant vehicles, (3) a preservation program for historic buildings, (4) a compliance program to provide the City of Berkeley with a Hazardous Material Inventory, and (5) a monitoring program for underground storage tanks. The Laboratory's construction program and facilities planning are conducted within the framework of a Long Range Development Plan approved by The Regents of the University of California and plans approved by the Department of Energy.

Recent Accomplishments

The Laboratory is currently undertaking institution-wide efforts to enhance safety and protect the environment. Examples of these efforts in FY 1991 serve to highlight the steps the Laboratory is taking to develop a meritorious ES&H program:

- LBL has initiated a NEPA/CEQA recommendation tracking system to aid management of the NEPA and CEQA compliance program. In addition, all Field Task Proposals, WFO, and construction projects submitted for the FY 1994 budget include initial review information for NEPA/CEQA status recommendations consistent with LBL's compliance program.
- LBL has served as a leading Laboratory in the development of a risk-based prioritization system for the development of 5-year S&H plans.

LBL is serving as a testbed for prioritization plans and has led workshops for contractor and field personnel.

- Comprehensive cleanup of laboratories and support facilities resulted in recycling of more than 727,000 pounds of metals and other materials to the local salvage industry, more than double the previous year's average. In addition, LBL has instituted a comprehensive recycling program in which all the Laboratory's nonhazardous waste is sorted for recycling, resulting in 80% of the waste being recycled and only 20% going to landfills. In addition, LBL has reduced its landfill cafeteria waste by two-thirds.
- Advances in high-voltage safety in electrophoresis have been made through special power supplies, shielded connectors, ground fault interrupters, and interlocks. These advances, recognized as a noteworthy practice by the 1991 Tiger Team, are being transferred to manufacturers.
- Chlorofluorocarbon recycling equipment has been acquired that allows for repair and reclamation of refrigeration equipment without freon releases. Special protective suits and gas monitoring equipment have been acquired, and procedures for confined space entry and lockout tagout have been upgraded.
- Comprehensive fire and electrical inspections have been implemented. As a result, a number of changes, such as additional fire doors, better fire alarms, and improvements in the type and availability of fire extinguishers have been made as initial steps in a program to upgrade fire and electrical safety.
- Materials Safety Data Sheets, other hazard information, and chemical inventory data are being made accessible to LBL's distributed computer network, enabling this important information to be readily available across the LBL site.

These examples are indicative of the developing momentum that is strengthening LBL's ES&H performance and compliance. A broad range of changes are now being advanced, as indicated in the Management Strategies and ES&H Planning Initiatives sections below.

ES&H ORGANIZATION AND MANAGEMENT

DOE, the University of California, and the Lawrence Berkeley Laboratory are strengthening policies and resources to address DOE Secretarial ES&H initiatives. The DOE Office of Energy Research (ER) has landlord responsibility for LBL that is carried out by the High Energy and Nuclear Physics program. ER Headquarters provides oversight and direction through its line programs and has established the Office of Assessment and Support, a staff organization with ES&H expertise to assist ER line programs. DOE/SF conducts oversight and communicates programmatic, budgetary, and scheduling guidance for ES&H activities at LBL. Lead responsibility for implementation of DOE/SF's ES&H activities at LBL lies with the Assistant Manager for Energy Programs, who also serves as Site Manager at LBL.

LBL addresses ES&H planning and operating requirements, including the implementation of DOE Orders, guidelines, and applicable Federal, state, and local ordinances through defined lines of management responsibility.

The Regents of the University of California, through the Office of the President, are responsible for corporate policy and contract approval. Within the Office of the President, the Office of the Senior Vice President for Administration has corporate support offices for Long Range Development and Environmental Planning, Hazardous Materials Planning, Environmental Health and Safety, and Environmental Planning for compliance with CEQA regulations. The Health, Safety and Environment Advisory Committee (HSEAC) was established by the President of the University to oversee the goals, plans, and ES&H performance of the UC-operated DOE laboratories. The Senior Vice President for Academic Affairs and the Special Assistant for Laboratory Affairs provide program management support for Laboratory activities and work closely with HSEAC and the administrative units of the University. In recognition of the strengthened requirements for University oversight of ES&H activities at its laboratories, the responsibilities of the Senior Vice President for Administration are being expanded. A new office to carry out specific oversight activities for ES&H and a new President's Council on the National Laboratories will be established.

The LBL Director is responsible for the establishment and administration of LBL ES&H policies. The Director is accountable for the ES&H requirements placed upon the University of California as a consequence of its management contract with DOE. The Director has assigned responsibilities and authorities necessary to implement and oversee the Laboratory's policies regarding ES&H to Associate Laboratory Directors and Division Directors.

Management policies, procedures, and responsibilities for supervisors and employees are formally communicated in the *Regulations and Procedures Manual* (PUB-201) and the *Health and Safety Manual* (PUB-3000), and separate technical documents and safety procedures address specific operations. The Occupational Safety Department is leading the major effort to rewrite the Laboratory's *Health and Safety Manual* to incorporate all new safety policies. Applicable rules and procedures extend to all Laboratory operations. It is the responsibility of supervisors to ensure that employees are familiar with these publications and to apply the rules and regulations in planning and carrying out their work. Compliance with ES&H policies and procedures is implemented, enforced, and ensured through line organization and support and control organizations:

- **Division Directors** are responsible for ensuring that the Laboratory's environmental, safety, health, and emergency preparedness policies are followed by employees within their own divisions.
- The **Associate Laboratory Director (ALD) for Operations** is responsible for the oversight and management of the technical support resources at the Laboratory, including ES&H operational support resources, and provides corrective action, self-assessment reporting, and quality assurance to ensure that the environmental, health, and safety management systems and procedures of the Laboratory are implemented by the divisions.
- The **Director of the Environment, Health & Safety (EH&S) Division** is responsible for supporting and enforcing the implementation of Laboratory-wide environmental, safety, and health programs. The Division provides technical support and technical audits to division operating programs for compliance with applicable ES&H standards.
- The **Associate Laboratory Director of the Office for Planning and Development** integrates ES&H plans in LBL site-wide planning pro-

cesses, including the Institutional Plan and Site Development Plan, and manages NEPA and CEQA procedures for LBL plans and proposed programs.

MANAGEMENT STRATEGIES

LBL has developed focused strategies directed toward improving underlying ES&H problems and issues. These strategies are part of the Corrective Action Plan to institutionalize ES&H throughout the Laboratory, build ES&H resources for compliance with the underlying regulatory framework, and strengthen the relationship between DOE and LBL.

- ***Develop and Implement ES&H Management Framework.*** Management goals and objectives for addressing LBL's ES&H needs must be well-defined and indicate the Laboratory's commitment. LBL is establishing goals and criteria for successful ES&H management, defining management responsibilities, providing a well-understood system for prioritizing needs, and using these priorities in allocating resources in the framework of long-range ES&H planning.
- ***Formalize ES&H Roles, Responsibilities, and Accountability.*** At every working level LBL is implementing policies to ensure that all employees know what is expected of them. LBL managers will be evaluated on how well they implement ES&H policies. A careful reassessment of organizational roles and responsibilities is being performed to eliminate unnecessary duplication of function, to clarify expectations, and to make sure that no important functions are omitted.
- ***Strengthen the Central ES&H Organization.*** Closely related to the development of an improved ES&H management strategy is an enhancement of the resources available to LBL's ES&H organization. Increased resources, both in terms of numbers of qualified ES&H personnel (45 FTEs hired in FY 1992), the range of expertise available, and adequate space and equipment, will be essential to correct existing deficiencies and to maintain levels of compliance.
- ***Comprehensive ES&H Training and Communication.*** More centralized responsibility will be established for coordination of LBL's training activities; existing training activities will be defined and described. The training program will reach all levels of the Laboratory, provide effective targeted material for the different job classifications, and include follow-ups to assess the effectiveness of the training.
- ***Augment Management Systems.*** Existing management systems will be augmented to respond effectively to ES&H needs. ES&H needs will be explicitly included in all LBL long-range planning and programmatic budget-planning processes, and prioritization methodologies are under development to ensure that resources are applied to activities of greatest importance.
- ***Multi-Level Self-Assessment Program.*** A rigorous self-assessment program is the responsibility of the Laboratory and its Divisions. The program is being developed in accordance with the Office of Energy Research Self-Assessment Program plan. LBL's program will serve as an important resource needed to address root causes. Self-assessment is a cornerstone of LBL's efforts to sustain high levels of ES&H performance.

- ***Strengthen interactions with DOE.*** LBL and DOE have implemented an action plan to strengthen programmatic resources for ES&H, clarify ER management responsibilities, define lines of communication among ER and DOE field offices and LBL, and institutionalize appropriate DOE-SF oversight roles in ES&H-related activities at LBL.

Examples of how LBL management strategies have already been applied are:

- The EH&S Division has increased its staff by approximately 30% in FY 1992. This planned increase was implemented to adequately respond to ES&H requirements identified in the 1991 Tiger Team Assessment and in ongoing LBL self-assessments. The high-quality personnel were recruited from within the Laboratory and from the outside corporate community. The new EH&S Division staff represents a wide spectrum of ethnic and social backgrounds and brings a new vitality in addressing the ES&H needs of the Laboratory.
- Two new EH&S Division student programs were initiated in the summer of FY 1991. Thirteen students worked from June to September and were mentored by EH&S Division scientists and engineers. The students were encouraged to attend training in health and safety, government compliance requirements, administrative methods, and computer science. At the end of the summer session, scientific and engineering mentors formally evaluated each student's training and contributions to the EH&S Division projects and programs.
- Pursuant to OSHA's new Bloodborne Pathogen Standard, the Industrial Hygiene Department is implementing a new Blood Safety Program at LBL. The Standard requires that LBL identify and train all workers who could potentially be exposed to blood and "other potentially infectious materials" while carrying out their assigned job duties. EH&S personnel training is under way, and researcher training will begin in the late summer of 1992. Other program elements include a written Exposure Plan, a Hepatitis-B Vaccination Program, and implementation of control measures and procedures.
- A Confined Spaces Safety Program has been designed, written, and implemented in response to a Category II requirement of the Tiger Team Corrective Action Plan. It is intended to increase awareness of and safety conduct in the Laboratory's confined spaces. The Industrial Hygiene Department is training LBL staff in the recognition of confined spaces, their hazards, permitting procedures, protective equipment and ventilation, and atmospheric testing techniques.
- An Asbestos Management Program is scheduled for publication in the fall of 1992. Designed to address all aspects of asbestos hazard control, the Plan will include training requirements, hazard identification protocols, air and bulk sampling criteria, contractor specifications for asbestos removal, and specifications for use by construction and Maintenance Department personnel to safely maintain the condition of asbestos-containing building materials.
- The Respiratory Protection Program was completed and implemented in February 1992. It establishes procedures and requirements necessary to meet Federal OSHA and ANSI regulations for the use of respiratory protection equipment. The Respiratory Protection Program includes guidelines for training, selection and fitting, and safe use and maintenance of Respiration Protection Equipment.

ES&H PLANNING INITIATIVES

To promote integration of strategic and program planning, the Laboratory maintains a Comprehensive Planning Calendar that defines annual planning requirements and provides a schedule that identifies necessary information exchange and preparation responsibilities. This process defines the responsibilities and information requirements intended to promote the integration of environmental, safety, and health concerns into institutional and program planning elements. Specific working groups strengthen communication, although each planning activity and product is the responsibility of individuals held accountable for the quality and accuracy of the plans. Examples of planning products include those for program plans and for ES&H support functions:

- ***ES&H planning and initiatives.*** The Environment, Health & Safety Division has realigned its mission with the broader mission of the Laboratory. As a service organization, the principal purpose of the Division is to respond to the needs of the Laboratory community. To this end, the EH&S Division effectively manages environment, health, and safety in a way that minimizes interference with new or ongoing scientific research. Creating value for the economy and contributing to the community through partnerships with industry is another part of the Laboratory mission. The EH&S Division is developing creative solutions for environment, safety, and health problems that can be transferred into the private sector for broader application.
- ***ES&H management and operations planning.*** LBL manages and coordinates its ES&H programs through strategic plans that define activities, source needs, staffing, and regulating responsibilities. These plans include, as examples, the Tiger Team Assessment Corrective Action Plan, the Safety and Health Five-Year Plan, the Self-Assessment Implementation Plan, NEPA programs planning, and waste minimization plans (see below). In addition, other examples are the Environmental Protection Implementation Plan, the Environmental Monitoring Plan, and the Groundwater Protection Management Plan.
- ***LBL emergency preparedness and response planning*** includes maintaining and updating a Master Emergency Plan, Building and Facility Emergency Plans, and individual equipment emergency plans. LBL is revising and strengthening these plans and implementation programs to ensure that resources and trained staff are available to address all credible emergencies.
- ***Research program planning.*** As an example of these plans, early in the formulation of the Induction Linac Systems Experiments (see Section 4), the underlying ES&H criteria for this facility were established, as documented in a Conceptual Design Report. The safety systems and procedures for this facility are being designed to meet all standards for the expected occupancy. Safety management operations are integrated with program plans and are included in cost estimates. NEPA tracking and the requirements for Operational Safety Procedures were also planned from the outset. As a second example, during the formulation of the Human Genome Laboratory, the underlying criteria for this facility were established, as documented in a Conceptual

Design Report. The safety systems were identified to meet all standards for the expected occupancy. NEPA tracking was also provided at the outset.

- ***Multiprogram Energy Laboratory Facilities Support program planning.*** L3L's objectives for the MEL-FS program are primarily directed toward ES&H needs, and the strategic elements of this program are set forth in Section 9. The process and justification, including Corrective Action Plan needs in response to Tiger Team Assessment, are developed in integrated and systematic procedures identified in the Comprehensive Planning Calendar and documented through ES&H criteria identified in DOE's Capital Asset Management Program. General Plant Projects and General Purpose Equipment planning are also integrated with ES&H needs (see also Section 9).
- ***Site development planning.*** The Site Development Plan integrates ES&H objectives and needs in all facilities-related programmatic building support projects. Site planning goals, existing conditions, and planning analysis integrate ES&H planning information, including NEPA/CEQA environmental documentation. Specific references are made to environmental monitoring, environmental impact studies, and the health and safety of facilities. To provide adequate ES&H support facilities, two general-purpose building initiatives are proposed within the period covered by this plan. Current Laboratory support service facilities are inadequate and inefficient because of obsolete design and substandard construction.

Corrective Action Plan

LBL's Tiger Team Assessment Corrective Action Plan, completed in September 1991, addresses the findings and concerns of the Tiger Team as well as the 1989 Technical Safety Appraisal. The Laboratory and DOE-SF developed 409 tasks with subsidiary milestones to correct the findings and concerns and eliminate the underlying root causes. These root causes addressed the need for:

- Greater formality of operations and effective verification of the accomplishment of environmental, safety, and health requirements,
- More effectively addressing the challenge of the demands of ES&H and the urgency of incorporating these demands into LBL operations; and
- Providing DOE program direction and oversight that places adequate emphasis on environmental, safety, and health requirements.

