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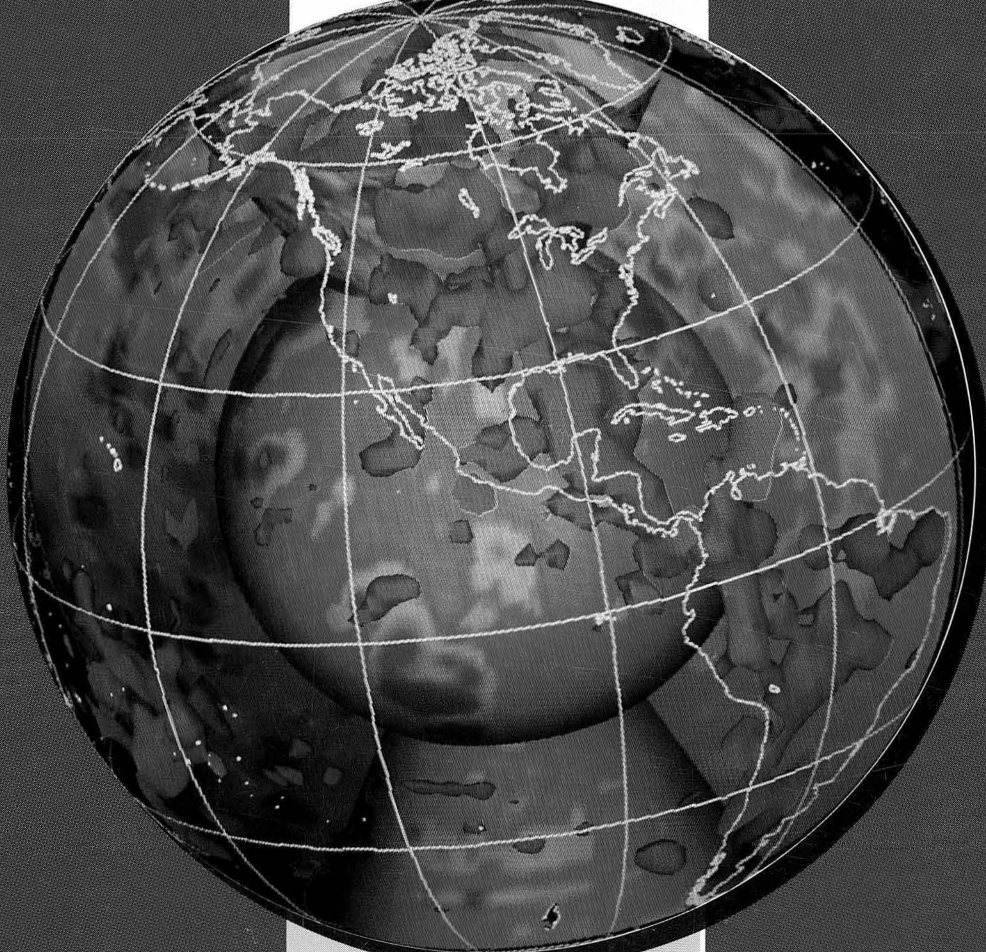

Institutional Plan FY 1991-1996

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LAWRENCE BERKELEY LABORATORY

Institutional Plan FY 1991-1996

November 1990

LAWRENCE BERKELEY LABORATORY
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Preface

The FY 1991–1996 Institutional Plan provides an overview of the Lawrence Berkeley Laboratory (LBL) mission, strategic view, scientific initiatives, research programs, educational and technology transfer efforts, human resources, and facilities needs.

The Strategic View 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 Education and Technology Transfer 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 tabulate estimates of required budgetary authority for the Laboratory's research programs.

The plan is an institutional management report that is developed through an annual strategic planning process. The plan identifies technical and administrative directions in the context of a developing national energy strategy. Preparation of the plan is coordinated by the Office of Environment and Laboratory Development from information contributed by the Laboratory's scientific and support divisions.

Contents

Chapter

1

Director's Statement

Charles V. Shank, LBL Director

As the Lawrence Berkeley Laboratory begins its 60th year, it continues a tradition of research accomplishment that makes it one of the premier scientific institutions in the world. This Institutional Plan for 1991–1996 articulates the Laboratory's mission and describes nationally important research initiatives developed through a strategic planning process. These plans are developed with broad national communities to advance creative, well-focused multidisciplinary programs. The Laboratory's research capabilities are enriched by the management of the University of California and the mutually constructive interactions with the adjacent Berkeley campus.

Mission

Carrying out leading multidisciplinary research is the cornerstone of LBL's mission and is dependent upon the extraordinary talent and broad interests of the Laboratory's staff. The planning process for the Laboratory enables staff to develop world-leading research programs. The research initiatives and programs described in this plan take advantage of LBL's capabilities that provide the nation with compelling opportunities to address critical energy supply and end-use issues, to advance science, and to create the knowledge base needed for future applications.

The international economy is challenged by threats to traditional energy supplies while the world's natural environment is stressed by man-made waste and effluents. In order to address these and other problems of our technology-dependent world, it is important for American citizens to assess critically the opportunities and risks of the science and technology that fuels innovation and improves our environment. LBL's mission to educate the next generation of scientists and engineers is part of the solution to these problems. It is also important to enable a wider cross section of society to understand the scientific process. LBL's science education programs can reach out and contribute to the scientific reasoning processes of educators and students with broad consequences for the nation. We are also beginning a new multilaboratory program specifically to target improved mathematics and science education for every teacher and student in the Oakland Unified School District.

At LBL, people working across disciplinary fields also create research facilities valuable to many scientific fields. The Advanced Light Source (ALS), for example, began with a focus on materials science and chemistry and now will play a major role in biological science as well. LBL's role in the development and operation of national user facilities takes advantage of cross fertilization between fields and affords strong opportunities for the future.

As the first LBL Director from an industrial laboratory, I am working to improve communication with industry and to identify national technology research needs. Support for technology research — using the same capabilities that the national laboratories bring to basic research — is the "missing link" in DOE's support of our national economic competitiveness. The challenge is to ensure that the Laboratory's facilities and its innovations are optimally utilized to serve the scientific and technical communities, to advance strategic national energy goals, and ultimately to add value to the nation.

Scientific Initiatives

The Institutional Plan presents the Laboratory's scientific, educational, and technology transfer initiatives developed by involving national communities, the Department of Energy (DOE), and Laboratory staff and management. The major research goals of the Laboratory support DOE programs in the Basic Energy Sciences, Health and Environmental Research, High Energy and Nuclear Physics, and Conservation and Renewable Energy. The Laboratory also has specific initiatives to strengthen educational and technology transfer programs.

LBL has been designated as a DOE center in the national effort to map and sequence the human genome. Our genome research will contribute significantly to the understanding, diagnosis, and prevention of hereditary and environmental disease. LBL's focused multidisciplinary effort will develop new mapping and sequencing methods, computational tools, and instrumentation. The Human Genome Laboratory at LBL will be an essential DOE resource for integrated and dedicated facilities to conduct this program.

In support of the national chemical sciences program, LBL, together with Sandia National Laboratories, is proposing a Combustion Dynamics Initiative to advance molecular-level understanding of combustion processes, the structure and dynamics of excited molecules, and the underlying energetics of reaction processes. LBL's component of the initiative, the Chemical Dynamics Research Laboratory, is aimed at fortifying the foundations of the chemical sciences to benefit combustion technology, fuels, and waste control industries. This national user facility would provide researchers with a state-of-the-art infrared free-electron laser, novel molecular beam facilities, advanced lasers, and ALS beam lines dedicated to chemical physics research.

In high-energy physics, LBL initiatives address forefront detectors and accelerator facilities. LBL, in conjunction with other scientific institutions, is leading an international collaboration for a solenoidal detector for the Superconducting Super Collider, and is co-proposing the construction of an asymmetric B-meson factory in cooperation with the Stanford Linear Accelerator Center, Caltech, and other institutions. These programs can provide physics leadership, directed at the fundamental properties of matter and the universe, for a new generation of scientists and instrumentation engineers.

LBL's conservation research programs have developed and introduced new energy-saving technologies that will save the nation millions of barrels of imported oil when fully utilized. LBL is proposing further advances in building energy systems through advanced computer-based building design and improvements in efficiencies that will be significant both nationally and internationally. These programs also offer benefits to our nation's energy security, the domestic economy, and the global environment. As in other areas of the Laboratory's research, these energy technology programs are closely coupled to the University and strengthen educational opportunities for students from grade school to graduate school.

Management Responsibility

The Laboratory is committed to the safe and efficient operation of its facilities and to the protection of the public and the surrounding environment. I strongly believe that safety and environment considerations must be a part of every research program. I have strengthened the Laboratory's management of its environment and safety programs, and we are working with the Department of Energy to maintain safe operations with the highest standards of excellence.

In summary, this Institutional Plan describes a vision to continue the scientific and technical excellence of the Laboratory in support of national research programs. As our nation moves forward to address energy issues and environmental challenges, I am confident that DOE will draw on the strengths that have made LBL one of the nation's leading research centers. We must assert our collective efforts to address new international conditions and to capture the opportunities of this new decade. We at LBL look forward to the challenge.

Charles V. Shank, Director

Chapter

2

Mission Statement

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 life sciences;
- Develop and operate unique national experimental facilities for use by qualified investigators;
- Educate and train future generations of scientists and engineers; and
- Foster productive relationships between LBL research programs and industry.

The following areas of research emphasis implement this mission and provide current focus for achieving strategic national research goals.

Energy Sciences

- **Applied Science**—building energy efficiency, environmental effects of technology, energy storage and distribution, fossil-energy conversion, solar energy for heating/cooling building systems, and national and international energy policy studies.
- **Chemical Sciences—**chemical physics and the dynamics of chemical reactions; structure and reactivity of transient species; electrochemistry, surface chemistry, and actinide chemistry and the atomic structure of heavy ions.

- **Earth Sciences**—structure, composition, and dynamics of the continental lithosphere; geophysical imaging methods; chemical and physical transport in geologic systems; isotopic geochemistry; and physicochemical process investigations.
- **Materials Sciences**—advanced ceramic, metallic, and polymeric materials for electronic, magnetic, catalytic, and structural applications; superconductivity; instrumentation for surface science; microstructural analysis by electron microscopy; electronic structure of solids and interfaces.

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, x-ray optics, 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.