LBL has already closed out 60% of the OSHA findings and has fully corrected the Category II concerns or reduced them to lower levels. However, addressing all the root causes, concerns, and findings will require complete implementation of the Corrective Action Plan, which will require additional resources from the Office of Energy Research and the Office of Environmental Restoration and Waste Management. LBL is allocating significant new resources to the Corrective Action Plan, and ER support is essential to maintain the momentum that has characterized LBL's staff commitment to ES&H.

ES&H Program and Corrective Action Plan Resource Requirements ($K)

Category	1991	1992	1993	1994	1995	1996	1997	1998
Corrective Action Plan								
Office of Energy Research								
Operating	0.5	1.9	1.7	1.7	1.7	1.7	1.7	1.7
GPP	0.1	0.7	1.3	1.2	1.1	1.0	1.0	1.0
GPE	0.1	0.6	0.7	0.5	0.5	0.5	0.5	0.5
MEL-FS	1.3	1.3	0.8	4.2	5.9	4.0	0.0	0.0
ERWM	3.2	2.5	2.2	0.9	0.9	0.8	0.8	0.8
Laboratory Overhead	2.3	7.4	6.9	6.2	5.9	6.2	6.2	6.2
Total Corrective Action Plan	6.7	14.4	13.5	14.7	16.0	14.2	10.2	10.2

Safety and Health Five-Year Plan

The Laboratory has developed a prioritized five-year plan for Safety and Health Activities that includes the existing core program of safety and health services and activities, additional core support, and specific projects needed to fully meet all LBL and DOE safety and health goals. LBL planning has contributed to the development of the ER prioritization system to allocate and rank necessary activities based on quantitative risk reduction criteria.

LBL planning projections indicate that budgeted resources, including those indicated in the resource projections (Section 10), will not be sufficient to implement all elements of the planned program without further research program growth or curtailment of other essential Laboratory services. In response to requirements of the Corrective Action Plan and to emphasize safety and health issues, LBL has increased its core safety and health programs by 30 FTEs in FY 1991–1992 and proposes an increase of approximately 30 FTEs by 1997. Increases in capital resources included in Section 9 and in noncapital resources are also planned. LBL proposes that environmental protection activities outside the scope of the EM Five-Year Plan be included in subsequent ER guidance for five-year plans.

Five-Year Plan Projections

Category	1992	1993	1994	1995	1996	1997	1998
Operating	13.9	15.7	17.3	18.2	19.2	19.9	20.4

Self-Assessment Plan

LBL has developed a Self-Assessment Program Implementation Plan that provides a formal process for assuring quality and regulatory compliance in all facets of Laboratory operations. It is a continual process of information gathering to determine whether the procedures designed to achieve quality performance are being followed adequately and, if not, what corrective

actions are appropriate to take. It ensures accountability, enables trend analyses, and improves communication of ES&H information.

In the LBL program, each division and office is responsible for implementing its individual program, with oversight provided by the Environment, Health & Safety Division and the Office of Assessment and Assurance (OAA), respectively. Divisions/Offices conduct self-appraisals annually to evaluate their performance in following ES&H, quality assurance, conduct of operations, and other procedures. The EH&S Division conducts triennial functional appraisals of Division/Office compliance with ES&H procedures. The OAA conducts triennial internal appraisals of selective line management activities to evaluate the effectiveness of Divisions/Offices in ensuring that ES&H, quality assurance, conduct of operations, and other program goals are being met. Other important elements of the Self-Assessment Program are: (1) development of Performance Objectives and Criteria; (2) analysis of Root Causes and Trends; (3) follow-up of Corrective Actions; and (4) training of Appraisal Teams. The LBL Self-Assessment Program Implementation Plan will be reviewed and approved by DOE.

Waste Minimization Plan

LBL's waste minimization program is an organized, comprehensive, and continual effort to systematically reduce hazardous, radioactive, and mixed waste generation. The DOE Waste Minimization and Pollution Prevention Awareness Program and SB14 HazWaste Source Reduction and Management Review are designed to eliminate or minimize pollutant releases to all environmental media from all aspects of the site's operations. These efforts offer increased protection of public health and the environment. They will yield the following additional benefits:

- reduce waste management and compliance costs
- reduce resource usage
- reduce or eliminate inventories and releases of hazardous chemicals
- reduce or eliminate civil and criminal liabilities under environmental laws

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

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

Category	1993	1994	1995	1996	1997	1998	Total
Operating	0.3	0.5	0.5	0.8	0.6	0.6	3.2
Equipment	0.0	0.0	0.3	0.0	0.0	0.0	0.4

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

National Environmental Policy Act Planning

The Laboratory has undertaken a program to achieve full compliance with the National Environmental Policy Act and the California Environmental Quality Act. The Laboratory has prepared draft *Guidelines for Compliance with the National Environmental Policy Act and the California Environmental Quality Act.* The guidance contains specific processes and procedures for LBL scientists and managers to ensure compliance and to prepare documents and recommendations to DOE and to the University of California, Office of the President (UCOP). LBL works closely with the DOE Headquarters and Field Office, including the DOE Compliance Officer in the development, review, implementation, and finalizing of proposed guidelines and rules.

LBL's general plan of action for projects includes preparation of an environment and safety review for projects such as Field Task Proposals and capital projects two years prior to funding. Principal investigators prepare initial information, which is reviewed at divisional levels. Final environmental review and recommendations to DOE and COP are prepared in the Office of Planning and Analysis. The environmental review information is also submitted to DOE in the budget documents, including Field Task Proposals and Construction Project Data Sheets.

During 1992 two NEPA Environmental Assessments were under development: the proposed Hazardous Waste Handling Facility and the Mini-Cyclotron – Biomedical Isotope Facility. The Laboratory also prepared a Draft Supplemental Environmental Impact Report for the proposed renewal of the operating contract between the DOE and the University of California. The Laboratory has instituted procedures and mechanisms, summarized above, to ensure that all proposed actions, such as Work for Others, Plant Engineering projects, and Field Task Proposals receive timely NEPA and CEQA evaluations.

Environmental Monitoring and Industrial Hygiene Building

To provide adequate space for environmental monitoring laboratories and offices, industrial hygiene offices and laboratories, and ES&H training facilities, LBL requires a new ES&H support facility, the Environmental Monitoring and Industrial Hygiene Building. This building responds to numerous and wide-ranging deficiencies in resources for ES&H functions at the Laboratory identified by the TSA and Tiger Team and is included in the Corrective Action Plan (above). Many of these deficiencies relate to the lack of space, insufficient centralized resources, and inadequate staff. As indicated in the LBL Tiger Team Assessment Corrective Action Plan, LBL must double its ES&H staff to meet minimum standards of performance. LBL was found to have inadequate training facilities, ES&H sampling and monitoring laboratories, and office space. The Environmental Monitoring and Industrial Hygiene Building is the centerpiece of LBL's program to provide the necessary resources for an effective ES&H organization that meets compliance needs.

Environmental Monitoring and Industrial Hygiene Building
Resource Requirements ($M)[a]

Category	1993	1994	1995	1996	1997	1998	Total
Operating	0.2	0.1	0.0	0.0	0.0	0.0	0.3
Construction	0.0	1.5	0.5	15.0	3.0	0.0	20.0

[a] Estimate of actual-year LBL Budgetary Authority.

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

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

The Laboratory's systematic and prioritized input to the EM Five-Year Plan supports DOE's national environmental restoration and waste management goals. The plan responds to specific environmental conditions at the Laboratory and includes facilities and operating programs for managing those conditions to maintain air quality, surface water quality, and groundwater quality. The plan is focused on three Environmental Management (EM) programs for restoration and management activities:

- ***Environmental Restoration.*** Assessment, characterization, and remediation of chemical contamination of soils and groundwater and the closure of the existing LBL Hazardous Waste Handling Facility and the decommissioning of the Bevalac facility.
- ***Corrective Activities.*** Corrective actions to achieve compliance with environmental regulations that protect soils, groundwater, and air and also prevent chemical discharges to sewers. Essential corrections are to laboratory ventilation systems, deionization systems, sanitary sewer systems, chemical storage tanks, and wastewater treatment units.
- ***Waste Management.*** Waste Management's program for continuity of hazardous and radioactive waste handling operations, disposal, waste minimization, planning, and the management of the construction of a new Hazardous Waste Handling Facility. Additional funding of waste management operations will be necessary to meet mandatory program requirements.

EM's Five-Year Plan is vital for compliance with DOE and other Federal regulations and for meeting requirements established by state and local agencies. The program has been developed in conjunction with DOE, state, and Federal reviews. The resource projections below and in Section 10 reflect existing guidance in Activity Data Sheets. These resources do not include additional corrective action planning requirements, maintenance projects, and other upgrades funded through LBL institutional resources. The resources also do not include the cost for decommissioning the Bevalac, following acceptance by EM, as described in Section 9.

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

Category	1992	1993	1994	1995	1996	1997	1998
Environmental Restoration							
Operating	4.3	2.7	5.7	6.6	5.1	2.7	2.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line Items	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.3	2.7	5.7	6.6	5.1	2.7	2.6
EM Corrective Action							
Operating	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0
GPP	4.2	0.0	0.7	0.0	0.0	0.0	0.0
Line Items	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.0	0.0	0.7	0.0	0.0	0.0	0.0
Waste Management							
Operating	6.8	7.3	9.9	9.8	10.4	11.3	11.7
Capital Equipment	0.0	0.1	1.2	0.8	0.1	0.5	0.6
GPP	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Line Items	1.6	0.0	5.8	0.0	0.0	0.0	0.0
Total	8.4	7.9	16.9	10.6	10.5	11.8	12.3
Total EM Funding	17.7	10.6	23.3	17.2	15.6	14.5	14.9

[a] Actual-year LBL Budgetary Authority as provided in the EM Five-Year Plan.

7 TECHNOLOGY TRANSFER AND EDUCATION

In support of national strategic goals to strengthen science education and technology transfer, LBL is expanding its education, training, and technology transfer activities as part of the Laboratory's mission. The following sections provide an overview and examples of the LBL efforts and plans in these areas.

TECHNOLOGY TRANSFER

LBL has developed a technology transfer program to support the development and use of LBL technology by industry and to strengthen the value of the Laboratory's research programs for the nation. The following section describes the goals and objectives of LBL's technology transfer activities, cooperative research, and technology transfer program achievements.

Technology Transfer Planning

To fulfill the Laboratory's mission, LBL's Technology Transfer program has the long-term objectives to:

- Develop technology research programs and Cooperative Research and Development Agreements (CRADAs) involving U.S. industry for long-term advancement of energy research and national competitiveness;
- Enhance technology transfer connections with industry through improved access and dissemination mechanisms, including training, personal exchanges, publications, conferences, and promotional efforts; and
- Optimize the use of intellectual property to serve the interests of U.S. industry and DOE, including reducing barriers and improving information use.

To meet these long-term objectives, specific goals include:

Enhanced Technology Research Opportunities

- Strengthen research centers and management organizations that promote fundamental innovative science and technology development germane to industrial research needs;
- Develop specific innovative technology research projects and advanced technology demonstrations to the point where industry commercial interest is attained; and
- Develop research staff awareness and recognition of technology transfer opportunities.

Industry Connection: Access and Dissemination

- Target key industries and industrial groups with a focused marketing program to inform industry of research results, new processes and technologies, and licensing of intellectual property;
- Develop and implement proactive programs for mobilizing Laboratory scientific staff to establish working relationships with industrial scientists; and
- Improve and diversify mechanisms for access and use of LBL's National User Facilities.
- Maintain a program of successful patent processing and reduce the real and perceived barriers to patent application; and
- Reduce the time between prepublication review, invention disclosure, patent application, and utilization.

LBL Technology Transfer Reorganization

In FY 1992 LBL restructured its technology transfer organization. LBL has established a new Technology Transfer Department (TTD) that reports to the Associate Laboratory Director for Administration. The former Office of Sponsored Research Administration (OSRA) and the former Technology Transfer Office (TTO) now report to the Technology Transfer Department Head. The Associate Laboratory Director for Planning and Development will continue to have responsibility for technology transfer policy, planning, and program development.

The new Department will have comprehensive responsibility for providing services to the divisions for matters of technology transfer, work for others, and user agreements. The new Department will work with research divisions to select, promote, and manage intellectual property generated at LBL. It will negotiate intellectual property agreements and CRADAs and manage the interface with licensees and CRADA participants. It will carry out all activities related to submission, approval, and tracking of sponsored research projects at the Laboratory.

Technology Transfer Activities

LBL continues to emphasize technology transfer through the publication of research results, technical consulting, personnel exchanges, and confer-

ences. An important Technology Transfer mechanism is training students who ultimately work for industry, universities, or government. More than 700 advanced students are supported at LBL. About 100 advanced degrees based on LBL research are granted annually, and approximately half of these students bring their technical talents to industry.

LBL has developed a "Technology and Invention Inventory." The inventory lists 200 technologies (including patentable inventions, public domain technologies, and copyrightable developments) in database form. The database yields information regarding subject area, patent and licensing status, scientists, and activity comments. Portfolio categories of technologies that interest U.S. companies include:

- Battery Technology
- Chemical Processes
- New Materials
- Advanced Particle and Radiation Detectors
- Energy Efficiency Technology
- Ion Sources
- New Instrumentation
- Medical Applications
- Software
- Environmental

LBL uses a multi-step approach to inform industry about LBL technologies. First, the attributes of the invention are summarized using attractive layouts and highlighting potential product applications. This package is sent to corporate executives in charge of company development; they are targeted through a high-technology corporate database that lists companies by product subject area. In addition, notices describing the inventions are distributed through technology newsletters that specialize in announcing new ideas to corporate executives. Articles are also sent to trade journals and are announced in general press releases. Other examples of technology transfer activities include the following:

- In FY 1991 LBL joined with the Haas School of Business on the UC Berkeley Campus to initiate several new projects in the MBA Engineering and Technology program. The students work with the UC Business schools and TTD, to develop economic market data that will help attract industry interest to LBL technologies.
- LBL has established an Inquiry Database that allows the Laboratory to keep inquirers updated as new Laboratory developments arise in a particular field of interest. The database now has over 700 entries expressing corporate interest in an LBL technology. There have been approximately 1300 additional inquiries resulting from trade journal articles on LBL technology.
- LBL has also focused attention on informing its scientists and potential inventors of technology transfer opportunities. A technology transfer

newsletter describes the many technology transfer approaches and services available to the LBL investigator. The newsletter features an ongoing series that details patent, copyright, and licensing procedures.

- LBL engaged in more than 300 industrially sponsored research agreements in FY 1991.
- The LBL Technology Transfer Employee Recognition Program acknowledges the accomplishments the Laboratory staff has made toward technology development and transfer to industry or other parts of the private sector. Award ceremonies recognize investigators for their technology transfer endeavors. LBL's highest honor for accomplishments in technology transfer is the Technology Transfer Excellence Award, and certificates of merit are also awarded.
- The East Bay Emerging Technology Advisory Board (EBETAB) promotes early-stage technologies for first-round, startup ventures. The board holds annual briefings to showcase new technologies to venture capitalists. LBL works with EBETAB to present LBL's latest promising technologies that have strong potential for licensing or to form startup companies.