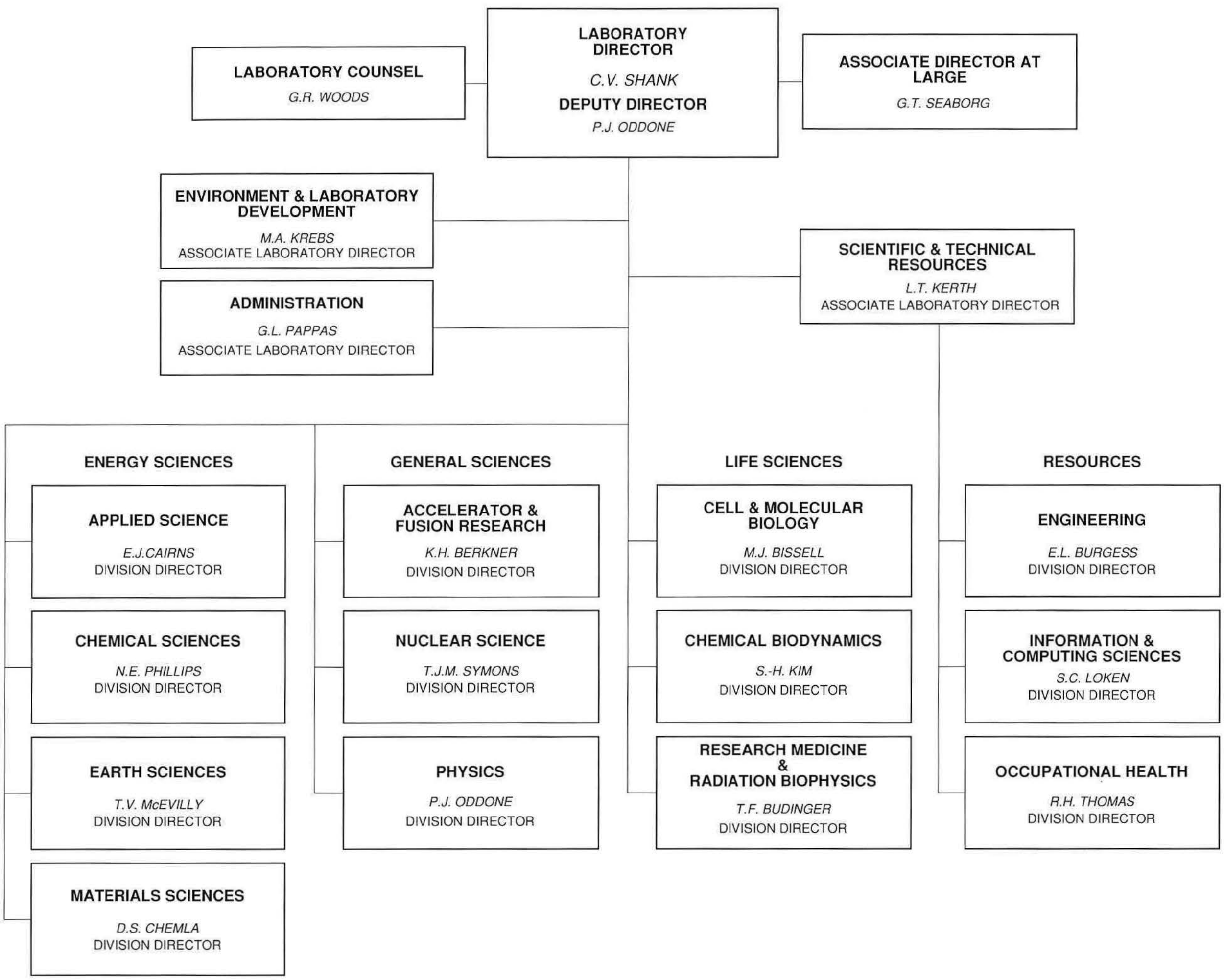
Life Sciences

- **Cell and Molecular Biology**—gene expression and molecular genetics, cellular differentiation and carcinogenesis, hematopoiesis, structural biology, DNA repair and recombination, radiation biology at the cellular and molecular levels, and the Human Genome Center.
- **Chemical Biodynamics**—structural and molecular biology of nucleic acids and proteins, genetics and mechanisms of photosynthesis, photochemistry, and mechanisms of mutagenesis.
- **Research Medicine and Radiation Biophysics**—diagnostic imaging, radiotherapy and radiosurgery, biochemical mechanisms of disease, and medical instrumentation.

Scientific and Technical Resources

- **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.
- **Information and Computing Sciences**—advanced software engineering, information management, scientific imaging and visualization tools, computation tools for the human genome project, and biostatistics.
- **Occupational Health**—technical support for safety and environmental protection, radiation associated with accelerator technology, advanced dosimeters, dispersion of radionuclides, and waste management.

The Laboratory benefits from its close working relationship with the University of California, 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.

Chapter

3

Strategic View

The Strategic View identifies external conditions and potential research directions that have significant long-term implications for the Laboratory. These conditions, and associated activity trends and their management implications, are described below.

PLANNING ASSUMPTIONS

National Energy Strategy

The Laboratory is strongly affected by national and international economic, political, and environmental conditions that influence energy policies and research programs. These strategic conditions include strengthening the U.S. technical base to improve energy efficiency, securing adequate domestic energy supplies, protecting the environment, and developing the foundation of scientific and engineering research. These conditions parallel the emerging context of a National Energy Strategy, developed in conjunction with the national laboratories, and will affect the Laboratory's programs during the 1990s and beyond.

Increasing Energy Efficiency

To meet national economic growth and security objectives while balancing environmental concerns and the demand for unsecure foreign energy supplies, the U.S. will increase its research and development on improvements in efficient energy use for residential, commercial, industrial, and transportation purposes. LBL's program supporting these efforts in building and community systems, electric energy storage, and utility system operations will contribute to these emerging national goals.

Securing Energy Supplies

To take more effective advantage of its domestic resource base, the U.S. will continue to invest in research and technology development for fossil, nuclear, and renewable energy technology. Environmentally acceptable development of these energy resources and the underlying research in materials and chemical sciences will receive continued support. As energy research and development policy changes in response to increased dependence on oil imports and global environmental issues, LBL will be called on to increase research in current programs on alternative energy-supply technologies, significantly affecting LBL's program in fusion energy, renewable energy, and fossil fuel sources.

Foundation of Scientific and Engineering Research

Basic research will continue to be supported strongly during an era of expanding national programs in the general sciences, basic energy sciences, and environmental and health research. Since LBL primarily serves DOE's basic research programs, these conditions provide a constructive environment for LBL research initiatives that have a fundamental focus. The national laboratories will retain their capability to contribute to the energy mission of DOE through their basic-research capability and their plans to develop and build new facilities that serve university and industrial research communities.

Federal laboratories will be increasingly seen as sources of new ideas and technology to improve the competitiveness of U.S. industries. LBL has a growing commitment to technology research, broadly guided by DOE's emerging goals in energy, general, and life sciences, and extending to research the full range of national needs where this multiprogram laboratory has outstanding capabilities. This capability in technology research is an emerging foundation for new scientific development that can support U.S. industry. It also can act as a strong basis for the Laboratory's interaction with educational institutions. These interactions extend from primary through postgraduate levels to attract, educate, and retain a creative workforce for the nation's manufacturing industries. A scientifically literate population and a technically trained workforce will be a foundation for long-term economic health.

LBL has established focal points for graduate training and related educational support and for industry collaboration, including the Bevalac, the 88-Inch Cyclotron, the National Center for Electron Microscopy, the Center for Advanced Materials, the Center for Building Science, the Center for X-Ray Optics, the Human Genome Center, the Center for Thin-Film Superconductivity, the Center for Isotope Geochemistry, and the Center for Computational Seismology. With the completion of the Advanced Light

Source (ALS), stronger industry and university involvement is anticipated. These centers, together with actions on a growing portfolio of licensable technologies, are evidence of the Laboratory's commitment to technology transfer.

Environmental Protection and Safety

On global, regional, and local scales, strengthened environmental protection, improved waste management, and thorough safety practices are receiving increasing emphasis. DOE's national facilities are required to review their policies and procedures to ensure full accountability and to reset priorities to emphasize environment and safety. LBL has been actively involved in the formulation of environmental and safety plans and programs for improved compliance.

At LBL, management is further developing plans for facilities modernization and is working with the Office of Energy Research to develop implementation programs. The Laboratory is contributing to the development of national environment programs and goals and is structuring its plans to allocate the necessary resources to implement new DOE policies in safety, environmental restoration, and waste management. Central to this effort is implementation of the DOE Five-Year Environmental Restoration and Waste Management Site Specific Plan. This plan—widely reviewed by state and local agencies—forms the basis for full compliance with environmental standards.

Fundamental Research

The following sections identify important conditions affecting LBL's research programs. These programs will be affected by the security of energy supplies, the technological foundations of the international economy, and by fiscal constraints associated with efforts to decrease the federal budget deficit: the overall size of Laboratory staff is not expected to grow significantly.

Energy Efficiency and Supply

Research activities in LBL's Energy Sciences programs are influenced by international patterns of energy supply and use, and 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 combustion research, new high-temperature superconducting materials, alternative means of generating electricity, and new methods of finding and producing fuels. The outlook for the Energy Sciences is affected by developments in many fields, but especially in environmental science, chemistry, geology, materials science, and physics. The following trends are anticipated:

- **Research on the chemistry of organic molecules** will increasingly depend on advanced techniques using intense photon beams and laser spectroscopy for studies of molecular reactivity, dynamics, and energy flow pathways. Advancements in photocatalysis, heterogeneous catalysis, and electrocatalysis are critical to efficient energy use, and studies of the structure and function of macromolecules, including artificial enzyme catalysis and materials synthesis, are promising for new and efficient materials production.

- **Energy efficiency research** will emphasize laboratory-scale investigations of advanced high-efficiency combustion, energy storage, electric lighting, energy-intensive chemical processes, and energy flow through walls and windows. Multidisciplinary research on energy use at the national and international level will also include studies of trends in demand and supply with analysis of the efficiency of buildings and their components.
- **Materials science research** will grow in areas involving the properties of thin films, surfaces, interfaces, and bulk materials; development of the science of wear and failure modes; and extension of the understanding of catalysts and novel processing and production techniques such as enzymatic synthesis. Key materials of interest include high-temperature superconductors, semiconductors, composites, ceramics, light alloys, polymers, magnetic, and optical materials.
- **Earth sciences research** priorities will include comprehensive technical and engineering studies for subsurface environmental restoration and waste management. Fundamental studies will be conducted on petroleum and geothermal reservoirs, groundwater systems, and repositories for energy-related wastes. Important themes will be the dynamics of transport processes and the evolution of the continental lithosphere.
- **National fusion research**, which has been under review by DOE's Fusion Policy Advisory Committee, will continue to emphasize the scientific characterization and performance of a fusion system. LBL's research in heavy-ion fusion accelerators—inertial-fusion devices that would employ accelerated beams of ions to ignite a fusion fuel pellet—continues to demonstrate the potential of this technology as an energy source for the next century. The major review by the National Academy of Sciences, requested by Congress and completed in 1990, has recognized the potential value of this research for power production. Development of neutral beams for supplemental plasma heating will support DOE's magnetic-fusion program. Negative-ion-based neutral beams have been selected as the reference design for driving toroidal currents and for plasma heating in the next-generation, steady-state tokamak—the International Thermonuclear Experimental Reactor.

Basic Research in the General Sciences

Research in the General Sciences programs is fundamental to the understanding of matter and provides a scientific and educational base for other fields. LBL's General Sciences programs are developed in conjunction with the high-energy and nuclear physics communities, and for accelerator-based materials research user facilities. LBL's national scientific outlook in these program areas includes the following developments:

- **Nuclear physics research** will emphasize new techniques that probe or alter the state of nuclei to explore nucleonic, hadronic, and quark-gluon matter, including program development at the Relativistic Heavy Ion Collider (RHIC). The 88-Inch Cyclotron, with its Advanced Electron Cyclotron Resonance (AECR) ion source, will provide an expanded range of light-ion and heavy-ion beams for the study of nuclear structure, exotic nuclei, reaction mechanisms, and nuclear astrophysics. The Bevalac will continue to provide heavy-ion beams of all the elements from hydrogen to uranium in a nationally unique and critical energy range to explore the behavior and phase transitions of nuclear matter during the early nineties.

- **High-energy physics research** at the Tevatron and at the Stanford Linear Accelerator Center, including the Stanford Linear Collider (SLC) and a proposed B factory, promises new scientific opportunities that will extend into the next decade. The construction of the Superconducting Super Collider (SSC), with the development of appropriate detector technology, will be a challenge for experimental progress during 1991 and into the 21st century. Research in particle astrophysics will take advantage of the early universe as a particle-physics laboratory.
- **National user facilities in materials sciences and related fields** will become increasingly important in providing the advanced photon and neutron probes for exploring all types of matter. Accelerator design, construction, and operation and the manipulation of intense beams of particles and electromagnetic radiation will continue to grow in importance. LBL's Accelerator and Fusion Research Division, including the ALS and the Center for X-Ray Optics, will be an active participant in these national efforts.

Health and Environment

The future of life sciences 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.