Industry-Laboratory Cooperative Projects

Technology Transfer Personnel Exchange Program

LBL supports strategic national goals to rapidly transform the Laboratory's research into economically practical technologies for U.S. industry. These efforts include collaborative technology research participation and active involvement in the Laboratory Technology Transfer Personnel Exchange Program. Through ER's Technology Transfer Program, support for Collaborative Technology Research projects is initiated and financial assistance is provided for extended visits by senior American industry scientists to the national laboratories. These visits are highly productive, and the Laboratory has requested program expansion.

Cooperative Research and Development Agreements

Several technology research participation programs have been initiated to develop and improve the transfer of emerging technology for the energy industry, including forefront developments in advanced nanostructures fabrication and in novel biomedical instrumentation. New CRADA opportunities at LBL are also being supported. LBL has made pilot projects to promote cooperative research opportunities within specific program areas. These projects were successful in attracting U.S. corporate interest. Approximately fifteen CRADAs are in preparation at LBL. These are in various stages of completion, ranging from initial discussions between LBL and participant scientists and management, to drafting of a Joint Work Statement (JWS). In addition to these CRADAs in progress, 5 CRADAs have been signed and 6 JWSs have been submitted to the DOE-SF office for approval.

Technology Transfer Effort (Estimated)

Category	FY 1990	FY 1991[a]	FY 1992[b]	FY 1993[c]	FY 1994[c]
Activity					
Industry Cooperative Agreements	16	15	16	18	25
Agreement Value ($M)	1.6	4.5	6.0	6.2	8.0
Personnel Exchanges	9	4	3	7	9
Staffing					
Technology Transfer Department[d]	2.5	3.5	4 (est.)	4.5 (est.)	5.0 (est.)

[a]Includes Joint Participation Agreements and collaborations entered into prior to formal CRADA authority. No CRADAs active in FY 1991.

[b]Includes three Joint Participation Agreements whose terms extended into FY 1992 and 13 estimated approved CRADAs.

[c]Estimated approved CRADAs only.

[d]Includes OSRA, promotion, and licensing efforts.

Patents and Licensing

LBL seeks to patent and license its intellectual property to strengthen the value of its inventions, both for use and application by industry and to promote the research and technology transfer interests of the Laboratory and its research staff. LBL made 17 patent applications in FY 1991, and 12 patents were issued.

LBL licensing activity has increased significantly since the 1980s when relatively few agreements were made during the decade. Over the past two fiscal years, seven license agreements (including options) have been made and seven more are estimated for 1992.

Licensing income typically arises from three terms in the license agreement: an upfront onetime, license issue fee; minimum annual royalties; and sales royalties. Intellectual property from a research laboratory may require considerable development effort. Thus, sales royalties are not expected to begin until several years after the license is signed. Licensing and royalty income is distributed according to University of California policy and is consistent with patent law. Patent prosecution costs are first deducted and University policy allows the Laboratory to assign 15% for administrative costs in maintaining the license and licensing effort. After the inventor receives a share, the remainder is available for Laboratory Research. Consistent with patent law, 75% of the royalty income that exceeds 5% of LBL's annual budget will be paid to the U.S. Treasury.

Intellectual Property Management

Category	FY 1990	FY 1991	FY 1992	FY 1993 (est.)	FY 1994 (est.)
New Licenses (No.)	1	6[a]	6[a]	6[a]	8[a]
License Income ($K)	50	90	100	105	150
Patent Applications	20	18	20	25	25
Patents Issued	16	12	15	20	20
Patent Staffing	1	1	2	3	3

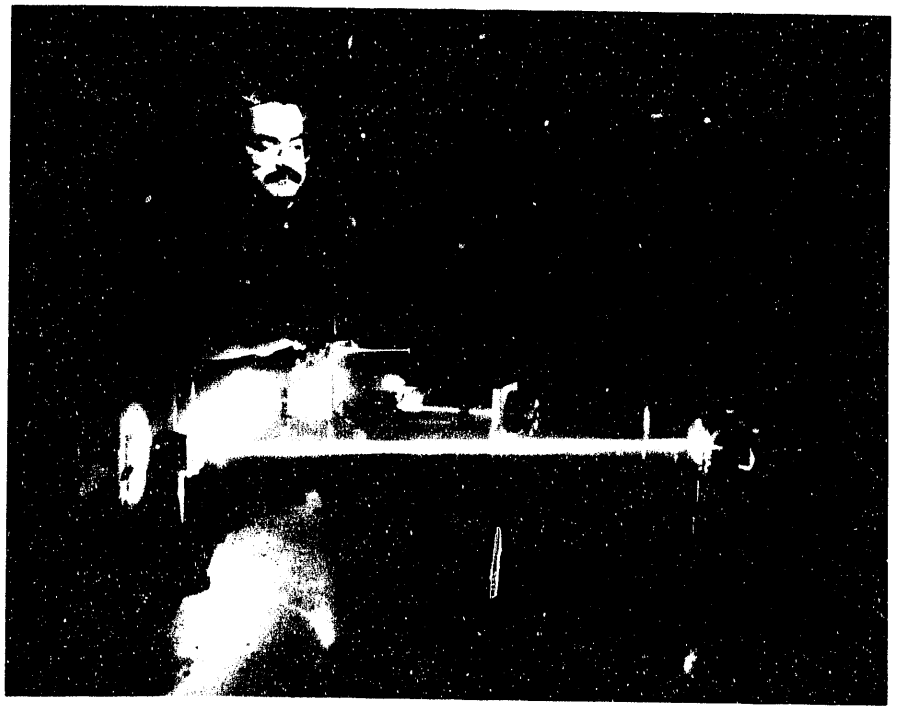
[a]Includes options.

Collaborative Centers

The Laboratory has established programmatic research centers with specific objectives of fostering collaborative research with industrial and educational institutions. These include, for example, the Center for Advanced Materials, the Human Genome Center, the Center for X-Ray Optics, the Center for Computational Seismology, and the Center for Building Sciences.

The Center for Advanced Materials (CAM) supports the goals of increasing U.S.-based industry in DOE research and has established research collaborations with related industries in surface science and catalysis (petrochemical), electronic materials (electronics), polymers (chemical), instrumentation for surface science (petrochemical and chemical), structural materials with an emphasis on light alloys (aerospace), and ceramic and metal interfaces (electronics). LBL's initiatives, such as the Atomic Scale Synthesis of Advanced Materials and Advanced Lithography initiatives, will provide a wide range of research opportunities and further extend these collaborations.

The California Institute for Energy Efficiency, a research unit coordinated by the University of California, has been formed to provide a vehicle for improved technology transfer and cooperative research support. The Center is developing efficient end-use technologies to benefit users, utility companies, and manufacturers.



A researcher adjusts the laser diagnostics on the subscale burner test stand at the UC Irvine Combustion Laboratory. The laser diagnostics experiment is part of a project to study ultra-low NO_x industrial natural gas burners managed by the California Institute for Energy Efficiency (CIEE). CIEE is hosted by LBL.

DOE National User Facilities

In support of national infrastructure for fundamental science and engineering research, LBL provides to investigators from industry, universities, and government a range of unique research facilities and centers. The major national facilities available to qualified investigators include:

- The Advanced Light Source, which will provide photon beams of unprecedented brightness and coherence and with picosecond time structure. The injector will be commissioned in early FY 1992, and the storage ring will be commissioned at the end of FY 1992. The facility will be available for use in FY 1993.
- The 88-Inch Cyclotron, which provides light ions, polarized protons and deuterons, and intense and high-charge-state beams of heavy ions (up to krypton) at energies up to about 35 MeV per nucleon. The cyclotron facility has experimental areas for conducting nuclear science experiments as well as research in other areas such as biomedicine, atomic physics, and radiation damage in semiconductors.
- The Bevalac, which provides beams of ions from protons to uranium nuclei at energies up to 2.1 GeV per nucleon. This facility offers the widest range of ions at intermediate energies in the world. The Bevalac may be utilized for NASA-related radiobiology research.
- The National Center for Electron Microscopy, which consists of the High Voltage Electron Microscope, operating at up to 1.5 MeV (highest energy in the U.S.); the Atomic Resolution Microscope, offering 1.5-Å resolution; and analytical microscopes and support facilities. An upgrade of the facility is planned (see Section 4).
- The National Tritium Labeling Facility, which provides advanced instrumentation to investigators needing high specific activities of tritiated compounds as tracers in chemical and biomedical research.

In addition to these national facilities, other research facilities involved in collaborative research include the Center for Computational Seismology, the Sky Simulator, the Mobile Window Thermal Test Facility, and the Low Background Counting Facility.

Metric Transition

LBL plans an orderly transition for employees to utilize the International System of Units (SI) wherever applicable and feasible. The use of non-SI units will be phased out as soon as practical. Conversion to International System of Units will be done in full compliance with the law, regulations, orders, guidance and the DOE Metric Transition Plan.

In order to assure a LBL-wide program to implement SI, a Metric Transition Council, Chaired by the Director of the Engineering Division and representatives from divisions/departments that have the most impact on a metric transition will be established. The council will be staffed by an SI-Metric Coordinator to provide information, resolve problems, coordinate between Laboratory divisions, and provide educational information. The Coordinator will work with DOE and others outside the Laboratory to expedite a smooth transition to SI consistent with the DOE schedule and available resources.

SCIENCE AND ENGINEERING EDUCATION

LBL's educational programs advance precollege, undergraduate, graduate, and minority educational opportunities. These programs support the objectives of the National Energy Strategy and the By the Year 2000 Report of the Federal Coordinating Council for Science, Engineering, and Technology's Committee on Education and Human Resources (CEHR). Through the Center for Science and Engineering Education, LBL has responded to the national education goals developed following the 1989 Education Summit with the nation's governors. The key strategies are to utilize the resources of LBL to

- Provide access to modern science for K–12 science students and teachers,
- Develop education partnerships for outreach and impact, and
- Deliver programs specifically for women and minorities.

Approximately 2000 visitors a year to LBL are exposed to LBL's frontier science and technology, and many more are exposed through the partnership with the UC Lawrence Hall of Science (LHS), an acclaimed education research center and science museum. To plan and conduct educational programs effectively, the Center for Science and Engineering Education (CSEE) was established in 1987. The mission of CSEE is to develop, implement, and evaluate programs that utilize LBL resources to improve the quality of mathematics, science, and technology education.

CSEE supports both formal and informal education program activities from public science and technology literacy, precollege (K–12), community college, and technical training through undergraduate and graduate education. The goals of the CSEE programs are to

- Promote equal access to scientific and technical careers for all students, including women, minorities, the handicapped, and the economically disadvantaged;
- Improve the quality of science and engineering teaching by supporting increased classroom emphasis on the scientific process and exposure to frontier science and technology;
- Increase the number of U.S. students who become scientists and engineers by developing and implementing strategies to provide continuity of opportunity from elementary school through graduate school; and
- Promote scientific literacy, including an understanding of relationships among frontier science, technology, and society.

Science/Math Educational Program Participation

Program	FY 1991 Total	FY 1991 Minorities	FY 1991 Women	FY 1992 Total	FY 1992 Minorities	FY 1992 Women
Precollege Programs						
Bay Area Science and Technology Education Consortium (Teachers)	500	200	350	700	280	490
Bay Area Science and Technology Education Consortium (Students)	4000	2950	2000	5600	4130	3920
Teacher Research Associates (Teachers)	32	9	18	42	11	23
New Perspectives in Science and Mathematics (Horizon) (Students)	250	135	125	250	150	125
High School Honors Program Life Sciences (Students)	64	8	35	64	8	35
High School Science Symposium (Students)	275	55	100	275	55	100
Updating Science Knowledge for Instruction (Teachers)	300	75	135	400	100	180
Science Bowl (Students)	80	5	5	80	5	5
Undergraduate Programs						
Access to Science Teaching Careers	3	2	2	5	4	3
Community College Transfer	4	3	1	6	5	3
Laboratory Co-op Program	14	5	1	15	7	8
Environmental Management Career Opportunities for Minorities	4	4	1	10	10	3
Minority Access to Energy Research Careers	11	7	4	12	10	5
LBL/JSU/AGMEF Science Consortium	29	28	17	40	35	25
Science and Engineering Research Semester	26	1	9	35	5	15
Faculty/Student Teams (Faculty)	3	3	0	5	4	1

Precollege Programs

Lawrence Berkeley Laboratory is working together with three other national laboratories, and 18 other colleges, universities, and organizations under the Bay Area Science and Technology Education Collaboration (BASTEC), to assist the Oakland Unified School District in restructuring and revitalizing mathematics and science education. The district serves 55,000 students and has 2,700 teachers and administrators. LBL, LLNL, SLAC, and Sandia National Laboratory Livermore have signed a formal memorandum of understanding with the Oakland Unified School District. BASTEC has been adopted by the District and serves to coordinate teacher enhancement opportunities in science and mathematics. Mini-grants were awarded to 36 teachers within the District. In January 1992, 455 Oakland school teachers participated in the second annual one day BASTEC workshop focusing on hands-on science and the new California State Science Framework. During the summer, BASTEC sponsored workshops for over 310 teachers. Inservice workshops for teachers in year-round schools were also provided. When the school year began in the fall of 1991, the Oakland School District Superintendent asked BASTEC to develop the science curriculum for all grades, K–12. This process is in progress and will be completed by September 1992 in time for adoption of texts and materials.

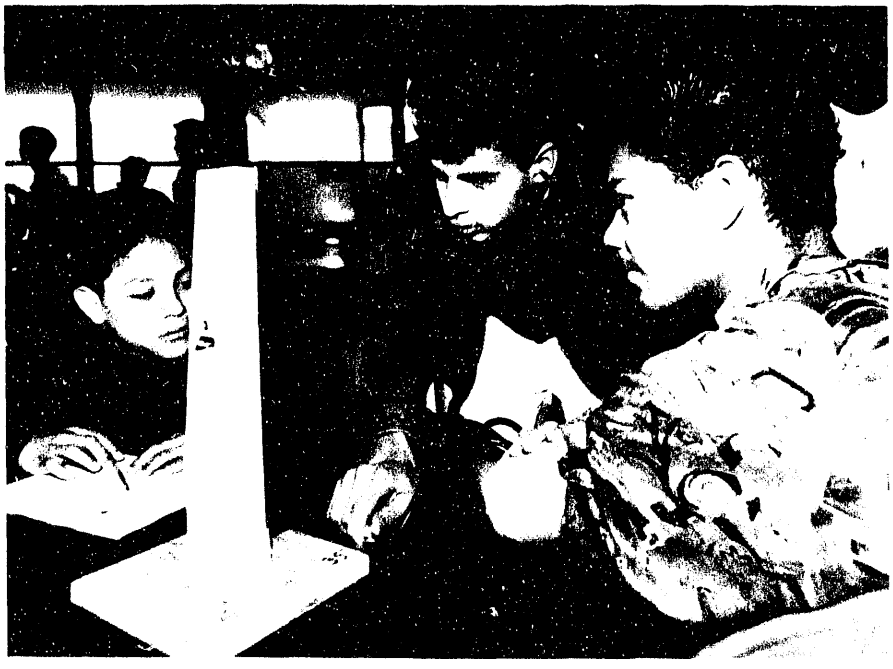
LBL provides high school and junior high school science and mathematics teachers with summer research positions through the DOE sponsored Teacher Research Associate Program. Teachers of chemistry, physics, biology, and mathematics spend eight weeks during the summer at LBL assigned to a research group working along with scientists, graduate students, and technical support staff. Through this experience teachers update their knowledge and revitalize their interest in science teaching.