- **Physical mapping and eventual sequencing of the human genome** will be emphasized, including determination of human genome structure and expression, clonal library preparation, robotics, novel instrumentation, and development of advanced computation and pattern-recognition techniques.
- **Structural biology research** will be directed toward determining the relationship between the structure of biological macromolecules and their functions, including DNA, RNA, and critical proteins, such as those involved in membrane signal transduction. The application of synchrotron radiation, scanning tunneling microscopy, and advanced computational techniques will allow the determination of the three-dimensional structure of proteins, nucleic acids, and supramolecular complexes.
- **Biomedical research** will expand the application of advanced technology to the study of human disease and the development of new methods for diagnosis and treatment. Innovations in instrumentation for positron-emission tomography, NMR, and charged-particle radiation therapy and radiosurgery will contribute to the transfer of these technologies to the private sector. Associated radiobiological information will be used to predict the radiation hazards of prolonged space travel.
- **Cell and molecular biology** studies will focus on underlying mechanisms in mutagenesis and carcinogenesis, with emphasis on the effects of the environment on gene expression and repair. Basic molecular

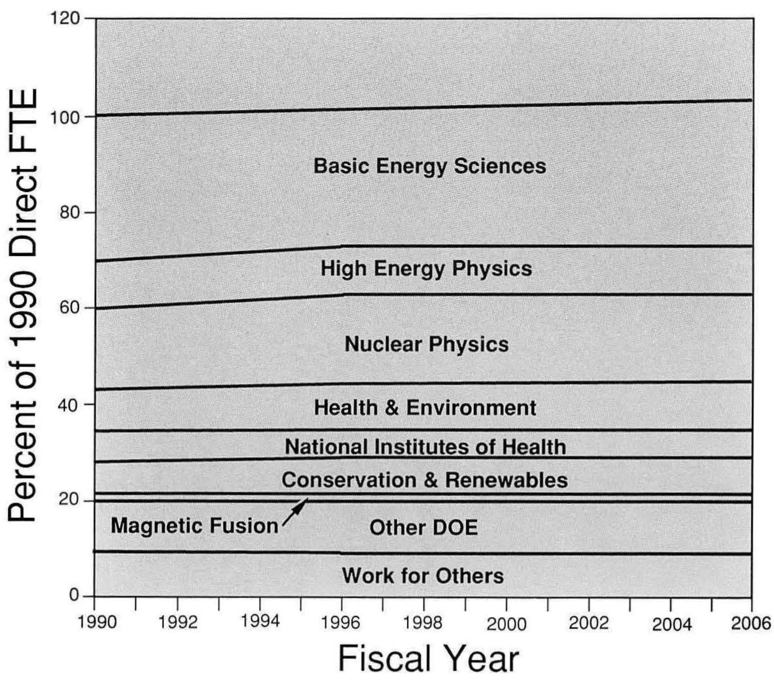
research in hematopoiesis and radiation biology and the search for bioassays to detect low-level radiation are expected to expand.

- **Global environmental effects** of energy use will continue to become more critical, both politically and economically. Reliance on fossil fuels and on nuclear power worldwide will require renewed research investments, in efforts to predict and control the effects of fossil-fuel-based air emissions and to devise safe means for storing nuclear wastes.

ACTIVITY TRENDS

The Laboratory is projected to remain generally stable in overall size but with selected growth in several initiatives, including those improving energy efficiency and supply and with industrial and university collaboration. Activities that strengthen LBL's historically significant educational and training role will continue to develop. Technology transfer and educational activities are projected to result in increases in guests and visitors.

The most likely research trends would include several initiatives, primarily in DOE's Office of Energy Research. Although some programs will grow substantially, such as the ALS and the Human Genome Center, after FY 1991, operating levels of most existing programs are projected at between 1.0 and 2.0% annual growth until FY 1996. Following FY 1996, some growth (1%/yr) in the Basic Energy Sciences programs is anticipated, whereas most other programs will remain stable (see figure). The projected budgetary assumptions during the 1991–1996 period are described in Section 9, Resource Projections. Program areas with potential impact on the Laboratory and DOE, associated with likely national trends and LBL's planning assumptions, are summarized in the following subsections.



The most likely trend in Laboratory activities will include some growth in the Basic Energy Sciences and Health and Environmental Research programs. Other DOE programs and Work for Others will remain relatively stable.

Energy Efficiency and Supply

- **Basic Energy Sciences research will grow.** An important component of this growth for LBL will be the ALS, which will be operational in FY 1993. To meet the needs for advanced combustion chemistry and reaction dynamics research and to capitalize on the capabilities of the light source, a Chemical Dynamics Research Laboratory is being proposed. An ALS Life Sciences Center is proposed in support of the Office of Health and Environmental Research (see below).
- **Chemistry and Materials research in the Basic Energy Sciences will continue to generate promising new areas of research.** Several areas proposed for expansion are a new program in combustion chemistry and reaction dynamics, thin-film applications for high-temperature superconductors, and advanced magnetic materials. These build on LBL's strengths in experimental and theoretical capabilities and in university and industry collaborations.
- **Energy conservation, supply, and use research has the potential for increased activity over the near- to mid-term.** Significant opportunities where the Laboratory has a major role include improved energy storage and buildings energy conservation, including integrated design improvements for window and lighting systems.
- **Induction linear accelerators have the potential for providing intense and focused kinetic energy from accelerated heavy-ion beams to compress and ignite a deuterium-tritium pellet.** The goal of the Heavy-Ion Fusion Accelerator Research program is to establish a data base to allow evaluation of heavy-ion technology as a driver for inertial confinement fusion. Steady progress in this field will continue. The pace could be increased with the Induction Linac Systems Experiment (ILSE), which can validate heavy-ion accelerators for inertial fusion by demonstrating a scaled system. The 1989–90 National Academy interim report has called for increased support of this work.
- **Energy supplied by high-current neutral beams will play a key role in plasma heating in the International Thermonuclear Experimental Reactor (ITER).** LBL is evaluating the possibilities for a 2–MeV accelerator test facility for ITER neutral-beam systems R&D.

Basic Research in the General Sciences

- **An SSC detector development program at LBL will contribute significantly to an international collaboration for a solenoidal detector at the SSC.** This detector will allow for full scientific use of the SSC's 20-TeV colliding-beam energies. The program takes advantage of LBL's expertise in instrumentation, electronic materials, and computing systems.
- **The Nuclear Physics program at LBL will continue to lead in relativistic heavy-ion physics while maintaining its strength in medium- and low-energy nuclear physics.** Through the early 1990s, the Bevalac will provide the nation with high-intensity heavy-ion beams emphasizing the energy range between 500 MeV and 2 GeV per nucleon, while higher-energy heavy-ion beams will be exploited at CERN. This will be complemented by the forefront low-energy nuclear science research conducted at the 88-Inch Cyclotron.

- **Conceptual development and engineering design of an asymmetric B factory based on the PEP ring at SLAC will be an ongoing activity with significant participation of scientists and engineers from both LBL and SLAC.** Such a facility would be unique in that it will allow fundamental studies of CP violation and rare B-meson decays through an upgrade of PEP and construction of a new positron ring to form a collider.
- **Developing new accelerator concepts will be necessary to the continuing strength of high-energy physics.** The benefits will include new, more-efficient and more-powerful accelerators and advances in technology for beams of electrons, ions, and photons. The production, acceleration, and transport of high-brightness electron and photon beams will be a major theme. In addition, concepts in small beam-plasma experiments for generating novel radiation and producing small beam-spot sizes in high-energy experiments will be developed.

Health and Environmental Research

- **Molecular genetics research is expected to expand significantly through the Human Genome Center.** This expansion will include development and application of techniques for mapping human chromosomes, sequencing selected important human-gene DNA fragments, and improving data analysis and interpretation. The Center's research will be relevant to the biomedical industry since it emphasizes technological approaches to mapping and sequencing and provides data that will be used in modern approaches to therapy and risk assessment for genetic disorders.
- **Cell and molecular biology and biological engineering research is expected to grow in support of industrial competitiveness in the biotechnology industry.** The ALS Life Sciences Center will provide biologists, including these from industry, with access to the world's brightest source of soft x-rays and will strengthen DOE's national role in biological research.
- **Research medicine programs in radiation biophysics and medical diagnosis and treatment are expected to expand.** The development of a regional resource for advanced positron-emission tomography includes the highest-resolution system in the world, a medical isotope training center, and development of methods for delivering radioactive agents. Medical therapy research programs using charged particles are also expected to expand through collaborations between LBL and the private sector. In related areas of occupational health research, further studies are anticipated to define radiation fields in high-energy accelerators and to develop highly accurate and reliable monitoring systems.
- **Geosciences research on containment and remediation of subsurface pollutants and on the safe disposal of radioactive, mixed, and other hazardous wastes should experience sustained growth.** These national efforts rely heavily on scientific disciplines in which LBL has unique capabilities (coupled transport processes, geophysical remote imaging, and geochemistry) and recognized expertise (properties and behavior of fractured rock masses and rock discontinuities).

- **Research on the emission sources and controls for energy technologies and on the transport and transformation of atmospheric pollutants will be important to the assessment of global change.** Components of this research will include combustion chemistry and control, heterogeneous chemical processes in cloud formation, the contribution of particulates and clouds to climate models, and climate change effects on ecosystems.

MANAGERIAL IMPLICATIONS

Achieving the Laboratory's objective of maintaining scientific excellence over the long term will require creative management and a sustained effort to revitalize the physical plant. LBL has developed priorities to maintain capabilities and to ensure that support facilities and laboratories meet LBL's high standards of environmental protection and safety. The Laboratory's management seeks to provide effective and efficient plans for the coming decades, which promise to be highly productive for research scientists and engineers. The institutional planning process will continue to be a management focal point for identifying the context for establishing the Laboratory's research goals for DOE.

- **Safety and Environment.** LBL management is committed to redirecting resources to strengthen the Laboratory's safety and environmental protection programs. This commitment centers on building-in line-management capabilities for effective conduct of operations at all organizational levels. The conduct of research under safe and environmentally sound conditions contributes to long-term vitality and productivity that fulfills the Laboratory's mission.
- **Technology Transfer.** As indicated by its mission, LBL is committed to technology transfer by developing new ways to collaborate with industry. The Laboratory has established a Technology Transfer Office to facilitate industry collaboration and the application of LBL-developed technology. The Office has initiated an active marketing and licensing program for the Laboratory's intellectual property and works with LBL's Office of Sponsored Research Administration to advance new Collaborative Research and Development Agreements with industry. Creative approaches to protecting DOE/LBL intellectual property rights, while responding to industry's needs, are being developed in coordination with DOE.
- **Education.** DOE's energy, general, and life sciences programs require advanced scientific and engineering expertise to achieve national programmatic goals. The Laboratory is committed to develop and train the human resources, reaching out to women and minorities, to sustain long-range national scientific objectives.
- **Modernization.** Institutional planning will continue to give priority to modernization and restoration of facilities because these sustain national programs while achieving standards of excellence in environment and safety. Modern facilities maintain safe operating conditions. They also create new opportunities for collaboration between national laboratory scientists and the university and industrial communities.

> The Laboratory couples the Long Range Site Development Plan with the Institutional Plan so that a safe working environment will allow implementation of DOE scientific programs.

The coming decade will see innovative arrangements for collaboration with industry, a revitalization of science education programs, and a renewal of investment in fundamental research facilities that support long-range national scientific objectives.

Chapter

4

Initiatives

The Laboratory's initiatives have goals and objectives 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. The proposed initiatives encompass the five-year planning period and span most of DOE's research program areas appropriate to this multiprogram Laboratory. Estimates of the approximate resource requirements for these initiatives include the incremental operating costs and construction costs over the period of the plan. The Resource Projections in Section 9 include only those funded and budgeted costs of Laboratory programmatic initiatives that are a part of ongoing DOE programs.

Basic Energy Sciences

- Combustion Dynamics Initiative
- Induction Linac Systems Experiment
- Advanced Transmission Electron Microscopes

High Energy and Nuclear Physics

- SSC Solenoidal Detector Collaboration
- B Factory at PEP
- Relativistic Heavy-Ion Collider Program
- Exotic Beam Facility at the 88-Inch Cyclotron

Health and Environmental Research

- Human Genome Laboratory
- ALS Life Sciences Center
- Biomedical Heavy Ion Center
- 10-Tesla Imaging Spectrometer
- Global Change Research Program

Conservation and Renewable Energy

- Advanced Energy Design and Operations Technologies
- Superconductivity Research and Technology Program

Fusion Energy

- Test Facility for Accelerators

Environmental Restoration and Waste Management

- Environmental Restoration Research Program
- Environmental Restoration Site Projects

Multilaboratory Collaboration

- Large Einsteinium Activation Program

Education/Technology Transfer Initiatives

- Cooperative Approach to Software Advancement
- Faculty/Student Experiment and Teaching Laboratory

General-Purpose Facilities

- Safety and Support Services Facility

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. The LBL effort, which encompasses the establishment of the Chemical Dynamics Research Laboratory (CDRL), will focus on fundamental advances in understanding the structure and reactivity of critical reaction intermediates and transients and the dynamics of elementary chemical reactions. The Sandia effort will emphasize complementary optical diagnosis of combustion, chemical kinetics, and reacting flows.

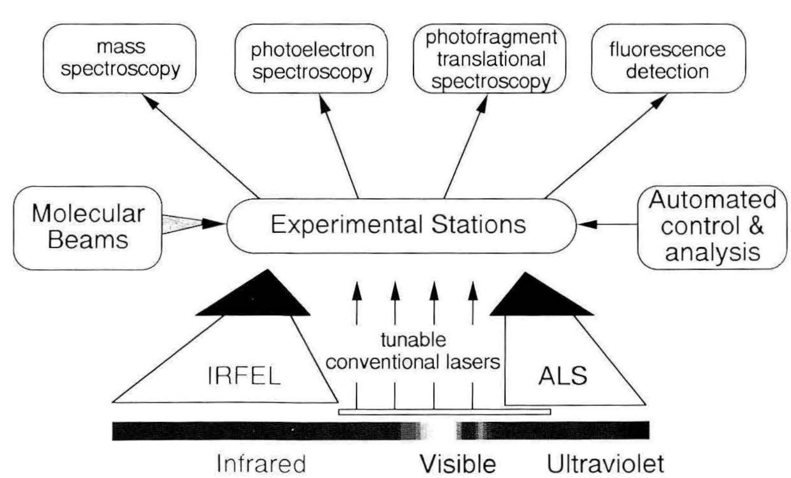
Unparalleled experimental resources for national users will enable new investigations of fundamental and applied combustion processes. At LBL, a new advanced infrared free-electron laser (IRFEL), experimental stations, dedicated chemical physics beam lines from the Advanced Light Source (ALS), and advanced lasers will be made available for dynamic, spectroscopic, and structural studies of many types of highly reactive molecules, radicals, clusters, and 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 universities and industry.

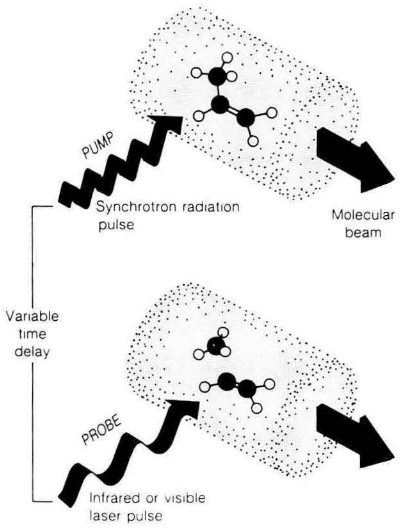
The CDRL's purpose is to achieve this new understanding by an intense experimental and theoretical effort, developing and applying FEL sources in the infrared region and ultrahigh resolution and picosecond lasers in the VUV region, as well as molecular-beam apparatus for these investigations. The proposed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

- An IRFEL optimized in the 3- to 50-μm wavelength region for chemical reaction research;
- Advanced lasers, molecular-beam machines, fully equipped experimental stations, ALS chemical-physics beam lines, and computer-based modeling and control systems;
- Computer hardware, as well as high-speed links to SNL's central computer facility for support of theoretical computations; and
- A laboratory facility to support and provide utilities, safety systems, and necessary space to conduct studies.

The IRFEL 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 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 in the past. The user facility will allow, for the first time ever, the integrated and simultaneous use of IRFEL and ALS beam lines for pump-probe experiments with crossed molecular beams.



Research at the experimental stations of the Chemical Dynamics Research Laboratory would utilize a new IRFEL and dedicated ALS chemical physics beam lines in combination with molecular beam apparatus and spectrometers. Tunable lasers and powerful computation and control systems would also be employed.



The Chemical Dynamics Research Laboratory at LBL will be ideal for dynamic pump-probe experiments: the IRFEL can excite molecules that can then be probed by the chemical physics beam line for time-resolved studies of reaction products.

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 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.

The CDRL will be managed to host visiting scientists, and its user facilities will be made available to all qualified 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. 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.

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

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	1.4	2.1	1.9	3.4	4.4	13.2
Construction	0.0	15.8	38.4	15.6	6.7	0.5	77.0

[a] Preliminary estimate of LBL Budgetary Authority.

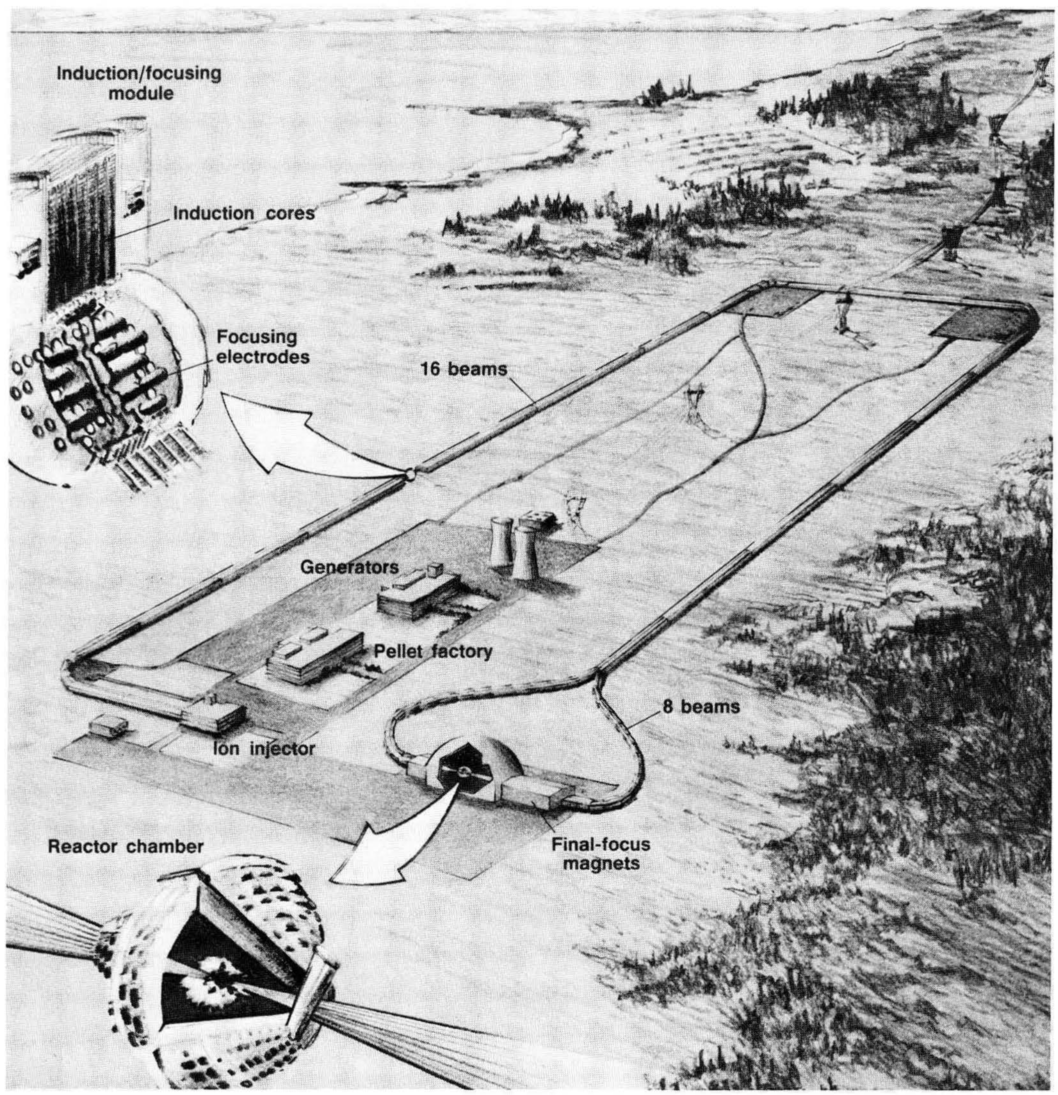
Induction Linac System Experiment

The U.S. Heavy-Ion Fusion Accelerator Research (HIFAR) program is building the research data base to assess the potential of heavy-ion accelerators as drivers for an inertial-fusion energy source for commercial power generation. Building on results of the successful single-beam transport experiment, the LBL Multiple-Beam Experiment is testing the crucial features of accelerating and longitudinally compressing four parallel heavy-ion (cesium) beams within an induction linac.

Yet to be demonstrated are beam merging with minimal phase-space density dilution, transition from electrostatic to magnetic focusing, multi-charged ion production, transport in bending magnets, and drift compression. Although these questions can be answered one at a time, the Induction Linac System Experiment (ILSE) is conceived as the next logical step necessary to attack the physics issues simultaneously. Controlling the size of the beam bunch without compromising stability is a stringent test of the overall accelerator system performance.

Using a 2-MeV injector, ILSE will accelerate ions such as C^+ or Al^{2+} to 10 MeV, after which they will be transported and focused to a small spot. Although ILSE will contain all the subsystems and beam manipulations appropriate to a driver (but on a much smaller scale), it could produce only a low-temperature plasma and hence cannot test the energy deposition of ions in hot matter. If information on this subject were to become available from the Sandia National Laboratories program in the next few years, ILSE could well complete the research data base that is the goal of the HIFAR program and, given success, could open the door in the 1990s for the planning of a fusion-power program based on inertial confinement. The 1989–90 National Academy of Sciences review group on inertial fusion, in its interim report, recommended increased support of HIFAR. Incremental costs of ILSE above the base HIFAR program are indicated in the following table.

Layout of a full-scale heavy-ion fusion system, showing ion injector, multiple-beam induction accelerating structure, and bending and focusing sections. ILSE would attack the physics issues and the accelerator components of this system at a small scale.



Induction Linac System Experiment Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	5.0	8.6	9.2	8.6	8.1	39.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

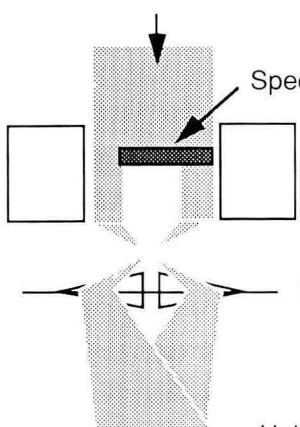
[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

Advanced Transmission Electron Microscopes

In support of the national research program in materials science, LBL is proposing a major 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:

- **An Advanced Atomic Resolution Microscope with point-to-point resolution near 1 Å (a 50% improvement);**
- **A Magnetic Materials Microscope for imaging magnetic materials in field-free space at high spatial resolution and equipped with a differential phase contrast detector combined with an Advanced Analytical Electron Microscope with a field emission gun, 5-Å probe, ultrahigh vacuum, and advanced spectrometers.**

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, 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.



Concept of an approach to improve atomic-scale resolution through off-axis electron holography. By correcting aberrations in complex phase components, the instrument would reconstruct holographic images with unprecedented resolution.

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

Category	1991	1992	1993	1994	1995	1996	Total
Operating	2.5	5.9	15.5	4.2	4.4	4.6	37.1
Construction	0.0	0.0	3.6	0.0	0.0	0.0	3.6

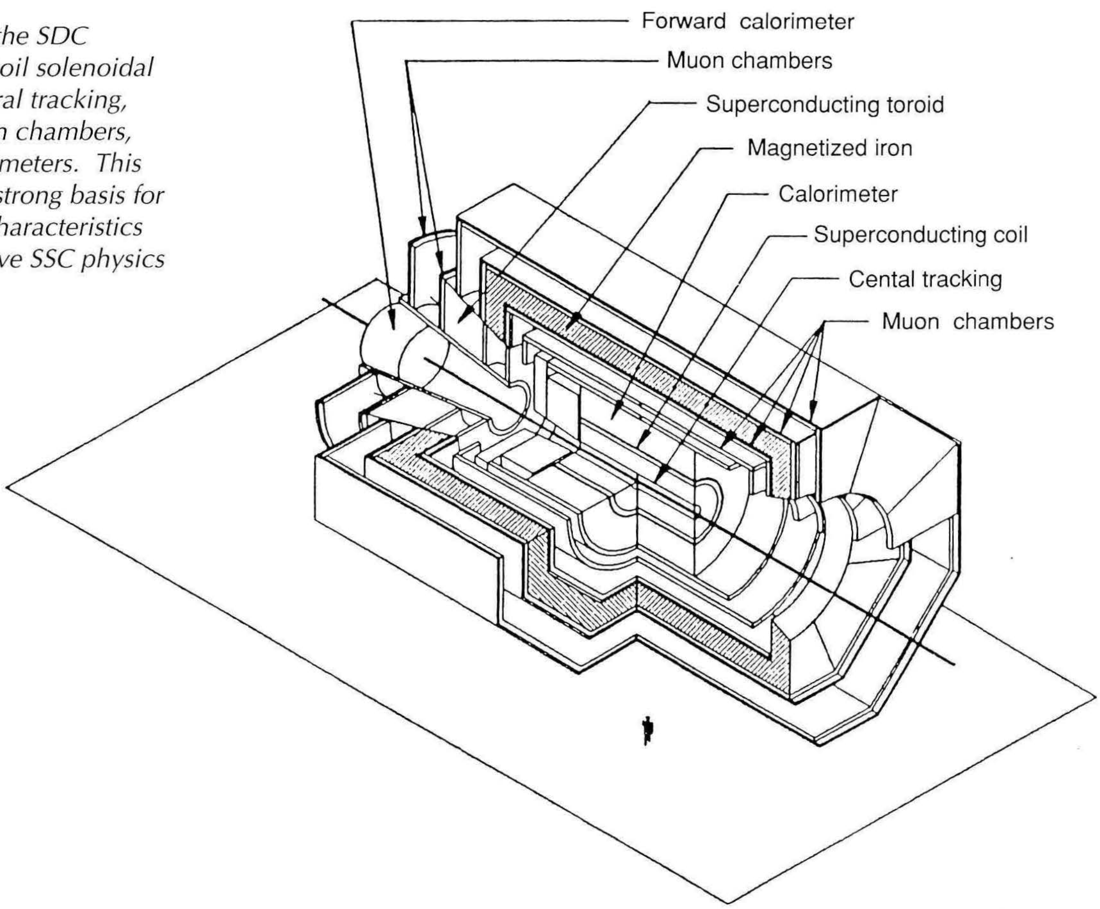
[a] Preliminary estimate of actual-year LBL Budgetary Authority.