The High School Honors Program in the Life Sciences brings 64 outstanding high school science students—one from each of the 50 states, the District of Columbia, Puerto Rico, and several foreign countries—to LBL for

Teachers at "Hands-on" workshop at a mini-conference sponsored by Bay Area Science and Technology Education Collaboration (BASTEC). LBL is the BASTEC lead institution.

two weeks of frontier lectures and hands-on laboratory experience. LBL's focus on Life Sciences not only gives students an opportunity to develop skills in recombinant DNA technology, but also prepares them for social and ethical issues in science and technology.

LBL maintains an outreach program to local schools and districts such as Berkeley and Richmond. The outreach coordinator provided support to the Richmond Unified School District in planning a February 1992 conference for over 2000 teachers and administrators and by providing 22 workshops on the teaching of science and computer science. Teaching and coordination for staff to participate in student mentoring and classroom consulting is provided. This is the second year LBL organized a regional 16 team Science Bowl competition. Winners go on to the national competition in Washington D.C. In addition, LBL cosponsors activities with LHS to promote public understanding of science and technology and to enrich teaching in local schools. A joint colloquium entitled "Updating Science Knowledge for Instruction" provides academic-year follow-up for teachers who have participated in LBL and LHS programs. A new cosponsored program was the High School Science Symposium on Biotechnology and Genetic Engineering, involving more than 26 teams of high school students.



Students in Project Health Link measured the blood pressure of all Fremont High School students for a database. Support came from BASTEC and Apple Computers.

The Seventh Annual California Invitational Chemathon included a scientific station developed and staffed by LBL scientists. Some 2000 students from 40 California high schools participated in this all-day marathon, participating in experiments and taking short exams in chemistry, physics, and biology.

LBL has provided leadership in the formation of the Science Education Academy of the Bay Area, SEABA, an academy without walls. Forty institutions ranging from the Exploratorium, California Academy of Sciences, to KQED and Africa Marine World signed a Memorandum of Understanding at LBL in January 1992. In doing so, they agreed to form SEABA, an academy to work together to provide teacher education in science for the over 35,000 teachers in the Greater Bay Area within 10 years.

Undergraduate Programs

Through the scientific divisions, 408 undergraduate students were research assistants or guests in FY 1991. These programs draw students from UC Berkeley and surrounding colleges during the academic year and from across the country during the summer.

Two undergraduate programs, the Laboratory Co-op Program and the Science and Engineering Research Semester (SERS), are national programs for talented students but with strong support for women and minorities in undergraduate student education. LBL undergraduate research participation programs provide advanced research participation for the top undergraduate students from colleges and universities throughout the nation. The primary goal is to attract, educate, and train scientists and engineers to meet the nation's future manpower requirements. Through a combination of hands-on laboratory research and direct interaction with scientists, the LBL Co-op and SERS programs provide undergraduate students with practical insight into research, a positive influence on educational goals, and a model for career opportunities.

The Faculty/Student Team Research program started in FY 1988 will be expanded and provides faculty from predominantly minority universities and colleges with an opportunity to develop collaborative research programs. LBL in cooperation with Associated Universities provides opportunities for underrepresented students through a number of programs. These include Minority Access to Energy Research Careers, (MAERC) for students from the California State Universities, Environmental Management Career Opportunities for Minorities (EMCOM), Environmental Management Career Opportunities Research Experience (EMCORE) for students and faculty, and a California community college transfer program for students entering UC Berkeley. These ongoing collaborations serve as a pipeline for minority students to work at LBL. This is the third year LBL has provided community college transfer students entering UC Berkeley with an opportunity for research and academic year mentorship at the Laboratory. Of the 83 students supported through CSEE programs in 1991, 46 were underrepresented minorities.

Graduate and Postgraduate Training and Research

LBL has a strong relationship with UC Berkeley, involving 218 faculty members who are LBL staff and about 500 graduate students. In addition, the Laboratory provides more than 80 postdoctoral appointments for researchers. Each year, typically over 100 doctoral dissertations and masters theses are completed on the basis of research performed at LBL.

LBL also attracts about 350 faculty visitors from 100 other academic institutions to participate in its research programs. The biomedical programs provide research and therapy opportunities for the medical faculty at UC San Francisco and for other physicians in the region. The LBL CSEE provides opportunities for post-baccalaureate-level minority students to continue research at LBL while preparing for graduate studies and acceptance into a graduate school in science or engineering.

Minority Education and Research Programs

LBL's primary program to further minority education in science is operated under a consortium of LBL, Jackson State University (JSU), and the Ana G. Méndez Educational Foundation (AGMEF). Joint scientific research is conducted among the participating institutions, as well as a strengthening of academic and research capabilities of JSU and AGMEF. The original Memorandum of Understanding establishing the Science Consortium set forth the following goals, to improve

- Faculty research opportunities;
- The quality of research seminars;
- Academic support systems for minority students;
- Undergraduate and graduate programs in the natural sciences, mathematics, computer science, engineering, and other math-based disciplines;
- Pre-university programs that better prepare minority students for college programs;
- The number of graduates from math-based programs; and
- Institutional capabilities to engage in competitive research and academics.

During the summer of 1991, a total of 11 AGMEF faculty worked on collaborative research projects at LBL. Summer research campaigns were held and led by LBL researchers for JSU and AGMEF faculty and students in Puerto Rico in 1989, at JSU in 1990, and UC Berkeley in 1991. These summer research campaigns have become key strategies for the development of self-sustaining collaborative research projects.

In support of the student-development efforts of JSU and AGMEF, two programs are conducted at LBL: the Semester Cooperative Program and the Summer Internship Program. Semester Cooperative Program students from JSU come to LBL for a full academic semester to work with LBL staff scientists. The program is offered to a limited number of eligible students who are majoring in a biological or physical science, mathematics, computer science, or pre-engineering. The Semester Cooperative Program is designed to be as complete an academic research experience as possible. Thirty students participated in FY 1991. In addition, a key strategy for preparing students for graduate school has been a post baccalaureate semester a year in research at LBL. Students prepare for the Graduate Record Exam and obtain key recommendations from LBL and U.C. Berkeley scientists.

Future Educational Program Plans

LBL expects to continue to expand its activities. Integration of minority education programs with other activities has resulted in nearly 60% minority participation in undergraduate programs. Undergraduate programs are targeted for the largest relative expansion among the education activities in FY 1993. Support for the base undergraduate education activities increased in FY 1992 but had been relatively constant to provide resources for development of precollege programs. The faculty/student team research approach, and community college transfer/technical programs provide the most promise for expanding the LBL underrepresented student pipeline into graduate school and eventually science and engineering careers The development of minority precollege teachers is being piloted for the second year in FY 1992 and will be expanded in the coming years by working with California state universities.

CSEE's precollege activities are also expected to increase in FY 1993. Maintaining the momentum and successes of BASTEC in its third year will be a high priority. The addition of new partners from industry into BASTEC

Energy Secretary James D. Watkins (center), Don Pearman (right), DOE Acting Director of Administration and Human Resources Management, and (far right) LBL Director Charles V. Shank visited several Oakland schools in support of the BASTEC program.

is being pursued this year. A number of LBL division-centered initiatives with strong precollege components are under development in such areas as automated hands-on astronomy, high-performance computing and communication technology for education, students imaging the brain for science literacy, and bioremediation technologies minority education center. These initiatives represent internal partnerships between the Center for Science and Engineering Education and LBL's scientific divisions. They also represent full integration of the precollege education and research activities at the division level. The development and inter-agency funding of these activities will be a major thrust for the next few years. These efforts support the need for the Faculty/Student Experiment and Teaching Facility to carry out the associated outreach to thousands of teachers and students every year.

The Science Consortium (LBL, JSU, and AGMEF) will shift resources to strengthen precollege programs at JSU and AGMEF and extend the benefits of successful strategies to other historically Black colleges and universities and minority institutions faculty and students. Faculty and student development through collaboration with LBL scientists will continue, with the goal of developing centers of research excellence.

Educational Programs Resource Requirements[a]

Category	1992	1993	1994	1995	1996	1997	1998
Budget	2.9	3.5	3.5	3.5	3.5	3.5	3.5
Staff (FTE)	12	15	15	15	15	15	15

[a]Projected funding through the Office of University and Science Education Programs.

8 HUMAN RESOURCES

LABORATORY PERSONNEL

The Laboratory's research is conducted by scientists, engineers, and support staff who together are responsible for the effective, efficient, and safe conduct of LBL's research projects and programs. The total LBL staff consists of 3370 employees, almost two-thirds with baccalaureate or advanced degrees. The employees include 449 graduate and 182 undergraduate students, important components that contribute to LBL's education and training mission. In addition, 223 senior staff scientists are jointly appointed as faculty on UC campuses, primarily UC Berkeley. This relationship with UC provides interactions with the broader university community and contributes to attracting and retaining a professional staff of high caliber.

LBL's scientific and engineering staff are known for a wide range of accomplishments and honors. Nine LBL scientists have become Nobel laureates, and of its present staff, 56 have been elected to the National Academies of Sciences or Engineering. Sixteen have won Lawrence Awards and four have won Fermi Awards. Such recognition is an important part in promoting the productivity and enthusiasm of the Laboratory staff.

In FY 1991, 204 LBL employees (including 20 faculty joint appointees) accepted a University-wide early retirement incentive. Nonetheless, LBL's retention rates have resulted in a trend toward an increase in overall professional staff age, and, as a result of the early retirements, the average employee age was lowered by only one year.

The unprecedented number of early retirements has presented the Laboratory with an opportunity to review its critical operations and to make critical staffing and organizational decisions to better position it for the 21st century. The recruitment of outstanding scientists and engineers is a crucial element in attaining our vision for the future. LBL is currently restructuring

its scientist and engineer classification and pay program so that it will provide more clearly defined career paths, in the areas of both scientific accomplishment and scientific management. This is one example of the efforts being made to retain young staff as well as to recruit and attract promising scientists and engineers to LBL.

The Laboratory is taking action to enhance its ability to recruit and retain the highly qualified employees it will need to continue and enhance its research programs. The Laboratory's recruitment program is directed toward ensuring a breadth of experience, a strong scientific and technical base, and a commitment to affirmative action, equal opportunity, and effective management of a diverse workforce. In addition, each Division is accountable for AA/EEO action-oriented programs aimed at achieving a diverse workforce that can only enhance LBL's image in its efforts to recruit the scientists and engineers for the future. LBL is active in recruiting promising scientists and engineers through its divisional fellow and postdoctoral associates programs.

Laboratory Staff Composition (Full- and Part-Time Personnel – FY 1991)

Group	Doctoral	Master's	Bachelor	Other	*Total*
Professional Staff					
Staff Scientists	601	69	75	14	*759*
Engineers	130	100	86	17	*333*
Management/Administrative	26	76	181	307	*590*
Support Staff					
Technicians	6	76	177	786	*1045*
All Other	13	111	362	157	*643*
Total	*776*	*432*	*881*	*1281*	*3370*

PERSONNEL PROGRAMS

The Laboratory supports and conducts professional development programs directed toward improving staff capabilities, establishing standards of safety excellence, and increasing opportunities for women and minorities. More than 30 development courses and seminars are offered on site each year. The Laboratory also provides support for off-site training and education, including baccalaureate and advanced degrees as well as other professional training credentials. Scheduled on-site training and programs are conducted in environmental safety and health and in management, personnel, computer, and workstation skills. A continued expansion of ES&H training is planned for FY 1993 (see Section 6).

The Laboratory's Employee Development and Training Office coordinates staff professional development training. Employees are informed of

the resources available and are encouraged to establish a formal Employee Development Plan in consultation with their supervisors, with assistance from the Development and Training Office. Special management institutes are conducted to improve both employee performance and relations as well as to enhance overall LBL management goals and practices.

Special employee assistance programs promote retention, personal well-being, and effective job performance. A new substance abuse training program is being implemented for supervisors and managers. These resources and programs are available through the Personnel Employee Relations Group and the Health Services Department. Included are on-site consulting services for emotional problems and substance abuse. Off-site referral services are also available when needed. Other programs for employees include the following:

- The Health Services Department at LBL provides a range of health services, including physical examinations, evaluations for return-to-work, eye examinations for laser users, a bioassay program for employees who work with radioactive substances, and blood bank and donation programs.
- The Vocational Rehabilitation Program provides counseling, vocational evaluation, job restructuring, and worksite modification. The Vocational Rehabilitation Coordinator is available to all employees.
- LBL has maintained a flextime program that provides some flexibility for scheduling employee work hours, consistent with meeting all operational requirements of divisions and departments. The flextime program facilitates commuting, childcare activities, and other scheduling needs of employees.

In addition to the consultation and information and referral services provided by the Employee Assistance Program (EAP), the Laboratory conducted a childcare information fair for employees and is planning a similar fair on eldercare for FY 1992. The EAP has published and distributed handbooks on meeting childcare and eldercare responsibilities. The eldercare guide has become a model for use in the UC system and will also be distributed to other national laboratories at a conference this year. In FY 1992 the Laboratory will conduct a survey to obtain information from LBL employees regarding their dependent care responsibilities. The Laboratory will use the results of this survey to lay the groundwork for programs to address work and family issues. A more extensive description of programs, benefits, and personnel services is provided in the Employee Handbook (PUB-80).

AFFIRMATIVE ACTION AND EQUAL EMPLOYMENT OPPORTUNITY

The Laboratory is committed to affirmative action (AA) and equal employment opportunity (EEO) in all aspects of employment. The number of women and minorities in its workforce has, however, remained relatively constant (see Table).

Equal Employment Opportunity

Ethnicity	1986	1987	1988	1989	1990	1991 Male	1991 Female
Citizens							
Asian	222	227	256	266	266	197	99
Black	189	194	215	210	195	100	99
Hispanic	104	101	118	127	122	91	37
Native American	11	9	9	8	7	6	2
White	2139	2188	2292	2244	2246	1770	508
Non-citizen	381	379	417	442	446	375	86
Total	*3046*	*3098*	*3307*	*3297*	*3282*	*2539*	*831*

To further develop its workforce diversity program and to effectively utilize and develop the changing demographics of the country's workforce, the Laboratory has issued to following statement on diversity.

> *LBL is an institution with a tradition of and dedication to excellence—in scientific research, technological innovation, educational opportunities, and service to the nation. Reflecting the nation's values, LBL is dedicated to integrating diversity in our research culture and to providing an environment that is accessible, equitable, and hospitable to all employees. We recognize that a workforce reflecting the nation's diverse cultures has value to the Laboratory.*

LBL's goals for a balanced workforce are achieved through:

- Aggressively seeking women and minority employee candidates who have the potential to achieve excellence at LBL.
- Identifying potential candidates early in their educational careers.
- Mentoring employees so that they can achieve the excellence that is synonymous with LBL.
- Providing a working atmosphere that is supportive and gives a sense of belonging to employees from all cultures.
- Supporting affirmative action and ensuring equal opportunity for career advancement for all employees.