HIGH ENERGY AND NUCLEAR PHYSICS

SSC Solenoidal Detector Collaboration

The international collaboration on a solenoidal detector system for the Superconducting Super Collider (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.

The Laboratory has emerged as a leading voice and technical manager of the Solenoidal Detector Collaboration as an outgrowth of involvement in the Collider Detector at Fermilab and D-zero detectors at the Fermilab Tevatron, hosting of activities for the SSC Central Design Group, and participation in national and international workshops on SSC detector systems at the



Representation of the SDC Detector, a large-coil solenoidal detector with central tracking, calorimeters, muon chambers, and forward calorimeters. This design provides a strong basis for the performance characteristics necessary to achieve SSC physics goals.

close of the 1980s and an extensive involvement in developing the challenging technologies that are required in the high-rate environment of the SSC. This collaboration now comprises more than 500 scientists representing more than 75 institutions from throughout the world. The Collaboration spokesperson and the technical manager are 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 been underway 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. An Expression of Interest has been presented to the SSC Laboratory Program Advisory Committee in June 1990, leading to an experimental proposal in early FY 1992, and to a detailed design report in late FY 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; the very preliminary cost projections beyond FY 1992 are not based upon a specific design or breakdown analysis.

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

Category	1991	1992	1993	1994	1995	1996	Total
Operating	6.0	8.2	10.0	15.0	15.0	15.0	69.2
Construction	0.0	0.0	10.0	20.0	35.0	35.0	100.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1990 dollars).

B Factory at PEP

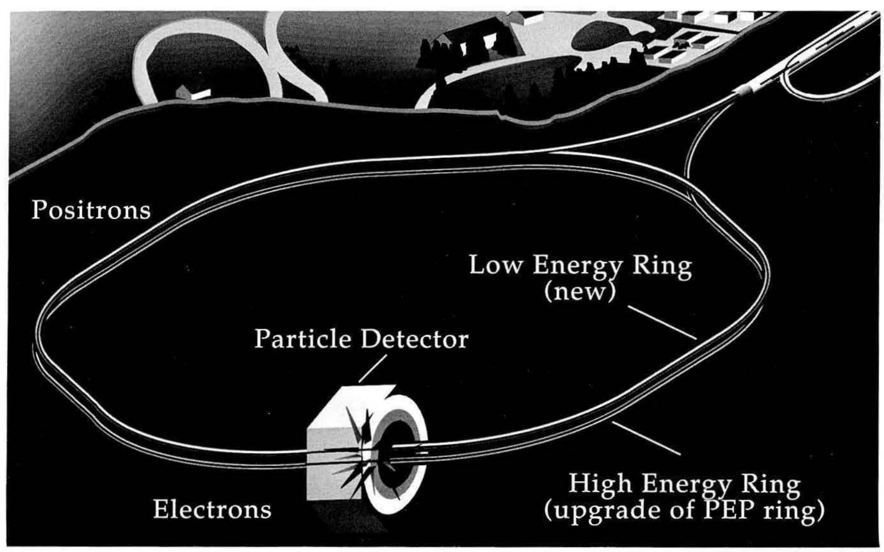
The study of B-meson decays will be one of the key elements of the worldwide high-energy physics program for many years to come. These studies are limited today by the relatively low rate of events produced at e^+e^- storage rings such as the Cornell Electron Storage Ring. An increase in the event rate by a factor of 20 or more is required for the study of the most interesting processes within the standard model, both rare decays and, even more importantly, 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 developed at LBL. Importantly, 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 energies of the two rings, the two B mesons move along the direction of the highest momentum, and their decays are separated in time (equivalently, space). This separation permits the reconstruction of individual B mesons and the study of the time evolution of their decay. The use of asymmetric collisions is equivalent to an additional factor of approximately five to ten in luminosity for the study of the most interesting channels for CP violation.

LBL, in collaboration with the Stanford Linear Accelerator Center (SLAC), is carefully evaluating the use of the Positron Electron Project (PEP) in conjunction with a new low-energy storage ring. The technical feasibility of a viable B factory based on PEP (a high-energy, 9–12 GeV ring), with the addition of a new low-energy (2–3 GeV) ring, would be attractive both scientifically and fiscally. The initial studies indicate that such an asymmetric B-factory scenario is entirely feasible with state-of-the-art technology.

The construction of the PEP-based B factory would be carried out in collaboration with SLAC. Studies are presently being carried out to design a new detector to exploit fully the opportunities made possible with an asymmetric B factory. Both the accelerator development and the detector construction and operation would be carried out in collaboration with universities and other national laboratories.

A B factory could be built at SLAC with the addition of a 3.1-GeV storage ring within the tunnel of the existing PEP storage ring. Because of the energy asymmetry, the center of mass of the collision moves in the laboratory frame of reference; thus, the decay products are separated in time, making detection easier.



B Factory at PEP Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	5.1	11.0	22.0	28.0	25.0	23.6	114.7
Construction	0.0	0.0	20.0	70.0	70.0	20.0	180.0

[a] Includes SLAC/LBL costs. Preliminary estimate of Budgetary Authority (FY1991 dollars).

Relativistic Heavy-Ion Collider Program

LBL continues to maintain a leadership role in the study of relativistic heavy-ion collisions. While continuing operation and research at the Bevalac, LBL has also been an essential element in starting programs at the CERN SPS and the Brookhaven AGS and is planning for future work at the Relativistic Heavy Ion Collider (RHIC). LBL's Nuclear Science Division plays a key role in exploring the new physics opportunities in these experimental programs.

RHIC has been recommended by the NSAC (Nuclear Science Advisory Committee) as the next new project for nuclear science research in the United States, and construction funds for RHIC are included in the President's FY 1991 budget. LBL has played a seminal role in defining the forefront of relativistic heavy-ion physics since the field's inception. Hence, LBL has begun planning for a major experiment at RHIC. A new group, the Relativistic Nuclear Collisions Group, has been formed by consolidation of several existing research groups to provide a focus for RHIC activities. Planning for a major RHIC experiment and the R&D necessary to provide the required detectors are underway.

LBL is actively pursuing an experimental concept in collaboration with other laboratories and universities to study the production of particles and high transverse-momentum jets to identify the phase transition from normal nuclear matter to quark matter. The immediate goal of this RHIC project is to compose a letter of intent and provide cost estimates for a major experiment by fall 1990. Thus, computer simulations and detector development to determine the capabilities and the precise design of an experiment to measure transverse momentum and particle production are underway. Full tracking of the expected 2000–3000 charged particles in the most violent central collisions will be performed in a Time Projection Chamber (TPC). Particle identification will be accomplished with time-of-flight and Cerenkov measurements radially outward from the TPC. Segmented calorimeters for jet identification and triggering would also be implemented.

Two projects are now underway with support from RHIC detector R&D funds through Brookhaven National Laboratory. One is for the development of a fast, particle-identifying trigger based on ring imaging Cerenkov techniques (in collaboration with University of California at Los Angeles and Johns Hopkins University); and the other is for large-scale integration of electronics for TPC readout. LBL expects this R&D effort to expand significantly in the next few years.

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

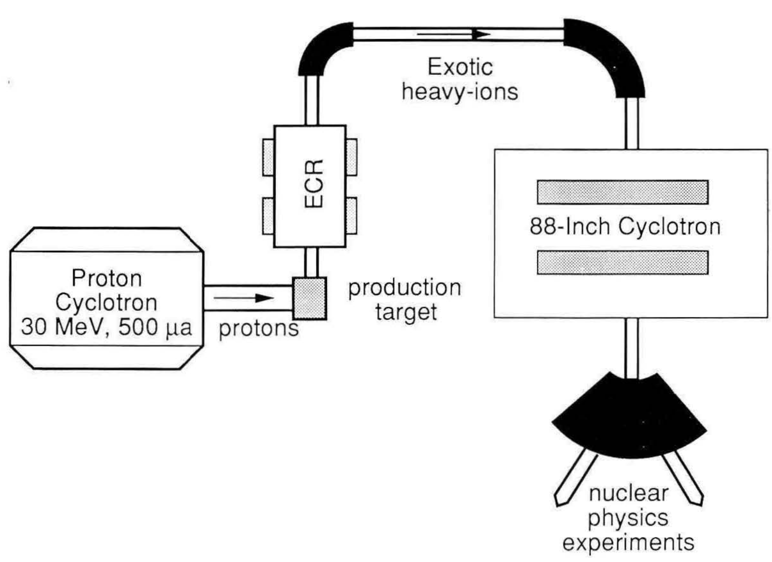
Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.5	1.5	2.5	4.0	5.0	6.5	20.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

Exotic Beam Facility at the 88-Inch Cyclotron

The Laboratory is proposing a facility for the production and acceleration of radioactive—or exotic—nuclei at the 88-Inch Cyclotron that, along with associated experiments in nuclear structure and nuclear reactions, will address both the local and national scientific interest. The facility will be an important step toward establishing a scientific and technical basis for a future proposal of a national high-intensity facility. The exotic beam facility will consist of a high-current proton cyclotron, a production target to generate the radioactive nuclei, and the 88-Inch Cyclotron to accelerate them. A high-efficiency, high-charge-state ion source will ionize the radioactive species, and a beam line will connect the target ion source with the axial injection line for the 88-Inch Cyclotron. The ECR ion source at the target produces a beam of ions having charge states of 2^+,3^+, or 4^+ at energies suitable for injection into the 88-Inch Cyclotron. Ions of ^{10}C, ^{11}C, ^{13}N, ^{14}O, ^{15}O, and other nuclei having half-lives of a fraction of a minute or longer will be accelerated to energies sufficient to induce nuclear reactions and to produce new nuclei far from stability.

The intensities of the proton-rich beams are expected to be in the range of 10^6 to a maximum of 10^9 particles per second—two to three orders of magnitude less intense than many stable beams, yet sufficient for many experiments. These experiments exploit the unique features of these unstable particle beams to address problems in nuclear astrophysics, the structure of nuclei far from stability, and the mechanisms of nuclear reactions. With beams of ^{13}N and ^{14}O, one can study the same reactions that occur in the interior of an exploding star. By colliding "mirror" nuclei such as ^{13}N and ^{13}C, it is possible to examine the effects of proton-neutron symmetry on the structure of nuclear excited states in new ways. Beams of ^{14}O and ^{15}O at energies just sufficient to overcome the Coulomb repulsion of nuclei permit experiments on the mechanisms of nuclear fusion. The prospects for research with a facility of this type, which will offer beams with high-energy resolution, continuous duty factor, and availability in all external beam lines at the 88-Inch Cyclotron, are of current interest to the community of low-energy nuclear physicists.