In order to achieve the goals identified in the *Statement*, the Laboratory has taken steps to enhance the AA/EEO program through communication, training, identification of levels of authority and accountability, and implementation of new methods to identify, recruit, and retain a diverse workforce. Communications and training are the key components in the strategy to achieve these goals and will include all levels of authority and supervision. The Laboratory Director has been actively involved by communicating his expectations and vision for a diverse workforce throughout the Laboratory.

A diversity training program is mandatory for all managers and supervisors. The program not only helps managers and supervisors to understand and value cultural differences and to manage diversity, it also solicits their

suggestions and assistance in creating a diverse workforce at the Laboratory. It is the Laboratory's policy that all managerial and supervisory employees are responsible for achieving a diverse workforce. The performance of all managers and supervisors is evaluated on an annual basis with respect to their adherence to AA/EEO policy.

The Laboratory prepares an annual Affirmative Action Plan, which is reviewed and approved by the University of California, and is subsequently provided to DOE. The Plan is the means by which the Laboratory establishes, reviews, and audits its AA and EEO activities and performance. The Plan is included in the Laboratory's annual comprehensive planning calendar, a document used by senior management to appropriate time and resources to major Laboratory activities. Meetings will be held on a regular basis with senior management to review the published annual milestones for the development of the Plan, including target dates and identification of the management-level staff personnel responsible for timely accomplishment of each milestone. Important EEO units and activities are:

- The Office of Equal Employment Opportunity is a unit within the Personnel Department, headed by the AA/EEO Administrator, who reports to the Personnel Director. The Personnel Director reports to the Associate Laboratory Director for Administration and has direct access to the Laboratory Director. The Personnel Director reviews and has concurrence authority on all significant employment actions, which results in an immediate assessment of the potential impact that proposed employment actions might have on Laboratory AA/EEO program and activities.
- The primary responsibilities of the EEO Office are to audit and provide resources to help managers and supervisors implement the Laboratory's Affirmative Action program, including development of action-oriented programs aimed at achieving a diverse workforce. New capabilities to review the Laboratory's and each division's performance in creating a diverse workforce are being developed, and the EEO Officer will meet with each Division Director on a regular basis to review progress and develop methods to achieve the Laboratory's goals. The distribution of the quarterly reports and the meetings with Division Directors are also included in the Laboratory's annual comprehensive planning calendar.
- Training and education are important components in the Laboratory's efforts to achieve a diverse workforce. Enhancement of managers' and supervisors' skills and awareness in valuing and managing a diverse workforce will assist them in fulfilling their responsibilities in AA/EEO. Employee development and training programs will enhance the individual employee's ability to take advantage of career growth opportunities at the Laboratory.

In addition to the diversity training discussed above, the Personnel Department also offers a wide range of managerial and supervisory development courses aimed at assisting managers and supervisors to be effective in their roles. This includes communicating the goals of the AA program and expectations for EEO performance by all Laboratory managers and supervisors. Barriers that affect the disabled must also be eliminated, and the Laboratory has an active, ongoing training program to assist managers and supervisors of disabled employees. Special events have been held to heighten the awareness of the Laboratory community regarding employment

of the disabled. These events have included workshops and demonstrations of equipment to assist disabled employees. The Vocation Rehabilitation Service is available to assist supervisors in making accommodation for employees and potential employees with disabilities. Other important Personnel Department programs and activities include:

- A program to assist employees to develop their skills includes both on- and off-site programs. Several courses emphasize communications, including *The Pronounced Difference: Speech Evaluation Workshop for Non-native Speakers of English.* In addition, the Laboratory has an education assistance and tuition reimbursement program to assist employees in obtaining advanced training and education through approved employee development plans.
- The Laboratory is working to increase its competitiveness in the recruitment marketplace in several ways, including a national advertising campaign, strong representation at job fairs, and training programs.
- An advertising campaign includes the use of advertisements targeted to publications, journals, and papers where there is an identified minority or female readership. The primary objectives of the campaign are to improve the visibility of the Laboratory as an affirmative action employer by enhancing its outreach network and to promote LBL as an environment that fosters diversity.
- Other outreach recruitment programs include a widely distributed job listing, representation at job fairs, professional seminars, and search committees. Hiring managers and supervisors participate extensively in these outreach recruitment activities. Special employment and internship programs are maintained to increase employment opportunities. These include summer, student, and youth employment programs, as well as minority education programs.

Since its beginning the Laboratory has had a strong commitment to train the next generations of scientists and engineers, and this commitment is included in the Laboratory's Mission Statement. The educational programs of the Center for Science and Engineering Education are instrumental in encouraging young people, especially women and minorities, to enter careers in science and engineering disciplines and to better position them to attain their career goals (see Section 7). LBL is now exploring ways to maintain contact with these students after they have completed a Laboratory program and as they progress through the educational system in order to continue to encourage and assist them in achieving their goals.

LBL is committed to creating a diverse workforce and an environment in which all employees feel comfortable to pursue their career goals. To achieve this goal, the Laboratory will continue to enhance its AA/EEO program for minorities, women, persons with a disability, special disabled veterans, and Vietnam-era veterans.

9 SITE AND FACILITIES

The Laboratory prepares site-development plans for meeting scientific and technical needs and for modernization and replacement of buildings and utilities to meet DOE research needs safely and efficiently. This planning effort is important to the Laboratory's programs because of the need to rehabilitate facilities to avert safety hazards, shutdowns, and failures and to optimize use of the Laboratory's land and building resources. Department-wide planning efforts, such as the Five-Year Non-defense Facilities Modernization Plan and Capital Asset Management planning are integrated with this planning process.

Resources to improve the Laboratory's facilities are provided through Multiprogram Energy Laboratory Facilities Support (MEL-FS), General Plant Projects (GPP), In-House Energy Management, and General Purpose Equipment (GPE). Adequate funding in these areas will provide DOE with a multiprogram Laboratory capable of efficiently meeting its mission in full compliance with environment and safety standards. A major effort is underway to provide conditions that meet accepted standards for LBL's environment, health, and safety programs, including providing adequate monitoring and sample processing laboratories, adequate emergency command and response facilities, and sufficient space for on-site offices for industrial hygiene, environment, and other essential ES&H staff (see Section 6).

LBL's facilities planning is coordinated through specific Laboratory management activities and DOE initiatives. The *Site Development Plan* (SDP) has been updated for FY 1992 and will continue to be updated annually. LBL has established a prioritization framework for its multiprogram capital projects and incorporates a safety and environmental program that supports the Capital Asset Management Program. The Laboratory's ten-year In-House Energy Management Plan represents significant opportunities for cost savings. All proposed projects undergo NEPA and CEQA review procedures for full compliance with SEN 15, DOE Order 5400.ID, and UC guidelines. Institutional planning acts to couple site management planning activities closely to program planning and other strategic management processes.

SITE DESCRIPTION AND STATUS

The first building on the LBL site was constructed in 1940. In FY 1992 the main site includes 81 permanent buildings and 110 trailers and temporary structures. Over 70% of the permanent buildings are more than 25 years old (see figure below). The existing facilities and the currently funded construction at LBL constitute 188,000 gm^2 (2.02 Mgsf) located on the main site, the UC campus, and leased off-site locations. The space distribution upon completion of current projects in FY 1992 is shown below.

LBL Space Distribution[a]

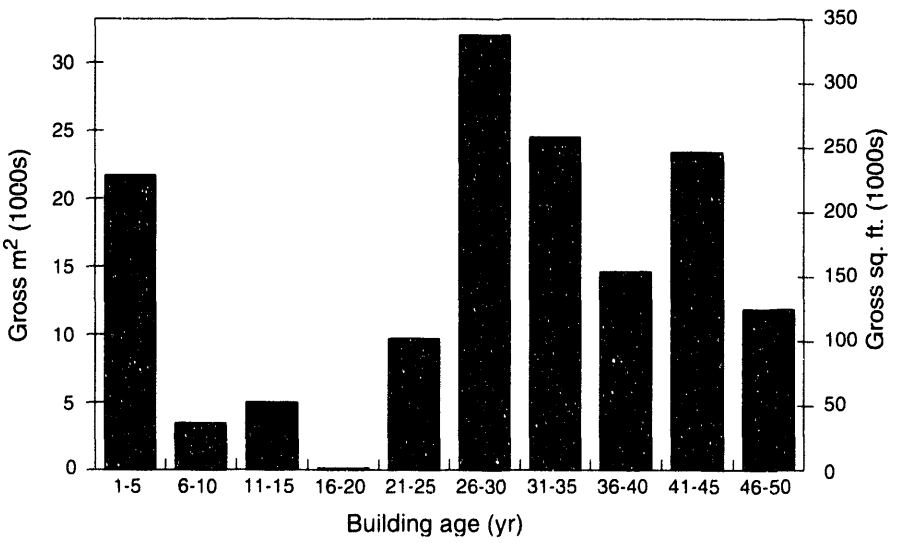
Location	Area (1000s m^2)	Area (Mgsf)	% of Total
Main site	151	1.62	80
On campus & RFS	24	0.26	13
Off-site leased	13	0.14	7
Total	188	2.02	100

[a] Includes funded and budgeted projects.

LBL space in campus buildings is available to DOE on a long-term arrangement. The off-site leased buildings provide space for essential research and support functions. Of the 151,000 gm^2 (1.62 Mgsf) on the main site, about 6,625 gm^2 (71,300 gsf) are in trailers and other temporary structures. The replacement value of the buildings, utilities, and other improvements at the main site, as determined by DOE's Real Property Inventory System for 1986, is more than $425 M (see table following).

The inventory of building space, including funded construction, is:

- Adequate: 55,300 gm^2 (595,300 gsf) that require maintenance such as painting, repairs, and minor alterations;



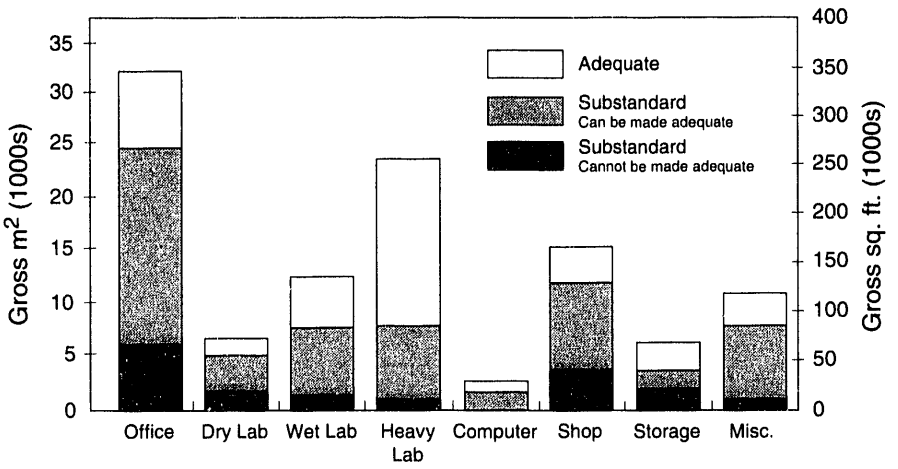
Age distribution of permanent main-site buildings (excludes proposed FY 1992 construction).

- Substandard, can be made adequate: 75,350 gm^2 (811,200 gsf) that do not meet existing standards—about 20% gsf require minor rehabilitation (in electrical, structural, and mechanical systems), and the balance require major rehabilitation (for existing or projected program requirements); and
- Substandard, cannot be made adequate: 19,950 gm^2 (214,600 gsf) that cannot be upgraded or rehabilitated at a cost less than new construction.

Facilities Replacement Value[a]

Type	Value ($M)	% of Total
Buildings	272.5	64
Utilities	123.9	29
Miscellaneous	28.8	7
Total	*425.2*	*100*

[a]Estimated in 1986.



Condition of main-site buildings, including existing construction projects (classified as adequate space).

FACILITIES PLANS AND OPTIONS

Site and facilities planning at the Laboratory reflects long-range institutional goals and values based on the University's management of LBL to support DOE missions. The site development planning objectives are to:

- Provide research facilities and accommodate changes or growth required for anticipated national scientific needs.
- Protect the environment, plan for site amenities and constraints, and buffer activities from adjacent populations.
- Ensure a safe, healthful, and efficient workplace; improve access to the Laboratory; improve communications within the Laboratory and with regional and national institutions; and provide effective transportation and parking for employees and visitors.

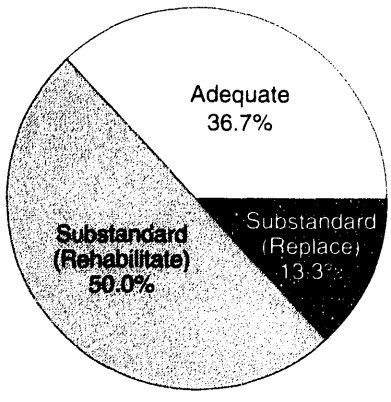
- Protect the national investment in valuable government-owned research and support facilities.
- Consolidate research and support services through proper siting of new buildings.
- Promote energy conservation and cost reductions through efficient building design, location, operation, parking and transportation, and maintenance.

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

- Consolidate activities within seven functional planning areas to enhance efficiency and effectiveness and to provide specialized research facilities;
- Redevelop obsolete buildings and infrastructure, eliminate temporary structures used for permanent functions, and improve building arrangements to increase safety and energy efficiency;
- Concentrate development along the east-west circulation and utilities axis to enhance transportation and service systems, e.g., develop off-road parking and improve pedestrian pathways;
- Improve and maintain perimeter and internal buffer zones to screen noise-generating activities and minimize potential incompatibility between adjacent operations; and
- Provide off-site facilities for receiving, warehousing, and other support and research activities suitable for decentralization.

Facility planning includes exploring options such as the selective and potential interim uses of off-site facilities for administrative and other support functions. This is due to current main-site space constraints and limited office construction over the past three decades while administrative requirements have been increasing. The principal options being explored for the long term are reconfiguration of some existing space, new additions of priority office and support buildings, and the removal of temporary office structures. These temporary office structures proliferated during the past several decades as a result of limited construction for offices and support buildings.

If the full programmatic capability of the site is developed to meet anticipated national needs in energy technology and supporting research, the sites and new buildings would result in a net increase of 37,000 gm^2 (0.4 Mgsf) to the existing main site of the Laboratory, for a total of approximately 186,000 gm^2 (2.0 Mgsf). For comparison, the 1992 total, including current construction, consists of 151,000 gm^2 (1.62 Mgsf) at the main site. The Laboratory's on-site space is now 100% utilized at an approximate 70% net to gross area efficiency. The useable on-site space is approximately 102,000 gm^2 (1.1 M net square feet). The building utilization efficiency is not projected to change significantly, although the efficiency of land use is expected to improve with the replacement of obsolete single- and two-story buildings with three- to five-story structures.