Conceptual diagram of exotic beam production. Unstable heavy atoms from the production target are ionized in the ECR source and accelerated by the 88-Inch Cyclotron for use in nuclear physics experiments.

Along with the purchase of a cyclotron of the type designed for producing medical isotopes, the project involves research and development on the target and ion-source systems. Indeed it is here that the technical challenges lie. The production of these beams will require extensions of present technology to higher power levels and to greater efficiency. Some of the technical problems to be solved both in the production of the radioactive beam and its use in practical experiments are similar to those that will be encountered with a future high-intensity facility. The proton and deuteron beams presently available from the 88-Inch Cyclotron can play an important role in this R&D effort.

The design and R&D required for the targets, ion source, and the shielding are underway. The cost of this project is estimated at $7.5 M, including the high-current cyclotron. With FY 1993 capital funding, operation for research will begin in FY 1995.

Exotic Beam Facility at the 88-Inch Cyclotron
Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.4	1.0	4.6	1.0	0.5	0.0	7.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

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 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 greatly 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 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 human genome research throughout the scientific community and to provide the computational foundation for the Human Genome Laboratory.

Develop the novel data-management techniques needed for map and sequence data. 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 separating large DNA fragments, up to the size of intact human chromosomes. Methods for direct imaging of electrophoresis gels using modern nuclear radiation detectors or optical and ultraviolet imaging systems will be explored, as will methods of manipulating, dissecting, and sequencing individual DNA molecules; and
- Structural and functional interpretation—interpret DNA codes 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 in close collaboration with 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 accelerate rapidly during the next two years, reaching a level of about 50 FTEs. During the following three years, the program will double to 100 FTEs. 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 37,000 gsf of light-laboratory space with functions dedicated to the conduct of mapping, cloning, and sequenc-

Computerized robotics speed repetitive tasks for mapping and sequencing DNA at LBL. Effective development and application of software and hardware to this problem requires multidisciplinary teams of biologists, computer scientists, and electrical and mechanical engineers. The Human Genome Laboratory would provide the necessary facilities to advance this effort.

ing activities along with integrated instrumentation, computation, and related support facilities.

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

Category	1991	1992	1993	1994	1995	1996	Total
Operating	5.0	6.0	7.0	8.0	10.0	10.0	46.0
Construction	0.0	1.7	6.6	6.0	6.0	0.0	20.3

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

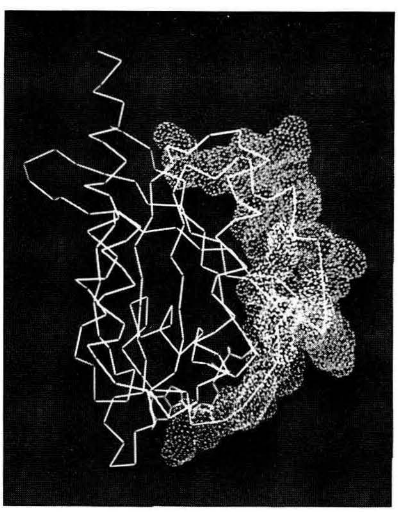
ALS Life Sciences Center

New applications of advanced imaging and diffraction techniques will greatly strengthen DOE's emerging national program in Structural biology. The Advanced Light Source (ALS) Life Sciences Center—a proposed national OHER user facility—is a centerpiece of this program. Complementing this facility, a structural biology research program is being formulated to develop research consortia at the ALS, initiate new collaborations, and conduct an international scientific program. Strengths at LBL include x-ray microscopy, holography, 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 macromolecular structure and subcellular architecture.

The ALS will offer major new opportunities for life sciences research in several emerging areas of scientific emphasis:

- **X-ray microscopy—element-specific maps and holograms of unaltered tissues, cells, and organelles that may approach macromolecular resolution;**
- **X-ray spectroscopy—determination of biochemical properties at high spatial and temporal resolution within cells and organelles; and**
- **Diffraction and scattering—static and dynamic analysis of macromolecular architecture with precise tuning and polarization.**

Diagram of a RAS oncogene protein, whose structure was largely elucidated through x-ray crystallography from a synchrotron radiation source. The region of change in surface shape that triggers cell growth is superimposed over the amino acid backbone.



To respond to these exciting scientific opportunities for DOE, an ALS Life Sciences Center is proposed to consist of operating support, fabrication of two insertion devices and their associated beam lines, and development of laboratory support space for visiting scientists and LBL personnel. The Center will facilitate use of the ALS by several communities of scientists, including those that may be unfamiliar with advanced photon techniques developed in the life sciences. These communities include:

- General users in the biological science community, both external and internal to LBL, who have shorter-term interests in the application of synchrotron radiation with needs for specific analytical tasks and who may have a limited physics background;
- Life scientists outside the Laboratory who are committed to longer-term research programs centered around the use of synchrotron radiation and who are typically more involved in the development of advanced instrumentation; and

- LBL-based scientists, either permanent or on a short-term appointment, who are actively using or developing the use of synchrotron light for biomedical research.

Research at the Center will be focused on experimental stations, initially at the ends of the two beam lines. The first beam line, from an undulator source of ultrabright soft x-rays, will illuminate two scanning x-ray microscope stations, one available for biological microscopy and the other for developing advanced microscopy techniques. The second beam line, 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 construction funds identified below will be for fabrication and development of these beam lines.

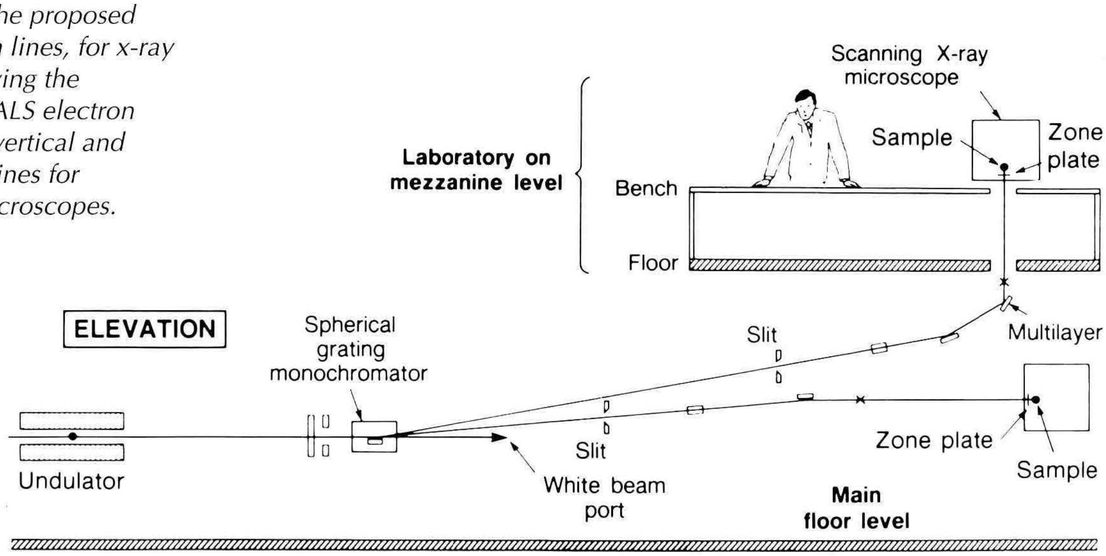
Support areas for the beam-line research activities are needed for preparation of fresh specimens, using complex sample-handling systems, and the evaluation of specimen materials following beam-line studies. These support areas will require a light- and electron-microscopy laboratory, a cell- and tissue-culture facility, animal-handling areas, a biochemistry laboratory, and computer facilities. These support laboratories and offices will be constructed adjacent to the electron-storage ring. Complementing this user facility, a collaborative structural biology research program is proposed, as described below.

ALS Life Sciences Center Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	1.1	2.0	2.7	3.2	3.5	3.5	16.0
Construction	0.0	4.7	14.8	9.1	0.0	0.0	28.6

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

Layout of one of the proposed life sciences beam lines, for x-ray microscopy, showing the undulator (in the ALS electron storage ring) and vertical and horizontal beam lines for scanning x-ray microscopes.



Biomedical Heavy-Ion Center

In support of the goals of OHER to use DOE's unique scientific and technological capability to solve major problems in medicine and biology, LBL is proposing the development of a Biomedical Heavy-Ion Center. The Center would advance a U.S. program of clinical and radiobiological research using beams of heavy ions. This program has been pioneered at the Bevalac, promises significant improvements to conventional medical technology, and offers insights into the mechanisms and risks associated with environmental radiation. The scientific goals of the facility are to:

- Carry out a long-range program of clinical testing and development to establish and improve the efficacy of heavy ions for radiotherapy and radiosurgery for the treatment of cancer and other diseases. Initial trials at LBL indicate that heavy ions have local control rates between 50% and 90% for certain tumor sites (despite the advanced condition of the neoplasms treated in these trials); and
- Conduct radiobiology research for treatment planning and evaluation of the risk of radiation-induced carcinogenesis. As a complement to the clinical research program, research would improve beam-delivery techniques, deepen the understanding of the mechanism of cancer induction, and define risks and mitigation from exposure to ionizing radiation in a range of environments.

Heavy ions have unique advantages for radiotherapy compared to conventional megavoltage x-ray treatment techniques and potential advantages over proton treatment methods. Because they ionize atoms more efficiently as they slow down, each ion deposits a high dose near the end of its path, aiding precise dose control and localization. In addition, the biological effectiveness of the delivered radiation for tumor control is high because the ionizing tracks of heavy ions deposit a large amount of energy into a small critical volume of a cell. In light of these advantages, the feasibility of a Biomedical Heavy-Ion Center has been studied by LBL, and the Laboratory proposes an OHER research facility that would provide:

- **A biomedical research accelerator** for radiotherapy, radiosurgery, and radiobiology. This new system would be fabricated at the site of the Bevalac. This modern synchrotron would be designed for efficient delivery of elements as heavy as neon with sufficient energy to penetrate 30 cm of biological tissue;
- **A research support and clinical research area,** with instrumentation for patient dosimetry control, beam manipulation, and radiobiological research. These systems would provide patient handling, radiation treatment control, and dose delivery to conform to tumor volumes; and
- **Facility operations support** for the accelerator and beam delivery systems. Facility operations would safely deliver stable and reliable beams to patients and experimental stations. Operating resources would include electrical, mechanical, control, and safety systems operations; quality assurance; and facility maintenance.

The Biomedical Heavy-Ion Center would be a major national asset for research during the late 1990s and into the 21st century. It would make possible a continuing program of basic heavy-ion biomedical research dedicated to broad national research goals, including the scientific missions of DOE, the National Cancer Institute, and the National Aeronautics and

Space Administration. The Center is at the early planning stages, and the projected schedule of resource requirements below represents a preliminary estimate for facility construction and operations. The overall level of Laboratory radiation medicine research would not be significantly expanded beyond current operations.

Biomedical Heavy Ion Center Resource Requirements ($ M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	0.0	0.0	0.5	2.5	4.0	8.0
Construction	0.0	0.0	0.0	0.0	7.0	18.0	25.0

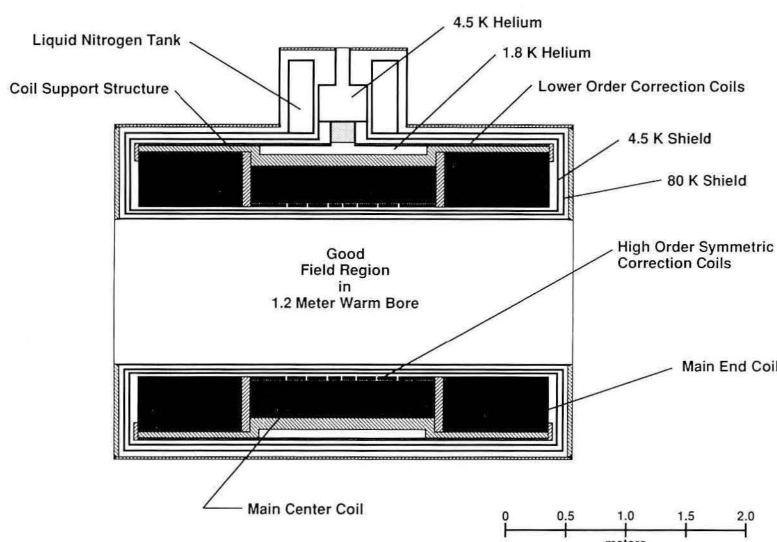
[a]Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars) through FY 1996.

10-Tesla Imaging Spectrometer

To advance significantly the field of diagnostic medical imaging and to reveal underlying biochemical mechanisms of disease, LBL is working with OHER to develop a 10-T Imaging Spectrometer. NMR spectroscopic imaging of ^{1}H, ^{13}C, ^{31}P, and other nuclei promises to yield otherwise unobtainable information on metabolic processes and anatomy in healthy and diseased humans.

The 10-T Imaging spectrometer will operate at five times the magnetic field of instruments currently available for human studies, achieving a signal-to-noise ratio per unit observation time that is five times greater, or reducing the time required to reach a given signal-to-noise ratio by 1/25. The time reduction is particularly important in medical studies, as the patient must be immobilized for the duration of the experiment.

The 10-T instrument will employ a 60-cm magnet and will serve as a prototype for future larger bore systems. The magnet will be large enough to accommodate the human head, providing a platform for studies of brain and tumor metabolism, cerebral blood flow, and brain anatomy, and will



Cross section of the proposed 10-Tesla whole-body magnet for nuclear magnetic resonance imaging and spectroscopy. This magnet design provides a field homogeneity of one-tenth of a part per million over a 0.4-meter diameter in the warm bore, which, together with the field strength, yields unprecedented spectroscopic resolution.

allow the technology necessary for NMR spectroscopic imaging at 10 T to be demonstrated before investing in the large cost of a large-bore (120-cm) magnet.

10-Tesla Imaging Spectrometer Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	0.5	5.0	1.0	0.25	0.25	7.0
Construction	0.0	0.0	0.5	0.0	0.0	0.0	0.5

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

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 effort 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 at other institutions, for example on cloud properties, 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 region, primarily forests and semi-arid areas; and
- Clarification of the relative contributions of anthropogenic sources of greenhouse gases (e.g., nitrous oxide, methane, and CFCs (chlorinated fluorocarbons).

The effort is coordinated by LBL's Center for Atmospheric and Biospheric Effects of Technology. Resource requirements projected for the program follow.

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

Category	1991	1992	1993	1994	1995	1996	Total
Operating	1.0	1.5	2.0	2.4	2.4	2.4	11.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

CONSERVATION AND RENEWABLE ENERGY

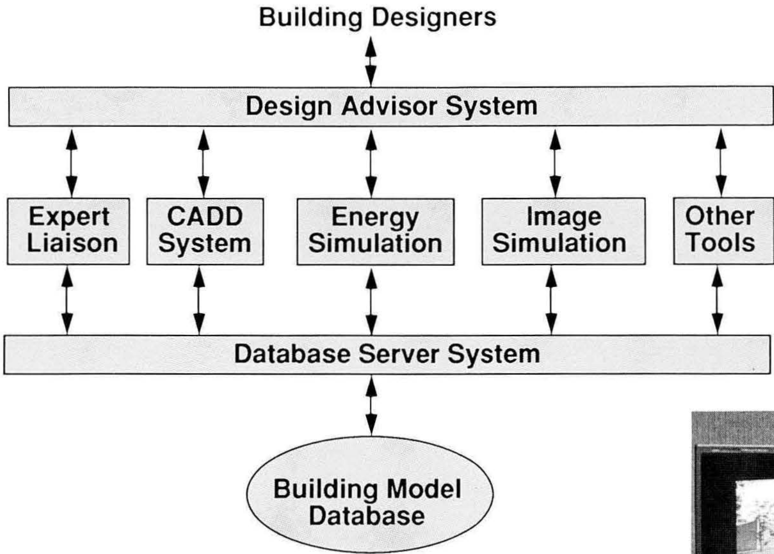
Advanced Energy Design and Operation Techniques

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. The design system would integrate new computer-aided design (CAD) systems with sophisticated graphics, expert systems, and computer-accessible mass storage. Activities underway at LBL coupled to the initiative include:

- The Energy Kernel System (EKS), the next-generation whole-building energy-simulation program;
- Computer-generated visualization of interior lighting and daylighting;
- Studies of innovative window lighting, ventilation, and indoor air quality and other research on appurtenances and design;
- User-friendly interfaces, CAD/CAM systems, and large data bases; and
- Exploratory research on expert systems for buildings.

AEDOT methods 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 integrate energy efficiency, building structure, and other design elements directly into architectural systems. Advanced simulation and imaging technology would provide accuracy and 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 to the building industry, since energy efficiency is often being 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.



A prototype workstation for advanced computer-based building design. A simulated video building tour can be conducted through a moving icon on plan drawings.

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

Category	1991	1992	1993	1994	1995	1996	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 Budgetary Authority (FY 1991 dollars).

Superconductivity Research and Technology Program

LBL is proposing to the Office of Conservation and Renewable Energy a research program on high-critical-temperature superconductors for applications in electric power systems. The program comprises three component stages:

- **Fundamental research relevant to the development of practical, high-current conductors based on high-T_c superconducting materials;**
- **Design and engineering of the conductors; and**
- **Engineering and fabrication of prototype magnets. These component activities will be initiated in a phased program, influenced by the current state of understanding of the superconductors and the progress made during each stage of research and technology development.**

The first stage includes research on conductors based on deposition of thin films: the investigation of techniques for fabrication of films of the high-

T_c superconductors and of suitable layers of reaction barriers and coatings for proper mechanical and electrical properties. Investigations of the use of metal cladding as an aid in controlling formability, providing thermal and electrical stability, and as an approach to making electrical contact to other circuit elements will be carried on in parallel. Characterization of these conductor elements and correlation of their properties with fabrication methods are important parts of the program.

The second stage will include long-length conductor design and engineering development to address the problems associated with tensile strength, uniformity, and other suitable mechanical properties. Alternative approaches to multilayers, metal matrices, and coatings will be studied. Properties such as elasticity and thermal expansion that affect mechanical failure will also be investigated.

Research on conductors will be coupled to the design of prototype magnets. Magnets of many types are used for motors, generators, magnetic energy storage, magnetic imaging, particle accelerators, and in a variety of research applications. Each magnet design has specific electrical conductor requirements. The development of the coils and conductors for specific applications permits optimization of the total system. Coil construction and testing will involve industrial participation to develop and evaluate conductor winding, coil compression, field uniformity, and other engineering and fabrication issues.

The program will be coordinated with existing LBL research in (1) ceramic materials and thin-film deposition techniques funded by the Office of Basic Energy Sciences, (2) thin-film technology funded by the Office of Conservation and Renewable Energy, and (3) superconducting magnet technology funded by the Office of High Energy and Nuclear Physics. The research program will complement the activities currently being conducted in the Center for Thin-Film Applications and will be coupled to LBL's technology transfer programs.

Superconductivity Research and Technology Program Resource Requirements ($M)[a]

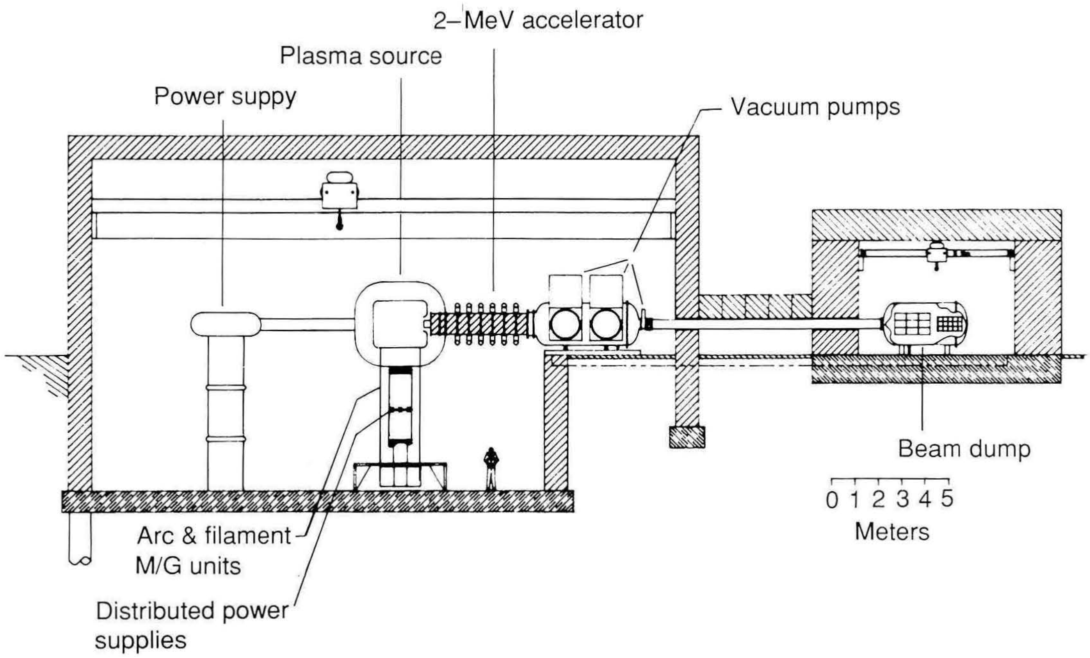
Category	1991	1992	1993	1994	1995	1996	Total
Operating	1.0	1.5	1.5	1.5	2.0	2.0	9.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

FUSION ENERGY

Test Facility for Accelerators

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 Test Facility for Accelerators is composed of power supplies, plasma source, vacuum systems, and beam dump. The facility uses some existing LBL structures and can be readily expanded to a scaled-down ITER neutral beam injector beam line.

The International Thermonuclear Experimental Reactor (ITER), a proposed next-generation tokamak to be built by a multinational collaboration, would 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^0 ion sources and high-voltage dc accelerators. LBL is now investigating the possibility of a major ITER neutral-beam development project, including a new accelerator test facility for conducting a proof-of-principle accelerator demonstration.

1.3-MeV Neutral-Beam Injector Resource Projections ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	9.8	26.6	1.2	1.2	1.2	1.2	40.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

Environmental Restoration Research Program

In support of DOE's efforts to restore the environment and better manage wastes at DOE facilities nationwide, LBL is proposing a program of near-term innovative technology development and demonstration projects. This multidisciplinary program is being advanced in conjunction with the UC Berkeley campus and is directed toward high-priority environmental restoration and waste-management problems. Among the technology development projects included in the Laboratory's initiative are:

- **In-Situ Containment Technologies**. A program of evaluation and development of in-situ techniques for permanent and temporary containment of waste forms prevalent at DOE sites is proposed. Technologies under study include flow-through in-situ treatment systems, electro-osmotic barriers, and geochemical barriers.
- **In-Situ Remediation and Removal**. Specialized methods for removing contaminants without excavation will be developed based on innovative application of petroleum industry and microorganism-based technologies. New technology concepts include: controlled steam-flooding methods employing remote steam-front imaging; steam-form stripping and flushing; and accelerated bioremediation/biodetoxification.
- **User Demonstration Field Facility**. The development of test sites is proposed for experimental facilities that will evaluate, demonstrate, and validate containment, remediation, and removal technologies. The test sites will serve as resources for Environmental Restoration and Waste Management contractors and Research Development Demonstration, Testing, and Evaluation research program participants.
- **Health and Ecotoxicological Risk Assessment**. Advanced methods for human and ecotoxicological risk assessment, for realistically prioritizing remediation strategies, will be developed from first principles. Methods will be developed for realistic dose and exposure estimates, worker exposure biomarkers, soil toxicity characterization, and accurate exposure effects predication.

In addition to these project areas, programs of technology support and assistance to DOE and for a University consortium for research, training, and education are proposed. Technical assistance to DOE contractors, field offices, and headquarters staff will be coupled to the applied research program and technology development elements summarized above. The interdisciplinary educational program will provide faculty and graduate training in support of DOE's Environmental Restoration and Waste Management (ERWM) goals and include a visitors program for industrial scientists and engineers, academic staff, and postdoctoral scholars. A fellowship program will focus graduate and undergraduate students on ERWM research and technology development issues.