Condition of Laboratory space (excludes proposed FY 1992 construction).

GENERAL PURPOSE FACILITIES PLANS

Multiprogram Energy Laboratory Facilities Support

The total proposed and budgeted five-year MEL-FS program represents an investment need of $169.8 M. This modernization program addresses needs primarily related to the many buildings and utilities that are 20 to 40 years old. Individual projects are evaluated against generic Laboratory site development priorities such as safety, environmental protection, reliability, maintainability, design standards and obsolescence, and delivery of research and support services. Full modernization of the site would require a long-term 20-year investment program.

Proposed MEL-FS Construction Projects FY 1994–1998

Category	TEC ($M)
Safety, health, and environment	57.7
Mechanical utilities[a]	19.9
Electrical utilities[a]	17.7
Building rehabilitation/additions	74.5
Total	169.8

[a] Also includes health- and safety-related building and utility improvements.

Safety and Health Improvements

Health and safety improvements are needed in safety services, health services, building illumination, radiation protection and monitoring, and in other safety systems (see Section 6). Many of these projects were initiated as MEL-FS projects. Examples of important funded projects include Slope and Seismic Stabilization (required in the Bevalac and Shops areas), the Original Labsite Substation Project, the Instrument Support Laboratory Rehabilitation, and the Building 90 Seismic Rehabilitation.

A Support Services Facility has been budgeted along with a Fire & Safety Systems Upgrade Project (Phase I), Rehabilitation of Site Mechanical Utilities (Phase II), and Hazardous Materials Safeguards Program (Phase I). Road safety improvements are required for safe and efficient operations and movement of staff and materials throughout the site. A new facility, the Environmental Monitoring and Industrial Hygiene Building, is necessary to correct deficiencies identified by the 1991 Tiger Team Assessment (see Section 6). This facility will allow the Laboratory to meet accepted standards for LBL's environment, health, and safety programs, including providing adequate monitoring and sample processing laboratories, adequate emergency command and response facilities, and sufficient space for on-site offices for industrial hygiene, environmental, and other essential ES&H staff.

In addition, other safety projects are needed for asbestos removal from the Health Services facility, fire safety, and emergency egress, as examples. Also, roads need widening, base materials need to be replaced to conform to current standards, acute curves and blind spots need to be eliminated, and road beds and adjacent slopes on steep hillsides need to be stabilized. As an example of the long-range safety needs, the plan calls for three phases of road rehabilitation as MEL-FS projects.

Mechanical Utilities/Safety

The Laboratory's mechanical/utility systems are up to 40 years old. Mechanical utilities consist of domestic- and cooling-water, storm-drain and waste, natural-gas, compressed-air, and vacuum systems. Recent MEL-FS funding for Phase I of the Mechanical Utilities Rehabilitation Plan has improved several critical mechanical systems, but nearly 60% of existing equipment is over 20 years old and beyond its useful service life. Full implementation of LBL's Six-Phase Plan would minimize the possibility of accidents or program disruption by loss of essential utilities and equipment.

Electrical Utilities/Safety

LBL's power-distribution system consists of 24 substations and 32 km (20 miles) of 12-kV primary distribution cable. Much of the distribution equipment and cables are beyond their expected service lives, resulting in reduced reliability and increased maintenance. The electrical rehabilitation projects have been prioritized into a six-phase program based on the expected failure rates of equipment and importance to site-wide facilities demands. Phase one, Grizzly Peak Substation, has been completed. Phase two, Original Labsite Substation, and phase three, East Canyon Electrical Safety Project, were funded in FY 1992. The three remaining phases, Blackberry Switching Station Replacement, Central Switching Station & Feeders, and the Upper Blackberry Switching Station, are proposed projects included in the Five-Year MEL-FS Plan. The upgraded switching and distribution system will provide the reliability, flexibility, and expandability necessary for efficient Laboratory operation and future growth.

Building Replacement and Modernization

The MEL-FS building replacement and modernization plan responds to the needs for safety, support and research infrastructure, and for general-purpose engineering facilities. Improvements in the condition of substandard space, as part of a long-term modernization program, would enhance conditions for safely and efficiently achieving the Laboratory's mission. Included in the long-range plan is the removal of substandard facilities that cannot be made adequate. Projects include upgrades and additions for plant engineering, and maintenance services, administrative services, applied sciences, and for science education and visitor facilities.

General Plant Projects

General Plant Projects (GPP) funds have been provided by DOE's Nuclear Physics Division to fund priority construction projects that have a funding ceiling of $1.2 M. Funding to date has been inadequate to meet the Laboratory needs in a timely schedule. This program has a significant backlog of projects exceeding $20 M. One half of this backlog is for environment, health, and safety needs and one half is for general improvements and replacements. The Laboratory also classified the projects as institutional (50%) and programmatic (50%), although some of the projects related to programs serve safety needs such as PCB capacitor replacement. Increasing GPP funding to $6 M annually and increasing the ceiling from $1.2 M to $2.0 M would ensure the success of the Laboratory's safety rehabilitation program and help reduce the current backlog of projects over the next five years. Support and coordination for GPP through the Office of Energy Research would facilitate effective management of GPP and overall facilities support needs. The current split between programmatic and nonprogrammatic projects is approximately 50/50.

General-Purpose Equipment

Essential support equipment has been funded through DOE's Nuclear Physics Division. LBL's Five-Year GPE Plan identifies needs based on a range of criteria, including environment, safety, and health; legal requirements; failed, worn, inefficient, or obsolete equipment; substandard performance; or increased workload and demand. The current funding level of $1.7 M/year is inadequate to meet the Laboratory needs. Currently there is a $38 M equipment backlog for environmental monitoring and fire safety, physical-plant maintenance, mechanical and electrical shops, transportation, and data processing and communications. Increasing GPE support $4 M/year would provide a basis for reducing the backlog. Consolidated GPE management at the level of the Office of Energy Research would facilitate the implementation of an integrated and longer-range GPE plan.

Maintenance Plans

Maintenance plans and budgets are developed annually within an overall five-year planning and safety management strategy. The Laboratory has improved its current maintenance scheduling system and backlog of maintenance projects through implementation of the site-wide Plant Inspection and Maintenance System Upgrade Program. These include noncapital alterations, general plant projects, and multiprogram general-purpose line items. Requirements are identified by periodic reviews and inspections, and new priorities are developed during the fiscal year.

As discussed in the MEL-FS and ERWM sections above, long-range site modernization also addresses many of the major maintenance issues. The road safety projects, slope and seismic stabilization, general-purpose-facilities replacement projects, and other environmental and safety improvements are examples. The operating expenses for maintenance include physical-plant maintenance, mobile-equipment maintenance, and noncapital alterations related to maintenance. In addition, specialized maintenance related to shop, computer, and telecommunications facilities is also performed.

The current strategy for improving maintenance relies on strengthening the capital outlays, continuing the operating-costs efforts, and implementing the maintenance planning system as indicated above. This allows the Laboratory to sustain DOE facilities while planning for maintenance cost economies. These economies can be achieved through the replacement of existing obsolete and high-maintenance-cost facilities with modern facilities and equipment supported by increased MEL-FS, GPP, and GPE funds.

PROGRAMMATIC FACILITIES PLANS

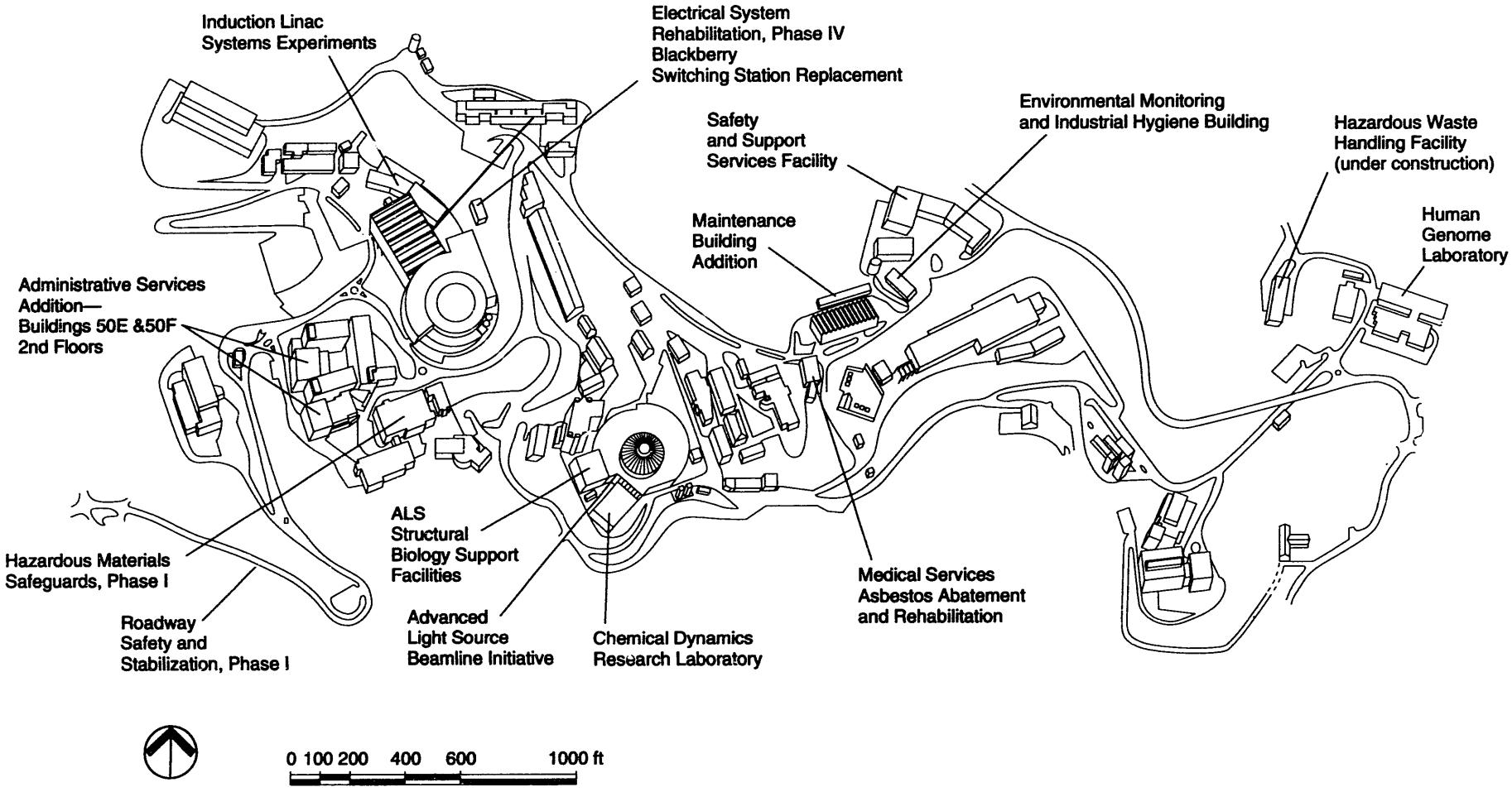
The new programmatic research buildings and facilities in the plan serve the national interest in several research areas where LBL has established programs. Several major scientific facilities form the core of LBL's plans to contribute to DOE's research capabilities (see following table and accompanying figure). The Chemical Dynamics Research Laboratory, Human Genome Laboratory, Induction Linac Systems Experiments, and ALS Beamline Initiative are significant resources for programs supported by the DOE's Office of Fusion Energy, Chemical Sciences Division, and Office of Health and Environmental Research. Implementation of the second floor of the ALS building for users is essential to meet ALS program requirements.

Five-Year Plan for Programmatic and General Purpose Facilities (FY BA, $M)

Project	TEC*	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
FUNDED PROGRAM RELATED PROJECTS:												
Advanced Light Source	99.5	23.0	6.4									
Biomedical Isotope Facility	2.3	0.6	0.7	0.6								
SUBTOTAL - FUNDED PROG RELATED	**101.8**	**23.6**	**7.1**	**0.6**								
FUNDED MEL-FS PROJECTS (KG):												
Envir Health & Safety Proj (ER Program)	13.2	1.6	0.5	1.5	2.0							
Original Labsite Substation	3.0	0.0	2.7									
Instrument Support Laboratory Rehabilitation	2.1	0.0	1.9									
Slope and Seismic Stabilization	3.7	2.4	0.8									
Building 90 Seismic Rehabilitation	6.8	3.7	2.7	00.4								
East Canyon Electrical Safety Project	3.9		0.4	1.5	2.0							
Roof Replacements, Phase I	2.5		2.0	0.5								
SUBTOTAL - FUNDED MEL-FS PROJECTS	**35.2**	**7.7**	**11.0**	**3.9**	**4.0**							
FUNDED ERWM PROJECTS:												
Hazardous Waste Handling Facility	12.0	0.0	1.6	0.0	5.8							
Envir Health & Safety Proj (ERWM Program)	1.8	0.0	0.0	0.0	0.7							
SUBTOTAL - FUNDED ERWM PROJECTS	**13.8**	**0.0**	**1.6**	**0.0**	**6.5**							
TOTAL FUNDED	**150.8**	**31.3**	**19.7**	**4.5**	**10.5**							
BUDGETED MEL-FS PROJECTS (KG)												
Safety & Support Services Facility	9.9			3.0	4.5	2.4						
Fire & Safety Systems Upgrade Proj, Ph I	4.6			1.5	2.0	1.1						
Upgrd of Site Mech Util, Ph II - Sewer Monit	7.1			0.8	3.4	2.9						
Hazardous Materials Safeguards, Ph I	5.1			1.5	3.6							
TOTAL BUDGETED MEL-FS PROJECTS	**26.7**	**0.0**	**0.0**	**6.8**	**13.5**	**6.4**						
TOTAL FUNDED and BUDGETED	**177.5**	**31.3**	**19.7**	**11.3**	**24.0**	**6.4**						
PROPOSED PROGRAM RELATED PROJECTS:												
Human Genome Laboratory (KP)	24.7				2.2	15.6	5.9	1.0				
Induction Linac Systems Experiment (AT)	61.0				8.3	13.1	14.0	13.5	12.1			
ALS Structural Biology Support Facilities	7.9				0.6	4.7	2.6					
ALS Beamlines Initiative (KC)	43.9				9.6	15.0	13.0	6.3				
Chemical Dynamics Research Laboratory (KC)	54.2				6.9	16.2	15.2	10.5	5.4			
SUBTOTAL - PROPOSED PROGRAM RELATED	**191.7**	**0.0**	**0.0**	**0.0**	**27.6**	**64.6**	**50.7**	**31.3**	**17.5**			
PROPOSED MEL-FS PROJECTS:												
Envir Monitoring & Industrial Hygiene Bldg	20.0				1.5	0.5	15.0	3.0				
Roadway Safety & Stabilization, Phase I	5.4				0.6	2.1	2.7					
Sanitary Sewer Restoration, Phase I	2.1				0.3	1.8						
Elec Sys Rehab, Ph IV - Blkby Swit Sta Replc	5.5				0.5	2.7	2.3					
Medical Serv Asbestos Abatement & Rehab	2.1				0.4	1.7						
Mechanical Equipment Replacement, Ph I	3.8				0.5	3.3						
Fire & Safety Systems Upgrd Project, Ph II	4.0					0.4	2.1	1.5				
Admin Services Addn - Bldg 50E/F 2nd Fl	7.0					1.0	3.6	2.4				
Roof Replacements, Ph II	5.0					0.5	2.5	2.0				
Hazardous Materials Safeguards, Phase II	6.5					0.6	2.8	3.1				
Facilities Building	9.0					0.9	4.5	3.6				
Elec Sys Upgrd, Ph V - Cntrl Swit Sta & Feedrs	5.5						0.5	3.0	2.0			
Building Modernization Project, Ph I	8.0						1.1	3.8	3.1			
Roadway Safety & Stabilization, Phase II	4.7						0.5	2.6	1.6			
Fire and Safety Systems Upgrade, Phase III	5.0						0.5	2.5	2.0			
Mechanical Equipment Upgrade, Phase II	4.0						0.4	2.1	1.5			
Maintenance Building Addition	5.0							0.5	2.5	2.0		
Roof Replacements, Ph III	4.1							0.4	2.2	1.5		
Mechanical Utilities Upgrade, Phase II	6.0							0.6	3.3	2.1		
Sanitary Sewer Restoration, Phase II	4.0							0.4	2.1	1.5		
Seismic Safety Improvement Project	4.0							0.4	2.1	1.5		
Energy & Environment Building	20.0								2.0	1.0	12.0	5.0
Elec Sys Upgrd, Ph VI - Upper Blkby Swit Sta	6.7								0.7	2.0	3.0	
Roadway Safety & Stabilization, Phase III	6.0								0.6	3.6	1.8	
Science Education and Visitor Center	8.0								0.8	4.5	2.7	
Building Modernization Project, Ph II	8.4								0.7	4.2	3.5	
SUBTOTAL - PROPOSED MEL-FS PROJECTS	**169.8**	**0.0**	**0.0**	**0.0**	**3.8**	**15.5**	**38.5**	**31.9**	**27.2**	**24.9**	**23.0**	**5.0**

February 1992 escalation rates at 2.1%, FY'92; 3.4%, FY'93; 4.3%, FY'94; 4.5%, FY'95; 4.7%, FY'96; 4.7%, FY'97.

* TEC includes costs prior to 1991.



Proposed major construction projects (FY 1993–FY 1995).

FACILITIES DECOMMISSIONING PLAN

The development of new program directions for nuclear physics will result in the phase-out of LBL's Bevalac nuclear physics program in FY 1993. Unless support for the Civil Space Mission or work for others (e.g., NASA) warrants continued use, the Bevalac will undergo decommissioning and decontamination (D&D) in accordance with plans being developed between LBL, OER, EM-6, and EM-40. Operations would be curtailed in mid-FY 1993. A "Stand-down and Secure" phase would be conducted by LBL in the remainder of FY 1993 and into FY 1994. Subsequent planning, operations, and funding will be identified by the responsible DOE office and LBL.

The Laboratory conducts periodic reviews of facilities that may become inactive. Other facilities to be decommissioned include cobalt irradiators and a standby propane storage facility.

Facilities Decomissioning Plan ($M)

Project Phase	FY 1993	FY 1994	FY 1995	FY 1996
Bevalac: "Stand-down and Secure" (OER)	6.0	4.0	--	—
D&D (EM)[a]	—	5.0	15.0	21.0
Gamma Irradiators (OER)	—	0.3	—	—
Propane Plant (OER)	—	0.2	—	—
D&D Base Program (OER)	0.07	0.4	0.6	0.6
Total	*6.07*	*9.9*	*15.6*	*21.6*

[a]Total D&D estimate for the Bevalac to completion in FY 1998 $76M.

FACILITIES RESOURCES REQUIREMENTS

A five-year construction plan for programmatic and general purpose facilities is provided in the table on page 9–8. MEL-FS proposed projects are listed in a prioritized order of sequence in accordance with CAMP criteria. All budgetary information as indicated is actual year authority. The yearly authority reaches a maximum of $40.1 M in FY 1996, which is primarily due to the construction of the Environmental Monitoring & Industrial Hygiene Building. This profile is under continuing review for integration with departmental planning guidance.

DATA PROCESSING AND TELECOMMUNICATIONS

The goal of LBL information technology planning is to provide computing, office automation, and voice and data communications to meet the long-range needs of the Laboratory in a flexible and cost-effective manner. Costs for some of these items are included in the GPE backlog identified above.

The foundation of the LBL long-range computing strategy is the development and operation of a distributed computing network offering access to a large-scale, interactive, high-speed computing resource, shared archival mass storage, satellite computers, and workstations. The internal LBL network, which handles a markedly increasing level of activity, is supplemented by national and international networks. The specific components of LBL's distributed network are

- A flexible and efficient communications network;
- Access to DOE's OER high-speed computing resources;
- A modern mid-scale interactive computer system in the LBL Central Computing Facility;
- Distributed computers and workstations for specific needs; and
- A large automated archival mass-storage facility.

Although individual computing needs change frequently, the LBL Laboratory-wide network permits flexible and versatile use of computational resources. This strategy is being supported by continuing development of the modern Central Computing Facility and the continuing extension and development of the LBLnet.

Summary of Computing Resources and Activities

Characteristic	FY 1990 Actual	FY 1991 Actual	FY 1992 (Estimated)
LBLnet (billion packets/mo)	7.0	10.9	13.0
LBLnet attached systems	1,732	2,610	2,725
Central processor (MIPS)	297	409	520
Central storage (Gbytes)	68	79	90

The Laboratory will promote the introduction of workstation-based "seamless" computing and communications environments so that all information technology resources are transparently available. State-of-the-art workstations, continuous upgrades of the Central Facility, adoption of new computing tools, and supercomputer access are important elements of the Laboratory's scientific computing plans.

10 RESOURCE PROJECTIONS

Resource projections for the Institutional Plan provide a description of the budgetary authority (BA) to implement the research programs. The resource tables also indicate actual FY 1991 BA and estimated FY 1992 BA for comparison. These tables include:

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

The FY 1993 estimate is based on FY 1993 DOE budget guidance and assessments by LBL divisions. The BA estimates do not indicate restoration of Goods and Services on Order (GSO) to 20–30 days balance, the stated contractual intent.

For fiscal years 1994 and beyond, operating cost projections are in FY 1994 dollars and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 1994 to FY 1998, the growth assumptions in program areas as tabulated range from 0% to 1.5% per year. These growth assumptions are based on the general direction indicated by DOE program personnel. Specific trend levels were established within each program activity.

The resource projections that follow include all funded and budgeted construction projects, the projected MEL-FS program, the approved Environmental Restoration and Waste Management program funding and construction and operational costs for the Advanced Light Source. The Nuclear Physics Program at the Bevalac is phased down in FY 1993 and closed in FY 1994. The new initiative costs are indicated in Section 4. Proposed

construction project costs are provided in Section 9. The distribution of direct and indirect full-time equivalents is integrated with ES&H staffing planning, but is insufficient for full support of the 5-year S&H plan and Corrective Action Plan (see Section 6), which requires additional program support for full implementation of these plans.

Funding Summary (Fiscal Year Budgetary Authority, $M)

Category	1991	1992	1993	1994	1995	1996	1997	1998
DOE Operating	163.9	178.5	183.4	183.0	186.9	190.6	192.4	193.9
WFO Operating	31.0	35.7	39.5	39.4	41.7	43.6	45.2	40.3
Total Operating	**194.9**	**214.2**	**222.9**	**222.4**	**228.6**	**234.2**	**237.6**	**234.2**
Capital Equipment	23.7	32.7	32.6	32.8	27.9	25.4	21.6	20.5
Program Construction	26.1	13.9	4.6	5.1	5.1	5.1	5.1	5.1
General Purpose Facilities	7.7	11.0	10.7	21.3	21.9	38.5	31.9	27.2
Environmental Restoration	1.1	5.0	0.5	5.6	6.5	5.8	6.3	6.0
General Plant Projects	2.7	2.5	3.1	4.0	4.0	4.0	4.0	4.0
General Purpose Equipment	1.5	1.7	1.7	1.8	1.8	1.8	1.8	1.8
Total Lab Funding	**257.7**	**281.0**	**276.1**	**293.0**	**295.8**	**314.8**	**308.3**	**298.8**

Personnel Summary (Fiscal Year FTE)

Category	1991	1992	1993	1994	1995	1996	1997	1998
DOE Effort	1487	1525	1479	1416	1446	1464	1473	1482
WFO	279	287	318	332	342	343	331	318
Total Direct	**1766**	**1812**	**1797**	**1748**	**1788**	**1806**	**1803**	**1800**
Total Indirect	**737**	**762**	**756**	**756**	**758**	**758**	**759**	**758**
Total Lab Personnel	**2503**	**2574**	**2553**	**2504**	**2546**	**2565**	**2562**	**2558**

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
Office of Energy Research								
Operating	116.6	132.8	136.7	134.2	137.7	139.7	141.2	142.7
Capital Equipment	19.6	21.8	18.4	16.3	12.7	12.7	12.7	12.7
Construction	34.4	24.2	16.4	28.4	29.0	45.6	39.0	34.3
Total	**170.6**	**178.8**	**171.5**	**178.9**	**179.4**	**198.0**	**192.9**	**189.7**
Conservation and Renewable Energy								
Operating	15.9	15.5	17.4	18.6	18.6	18.6	18.6	18.6
Capital Equipment	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8
Total	**16.5**	**16.1**	**18.2**	**19.4**	**19.4**	**19.4**	**19.4**	**19.4**
Fossil Energy								
Operating	2.1	2.2	2.1	2.2	2.2	2.2	2.2	2.2
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Total	**2.1**	**2.2**	**2.2**	**2.2**	**2.3**	**2.2**	**2.3**	**2.2**
Civilian Waste Management								
Operating	3.3	3.6	4.1	4.3	4.3	4.3	4.3	4.3
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**3.3**	**3.6**	**4.2**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
Environmental Restoration and Waste Management								
Operating	6.3	8.7	8.7	8.2	8.1	8.8	9.1	9.0
Capital Equipment	0.0	0.5	0.1	1.2	0.8	0.1	0.5	0.5
Construction	1.1	5.0	0.5	5.6	6.5	5.8	6.3	6.0
Total	**7.4**	**14.2**	**9.3**	**15.0**	**15.4**	**14.7**	**15.9**	**15.5**
Environment, Health and Safety								
Operating	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.7**	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
Administration and Human Resource Management								
Operating	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	2.1	3.2	2.0	2.0	2.0	2.0	2.0	2.0
Total	**2.3**	**3.5**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
Policy, Planning and Analysis								
Operating	1.3	1.5	2.2	2.8	2.8	3.3	3.3	3.3
Total	**1.3**	**1.5**	**2.2**	**2.8**	**2.8**	**3.3**	**3.3**	**3.3**
Work for Other DOE Contractors								
Operating	16.5	12.2	10.2	10.7	11.2	11.7	11.7	11.7
Capital Equipment	1.7	2.0	6.0	6.0	6.0	6.0	6.0	6.0
Total	**18.2**	**14.2**	**16.2**	**16.7**	**17.2**	**17.7**	**17.7**	**17.7**
Total DOE								
Operating	163.9	178.5	183.4	183.0	186.9	190.6	192.4	193.9
Capital Equip. (inc.GPE)	21.9	24.9	25.5	24.4	20.5	19.7	20.2	20.1
Construction (inc. GPP)	37.6	32.4	18.9	36.0	37.5	53.4	47.3	42.3
Total	**223.4**	**235.8**	**227.8**	**243.4**	**244.9**	**263.7**	**259.9**	**256.3**
Work for Others	34.3	45.2	48.3	49.6	50.9	51.1	48.4	42.5
Total Lab Funding	**257.7**	**281.0**	**276.1**	**293.0**	**295.8**	**314.8**	**308.3**	**398.8**

Personnel By Assistant Secretary Level Office (Fiscal Year FTE)

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
Office of Energy Research	1156	1181	1119	1044	1067	1079	1087	1096
Conservation & Renewable Energy	133	135	140	144	144	144	144	144
Fossil Energy	17	18	18	18	18	18	18	18
Civilian Waste Management	27	29	31	31	31	31	31	31
Environment, Health and Safety	10	8	8	8	8	8	8	9
Environmental Restoration	18	36	42	42	44	45	45	45
Administration & Human Resource	3	5	5	5	5	5	5	5
Policy, Planning and Analysis	7	8	11	13	13	13	13	13
Other DOE Contractors	116	105	105	110	115	120	120	120
Total DOE	**1487**	**1525**	**1479**	**1416**	**1446**	**1464**	**1473**	**1482**
Work for Others	279	287	318	332	342	343	331	318
Total Direct	**1766**	**1812**	**1797**	**1748**	**1788**	**1806**	**1803**	**1800**
Total Indirect	**737**	**762**	**356**	**756**	**758**	**758**	**759**	**758**
Total Personnel	**2503**	**2574**	**2553**	**2504**	**2546**	**2565**	**2562**	**2558**

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
AT Fusion Energy								
Operating	6.7	7.8	9.2	9.6	9.6	9.6	9.6	9.6
Capital Equipment	1.2	1.3	1.4	1.5	1.5	1.5	1.5	1.5
Total	**7.9**	**9.1**	**10.6**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**
Direct FTE	62	64	73	75	75	75	75	75
KA High Energy Physics								
Operating	19.7	20.5	18.5	19.2	19.5	19.8	20.1	20.4
Capital Equipment	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Total	**21.7**	**22.6**	**20.6**	**21.3**	**21.6**	**21.9**	**22.2**	**22.5**
Direct FTE	156	156	140	139	142	144	146	148
KB Nuclear Physics								
Operating	31.1	32.6	25.3	15.3	15.3	15.3	15.3	15.3
Capital Equipment	8.2	10.7	8.0	5.7	2.1	2.1	2.1	2.1
Construction	3.7	3.5	3.2	4.1	4.1	4.1	4.1	4.1
Total	**43.0**	**46.8**	**36.5**	**25.1**	**21.5**	**21.5**	**21.5**	**21.5**
Direct FTE	307	315	237	154	154	154	154	154
KC 02 Materials Sciences								
Operating	26.8	35.1	41.5	43.9	44.6	45.3	45.9	46.6
Capital Equipment	3.5	3.8	4.5	4.5	4.5	4.5	4.5	4.5
Construction	22.9	8.0	2.5	3.0	3.0	3.0	3.0	3.0
Total	**53.2**	**46.9**	**48.5**	**51.4**	**52.1**	**52.8**	**53.4**	**54.1**
Direct FTE	349	347	341	326	329	331	334	336
KC 03 Chemical Sciences								
Operating	7.5	7.9	7.9	8.2	8.4	8.5	8.6	8.8
Capital Equipment	1.2	1.4	0.9	1.0	1.0	1.0	1.0	1.0
Total	**8.7**	**9.3**	**8.8**	**9.2**	**9.4**	**9.5**	**9.6**	**9.8**
Direct FTE	72	72	69	69	70	71	72	73
KC 04 Engineering and Geosciences								
Operating	2.3	2.4	2.4	2.5	2.5	2.6	2.6	2.6
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**2.5**	**2.5**	**2.5**	**2.6**	**2.6**	**2.7**	**2.7**	**2.7**
Direct FTE	24	24	25	25	25	25	26	26
KC 05 Advanced Energy Projects								
Operating	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.7**
Direct FTE	2	4	4	4	4	4	4	4
KC 06 Energy Biosciences								
Operating	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**1.2**	**1.2**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**
Direct FTE	8	8	8	8	8	8	8	8
KC 07 Applied Math Sciences								
Operating	2.1	3.1	3.5	4.1	4.7	4.8	4.8	4.9
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**2.2**	**3.2**	**3.6**	**4.2**	**4.8**	**4.9**	**4.9**	**5.0**
Direct FTE	20	23	28	32	36	37	37	38

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
KC Basic Energy Sciences (Total)								
Operating	40.3	50.1	56.9	60.4	61.9	62.8	63.7	64.7
Capital Equipment	5.2	5.6	5.8	5.9	5.9	5.9	5.9	5.9
Construction	22.9	8.0	2.5	3.0	3.0	3.0	3.0	3.0
Total	**68.4**	**63.7**	**65.2**	**69.3**	**70.8**	**71.7**	**72.6**	**73.6**
Direct FTE	475	478	475	463	472	476	481	486
KG General Purpose Facilities Revitalization								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	7.7	11.0	10.7	21.3	21.9	38.5	31.9	27.2
Total	**7.7**	**11.0**	**10.7**	**21.3**	**21.9**	**38.5**	**31.9**	**27.2**
Direct FTE	11	13	15	18	18	18	18	18
KP Biological and Environmental Research								
Operating	15.8	17.2	21.6	23.4	25.2	25.9	26.2	26.4
Capital Equipment	1.0	1.7	1.1	1.1	1.1	1.1	1.1	1.1
Construction	0.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	**16.9**	**20.6**	**22.7**	**24.5**	**26.3**	**27.0**	**27.3**	**27.5**
Direct FTE	124	135	157	166	178	184	185	187
KS Superconducting Super Collider								
Operating	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.5**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct FTE	13	5	0	0	0	0	0	0
KT University and Science Education								
Operating	2.5	2.5	2.9	3.0	3.0	3.0	3.0	3.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.5**	**2.5**	**2.9**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
Direct FTE	8	9	11	13	13	13	13	13
KU Laboratory Technology Transfer								
Operating	0.0	2.1	2.3	3.3	3.3	3.3	3.3	3.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**2.1**	**2.3**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Direct FTE		6	10	15	15	15	15	15
Total OER								
Operating	116.6	132.8	136.7	134.2	137.7	139.7	141.2	142.7
Capital Equipment	19.6	21.8	18.4	16.3	12.7	12.7	12.7	12.7
Construction	34.4	24.2	16.4	28.4	29.0	45.6	39.0	34.3
Total	**170.6**	**178.8**	**171.5**	**178.9**	**179.4**	**198.0**	**192.9**	**189.7**
Direct FTE	**1156**	**1181**	**1119**	**1044**	**1067**	**1079**	**1087**	**1096**

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
AK Electric Energy Systems								
Operating	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.6**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Direct FTE	4	2	2	2	2	2	2	2
AM Geothermal Energy								
Operating	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**1.5**	**1.6**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
Direct FTE	9	9	9	9	9	9	9	9
EC Building Sector								
Operating	9.3	8.6	10.5	11.4	11.4	11.4	11.4	11.4
Capital Equipment	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Total	**9.8**	**9.1**	**11.1**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
Direct FTE	86	88	95	99	99	99	99	99
ED Industrial Sector								
Operating	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.2**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Direct FTE	9	11	10	10	10	10	10	10
EE Transportation Sector								
Operating	2.8	3.0	3.0	3.1	3.1	3.1	3.1	3.1
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**2.8**	**3.0**	**3.1**	**3.2**	**3.2**	**3.2**	**3.2**	**3.2**
Direct FTE	21	21	21	21	21	21	21	21
EF State/Local Programs								
Operating	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.2**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Direct FTE	1	1	1	1	1	1	1	1
EK Utility Sector								
Operating	0.4	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.4**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Direct FTE	3	3	3	3	3	3	3	3
Total Conservation and Renewable Energy								
Operating	15.9	15.5	17.4	18.6	18.6	18.6	18.6	18.6
Capital Equipment	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8
Total	**16.5**	**16.1**	**18.2**	**19.4**	**19.4**	**19.4**	**19.4**	**19.4**
Direct FTE	133	135	140	144	144	144	144	144

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
AA Coal								
Operating	1.2	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Total	**1.2**	**1.0**	**1.0**	**0.9**	**1.0**	**0.9**	**1.0**	**0.9**
Direct FTE	9	7	7	7	7	7	7	7
AB Gas								
Operating	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Direct FTE	2	3	3	3	3	3	3	3
AC Petroleum								
Operating	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total	**0.6**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Direct FTE	6	8	8	8	8	8	8	8
Total Fossil								
Operating	2.1	2.2	2.1	2.2	2.2	2.2	2.2	2.2
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Total	**2.1**	**2.2**	**2.2**	**2.2**	**2.3**	**2.2**	**2.3**	**2.2**
Direct FTE	17	18	18	18	18	18	18	18
DB Civilian Waste Management								
Operating	3.3	3.6	4.1	4.3	4.3	4.3	4.3	4.3
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**3.3**	**3.6**	**4.2**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
Direct FTE	27	29	31	31	31	31	31	31
EX Environmental Restoration and Waste Management								
Operating	6.3	8.7	8.7	8.2	8.1	8.8	9.1	9.0
Capital Equipment	0.0	0.5	0.1	1.2	0.8	0.1	0.5	0.5
Construction	1.1	5.0	0.5	5.6	6.5	5.8	6.3	6.0
Total	**7.4**	**14.2**	**9.3**	**15.0**	**15.4**	**14.7**	**15.9**	**15.5**
Direct FTE	**18**	**36**	**42**	**42**	**44**	**45**	**45**	**45**
HA Environment, Safety & Health								
Operating	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.7**	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
Direct FTE	10	8	8	8	8	8	8	9
WB Administration and Human Resource Management								
Operating	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Construction	2.1	3.2	2.0	2.0	2.0	2.0	2.0	2.0
Total	**2.3**	**3.5**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
Direct FTE	3	5	5	5	5	5	5	5
PE Policy, Planning and Analysis								
Operating	1.3	1.5	2.2	2.8	2.8	3.3	3.3	3.3
Total	**1.3**	**1.5**	**2.2**	**2.8**	**2.8**	**3.3**	**3.3**	**3.3**
Direct FTE	7	8	11	13	13	13	13	13
Work for Other DOE Contractors								
Operating	16.5	12.2	10.2	10.7	11.2	11.7	11.7	11.7
Capital Equipment	1.7	2.0	6.0	6.0	6.0	6.0	6.0	6.0
Total	**18.2**	**14.2**	**16.2**	**16.7**	**17.2**	**17.7**	**17.7**	**17.7**
Direct FTE	116	105	105	110	115	120	120	120

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

Office/Program	1991	1992	1993	1994	1995	1996	1997	1998
Other Federal Agencies								
AID	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Direct FTE	2	2	1	1	1	1	1	1
Defense	3.2	13.2	13.2	13.2	13.2	13.2	10.2	4.0
Direct FTE	32	40	60	60	60	60	46	32
EPA	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8
Direct FTE	12	11	11	11	11	11	11	11
DOI	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Direct FTE	8	7	7	7	7	7	7	7
NASA	2.0	2.2	5.3	5.3	6.3	6.3	6.3	6.3
Direct FTE	19	19	34	45	53	53	53	53
NIH	13.6	14.8	13.4	13.8	13.9	13.9	14.0	14.1
Direct FTE	106	111	96	96	97	97	97	98
Other	0.2	0.4	0.9	1.1	1.3	1.5	1.7	1.9
Direct FTE	1	2	4	5	6	7	8	9
Total Other Federal Agencies								
Operating	19.8	24.9	27.2	26.4	28.7	30.6	32.2	27.3
Capital Equipment	2.0	8.5	8.4	9.8	8.8	7.1	2.8	1.8
Total	**21.8**	**33.4**	**35.6**	**36.2**	**37.5**	**37.7**	**35.0**	**29.1**
Direct FTE	180	192	214	225	236	236	224	212
State/Private								
Operating	11.2	10.8	12.3	13.0	13.0	13.0	13.0	13.0
Capital Equipment	1.3	1.0	0.4	0.4	0.4	0.4	0.4	0.4
Total	**12.5**	**11.8**	**12.7**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**
Direct FTE	99	95	104	106	106	106	106	106
Total Work for Others								
Operating	31.0	35.7	39.5	39.4	41.7	43.6	45.2	40.3
Capital Equipment	3.3	9.5	8.8	10.2	9.2	7.5	3.2	2.2
Total	**34.3**	**45.2**	**48.3**	**49.6**	**50.9**	**51.1**	**48.4**	**42.5**
Direct FTE	279	287	318	332	342	343	331	318

Subcontracting and Procurement ($M)

Recipient	FY 1990	FY 1991	FY 1992 (Projected)
Universities	10.9	9.1	10.0
All Other	72.3	87.7	80.0
Other DOE	0.7	0.2	2.0
Total	**83.9**	**97.0**	**92.0**

Procurement from Disadvantaged, Women Owned, and All Small Businesses

Business Category	FY 1990 $M (%)	FY 1991 $M (%)	FY 1992 (Projected) $M (%)
Disadvantaged	8.7 (11.6)	8.2 (9.8)	6.4 (8)
Women Owned	5.0 (6.7)	5.4 (6.5)	4.0 (5)
All Small	38.4 (51.5)	39.3 (47.0)	36.0 (45)

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ACRONYMS AND ABBREVIATIONS

AA	Affirmative Action
ACME	Advanced Combustion Modeling Environment
AECR	Advanced Electron Cyclotron Resonance
AEDOT	Advanced Energy Design and Operation Technologies
AGMEF	Ana G. Méndez Educational Foundation
AGS	Alternating Gradient Synchrotron
ALD	Associate Laboratory Director
ALS	Advanced Light Source
AVMs	arteriovenous malformations
BA	Budgetary Authority
BASTEC	Bay Area Science and Technology Education Collaboration
BES	Basic Energy Sciences (Office)
BESAC	Basic Energy Sciences Advisory Committee
BNL	Brookhaven National Laboratory
CAD	computer-aided design
CAM	Center for Advanced Materials
CAMP	Capital Acid Management Program
CAP	Corrective Action Plan
CCD	charge-coupled device
CCVV	Constant Current Variable Voltage
CDF	Collider Detector Facility at Fermilab
CDRL	Chemical Dynamics Research Laboratory
CEHR	Committee on Education and Human Resources
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERN	European Organization for Nuclear Research
CFPA	Center for Particle Astrophysics
CIEE	California Institute for Energy Efficiency
COBE	Cosmic Background Explorer
CP	charge parity
CRADAs	Cooperative Research and Development Agreements
CSD	Chemical Sciences Division
CSDP	Continental Scientific Drilling Program
CSEE	Center for Science and Engineering Education
CXRO	Center for X-Ray Optics
D&D	Decontamination and Decommissioning
DARPA	Defense Advanced Projects Research Agency
DLS	Dilepton Spectrometer
DOD	Department of Defense
DOE	U.S. Department of Energy
DOE-SF	DOE Field Office, San Francisco
DOI	U.S. Department of Interior
EAP	Employee Assistance Program
EBETAB	East Bay Emerging Technology Advisory Board
ECR	electron cyclotron resonance
EEO	equal employment opportunity
EH&S	Environment, Health and Safety Division (LBL)
EM	Environmental Management
EMCOM	Environmental Management Career Opportunities for Minorities

EMCORE	Environmental Management Career Opportunities Research Experience
EOS	equation of state
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	Office of Energy Research (see also OER)
ERWM	Environmental Restoration and Waste Management
ES&H	environment, safety, and health
ESQ	electrostatic quadrupole
EUV	extreme ultraviolet
FTE	full-time equivalent
FY	fiscal year
GPE	General Purpose Equipment
GPP	General Plant Projects
gsf	gross square feet
GSO	Goods and Services on Order
HERA	High-Energy Resolution Array
HIFAR	Heavy-Ion Fusion Accelerator Research
HSEAC	Health, Safety and Environment Advisory Committee
ILSE	Induction Linac Systems Experiments
ITER	International Thermonuclear Experimental Reactor
JSU	Jackson State University
JWS	Joint Work Statement
KEK	National Laboratory for High Energy Physics (Japan)
LBL	Lawrence Berkeley Laboratory
LDRD	Laboratory Directed Research and Development Program
LEED	low-energy electron diffraction
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
MAERC	Minority Access to Energy Research Careers
MEL-FS	Multiprogram Energy Laboratory Facilities Support
Mgsf	million gross square feet
MoWitt	Mobile Window Thermal Test Facility
NASA	National Aeronautics and Space Administration
NCEM	National Center for Electron Microscopy
NEPA	National Environmental Policy Act
NES	National Energy Strategy
NESHAP	National Elimination System for Hazardous Air Pollutants
NIH	National Institutes of Health
NMR	nuclear magnetic resonance
NPDES	National Pollution Discharge Elimination System
NSCORT	NASA Specialized Center of Research and Training
NSF	National Science Foundation
NSLS	National Synchrotron Light Source
OAA	Office of Assessment and Assurance
OER	Office of Energy Research (see also ER)
OFA	other federal agencies
OHER	Office of Health and Environmental Research
OPD	Office for Planning and Development
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration Act
OSRA	Office of Sponsored Research Administration
OSTP	Office of Science and Technology Policy
PEP	Positron Electron Project
PET	Positron Emission Tomography

QA	Quality Assurance
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RHIC	Relativistic Heavy-Ion Collider
RNB	Radioactive Nuclear Beam
S&H	safety and health
SD	superdeformed
SDP	Site Development Plan
SEABA	Science Education Academy of the Bay Area
SEN	Secretary of Energy Notice
SERS	Science and Engineering Research Semester
SI	Standard International (system of units)
SLAC	Stanford Linear Accelerator Center
SLC	Stanford Linear Collider
SMUD	Sacramento Municipal Utilities District
SNL	Sandia National Laboratories
SNO	Sudbury Neutrino Observatory
SPS	Super Proton Synchrotron
SQUID	Superconducting Quantum Interference Device
SSC	Superconducting Super Collider
SSCL	Superconducting Super Collider Laboratory
STAR	Solenoidal Tracker at RHIC
SXR	soft x-ray
TEC	total estimated cost
TPC	Time Projection Chamber
TTD	Technology Transfer Department
TTO	Technology Transfer Office
UC	University of California
UCOP	UC Office of the President
USGS	U.S. Geological Survey
UV	Ultraviolet
VLSI	very large scale integration
VUV	vacuum ultraviolet
WFO	Work for Others

END

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