Environmental Restoration Research Program Resource Projections ($M)[a]

Category	1990	1991	1992	1993	1994	1995	1996	Total
Operating	2.9	9.6	14.9	16.9	16.9	16.9	16.9	95.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Environmental Restoration Site Projects

To correct and restore environmental conditions at LBL and to improve the management of waste-handling operations, the Laboratory has prepared a systematic and prioritized plan in support of DOE's national environmental restoration and waste-management goals. The plan responds to specific conditions at the Laboratory, including facilities and operating programs for management of conditions in soils, water, and air. The plan is focused on three Environmental Management (EM) programs for restoration and management activities:

Environmental Restoration

- An assessment, characterization, and remediation of chemical contamination of soils and groundwater and the closure of the existing LBL hazardous waste-handling facility;

Corrective Activities and Waste Management

- A corrective action program to achieve and maintain required exposure and risk levels to chemicals in soils, groundwater, and air and in discharges to sewers. Essential corrections are to laboratory ventilation systems, deionization systems, sanitary sewer systems, chemical storage tanks, and wastewater treatment units; and
- A waste-management program for continuity of operations, waste minimization, sewer systems assessment and replacement of deteriorated pipe, and the construction of a new hazardous-waste-handling facility.

The five-year program is vital for full 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 estimated budgetary authority indicated below is consistent with DOE budget guidance and is also included in the resource projections in Section 9. These resources do not include maintenance projects and other upgrades funded through LBL institutional resources.

Environmental Restoration Site Projects Resource Projections ($M)[a]

Category	1990	1991	1992	1993	1994	1995	1996	Total
Operating	1.0	6.6	5.2	4.8	4.2	3.9	3.3	29.0
Construction	1.7	1.2	5.8	5.9	5.2	6.2	0.0	26.1

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

MULTILABORATORY COLLABORATION

Large Einsteinium Activation Program

The Large Einsteinium Activation Program (LEAP) has been proposed by a consortium of four national laboratories—Lawrence Berkeley, Lawrence Livermore, Los Alamos, and Oak Ridge. The program is a response to the recommendations of the National Research Council Workshop on Future Directions in Transplutonium Element Research requested by the Office of Basic Energy Sciences. Central to the proposal is the preparation of a large (30–40 micrograms) target of ^{254}Es to accomplish a unique scientific program:

- Produce new neutron-rich isotopes of the heaviest elements by bombardment of the ^{254}Es target with neutron-rich heavy ions (^{18}O, ^{22}Ne, ^{48}Ca) for study of nuclear properties, especially spontaneous fission, at the extreme limits of nuclear stability;
- Prepare sufficient quantities of the heaviest actinides and transactinides from appropriate heavy-ion bombardments for studies of their chemistry; and
- produce new superheavy elements.

The ^{254}Es target will constitute an international scientific resource. A program committee will review research proposals from consortium members and outside users. The LEAP initiative would provide an opportunity to explore the frontiers of heavy isotopes and new elements, providing insights into the ultimate limits of nuclear stability and relativistic effects in the heaviest elements. Such studies provide rigorous training for the graduate students in chemistry and physics needed to maintain U.S. capabilities in nuclear fields.

Large Einsteinium Activation Program Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	0.5	0.8	1.1	0.9	0.8	4.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

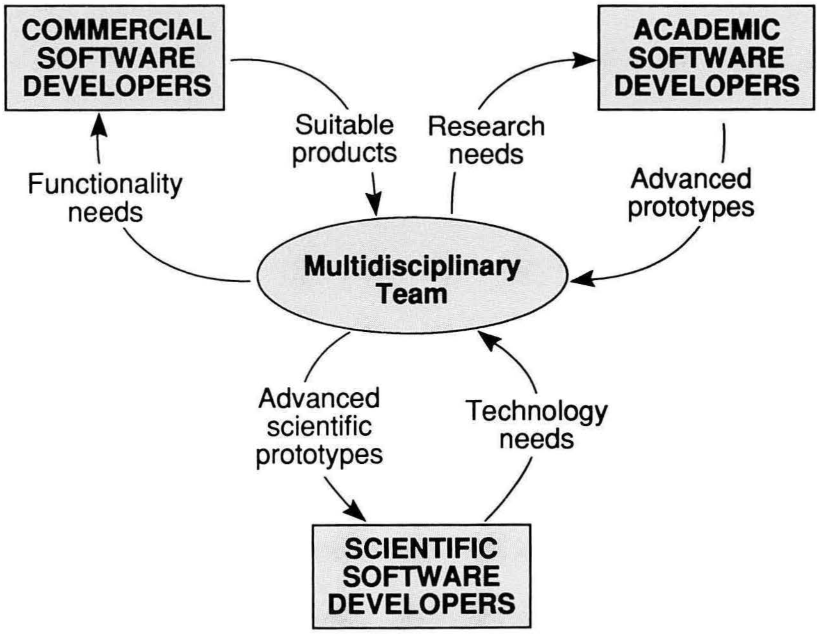
[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

EDUCATION/TECHNOLOGY TRANSFER INITIATIVES

Cooperative Approach to Software Advancement

The primary goal of the Cooperative Approach to Software Advancement (CASA) initiative is to enhance DOE and other federal research through the development and distribution of advanced computation tools. 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 be-

CASA will be conducted by an LBL-led multidisciplinary team working with commercial, academic, and scientific software developers. The result of these interactions will improve scientific functionality for commercial software developers and provide high-quality, interconnective software for scientific and technical applications.



tween successful federal scientific research and enabling high-performance computing. Further, the initiative stresses the importance of the U.S. computer industry to the national economy.

CASA will produce an advanced scientific research environment based on modern multi-window workstations, supporting special-purpose scientific software, together with object-oriented commercial software. These workstations will provide the human interface to a large distributed computer system consisting of workstations, mid-range computers, mass storage systems, and supercomputers. These would be connected locally by high-speed networks and nationally by the Energy Sciences network. The success of the CASA initiative will rely heavily on the cooperation of researchers and computer scientists in government, industry, and academia; more than 10 firms have become involved in the planning stage.

The CASA environment will significantly accelerate large scientific research in programs including many government-sponsored research programs. The improved utility, interconnectivity, and marketability of commercial software packages will increase the international competitiveness of the U.S. computing industry.

The program will serve as the umbrella for a number of related projects, of which the first two have been identified: a Fault Detector System for High-Energy Physics particle detectors, and a Software Environment for Magnet Testing for the Superconducting Super Collider. One or two additional CASA projects would be initiated during each of the following fiscal years. Each CASA project is expected to last about four years. The CASA program would be managed at LBL.

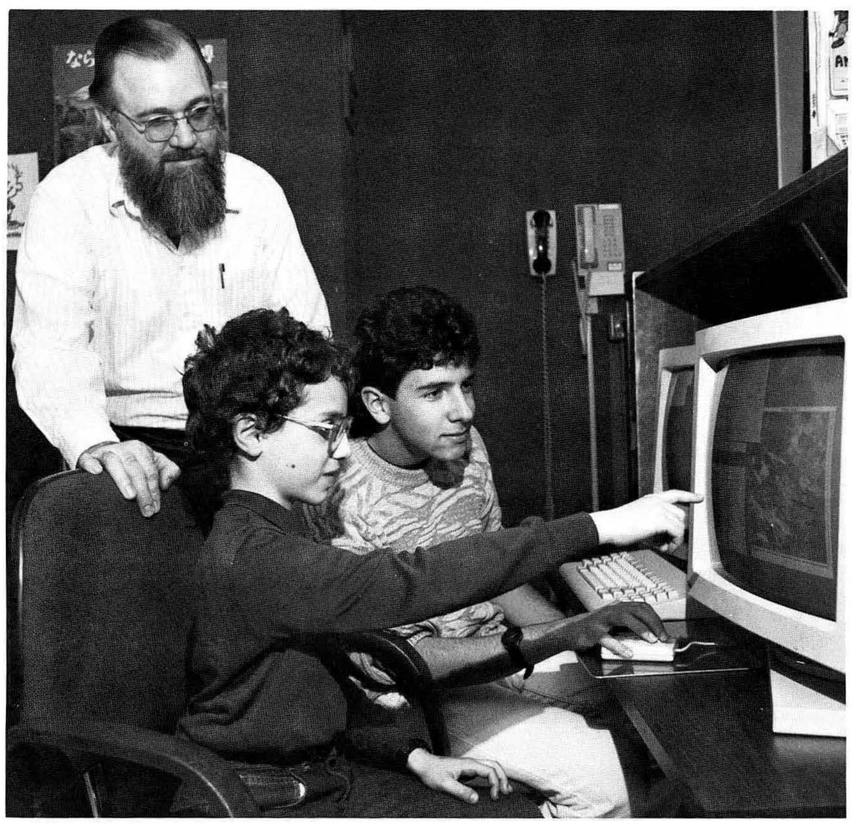
Cooperative Approach to Software Advancement
Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	1.5	2.0	2.5	3.0	3.0	3.0	15.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

Faculty/Student Experiment and Teaching Laboratory

The primary purpose of the Faculty/Student Experiment and Teaching Laboratory (FSETL) is to leverage the human and physical resources of LBL to improve math, science, and technology education. Critical problems addressed by the proposed laboratory are the female, minority, and economically disadvantaged students in northern California schools who are being lost to science and engineering because of lack of resources, motivation, or quality of experience. FSETL can provide the physical and programmatic support necessary for underprepared students and teachers to make the transition into existing LBL research opportunities. Goals of FSETL are to improve the quality of the initial science experience, to increase retention of students in the science pipeline, and to provide equity in access to scientific careers. FSETL would provide a support system for inner city



A principal investigator in LBL's Information and Computing Sciences Division works with high school science students. FSETL would provide a working area to support on-site demonstrations and transitional research activities to allow these experiences to reach a broad range of science and math students and teachers.

science educators, including those from Oakland, Richmond, Berkeley, and other East Bay communities.

FSETL will provide an addition/renovated space for a light laboratory for 20–30 faculty and students. This flexible resource will allow focused exercises and demonstrations as a transition to a full research experience in LBL's program laboratories. For some groups, this environment will be the primary initial science exposure. It will act as a transition facility for others, to provide a phased approach to access LBL's research facilities. Focused demonstrations proposed include low-power laser demonstrations and exercises, a small scanning electron microscope, and other tools and equipment developed or used in LBL's scientific programs. The laboratory staff would also include a small support staff and in many cases those involved in the conduct of LBL programs, as resources for managing and conducting programs.

FSETL will require a capital investment to create an experiment and teaching laboratory within LBL. Construction and equipment costs of $2.0 M over two years are expected. The annual operating budget would be required for support of technical staffing of FSETL, administrative support in Center for Science and Engineering Education, and program expenses.

Faculty/Student Experiment and Teaching Laboratory Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	1.2	1.2	1.2	1.2	1.2	1.2	7.2
Construction	0.0	0.0	1.0	1.0	0.0	0.0	2.0

[a] Preliminary estimate of LBL Budgetary Authority (FY 1991 dollars).

GENERAL-PURPOSE FACILITIES

To modernize and improve the safety of technical support facilities, several general-purpose building initiatives are proposed within the period covered by this plan. These initiatives include constructing a Safety and Support Services Facility and Mechanical Engineering Replacement Projects.

Safety and Support Services Facility

Laboratory support service facilities are inadequate and inefficient due to obsolete design and substandard construction. A general-purpose building, the Safety and Support Services Facility, would mitigate these limitations by correcting inadequate physical resources for safety services and maintenance needs. The LBL environmental health and safety functions, chemicals and materials management, and instrumentation maintenance would be located in this structure. The Environmental Health and Safety Department (EH&S) personnel would be relocated from a temporary trailer complex. Engineering would vacate an obsolete World War II era wooden building. Materials operations, located in three buildings, would be consolidated to satisfy DOE support requirements more effectively.

The proposed facility would be attached to existing Building 69, which houses materials purchasing and transport. The activities are closely allied with the EH&S Department and safe-materials-handling functions. Buildings vacated by these groups would be removed or demolished, offsetting the new construction.

Safety and Support Services Facility Resource Requirements ($M)[a]

Category	1991	1992	1993	1994	1995	1996	Total
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.6	3.0	4.7	0.0	0.0	8.3

[a] Estimate of actual year LBL Budgetary Authority.

Chapter

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 and a nationally oriented research program. In addition, other DOE offices, including the Nuclear Regulatory Commission, will support LBL programs. Work for Others (WFO) supports less than one-fifth of the Laboratory's programs. This section summarizes current LBL research programs, including anticipated program trends.

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

Major Program/Office	1989	1990	1991	1992
Office of Energy Research	150.1	158.0	170.8	182.1
Conservation & Renewable Energy	13.6	13.8	16.7	17.6
Fossil Energy	1.7	1.5	1.8	1.8
Environmental Restoration & Waste Mgt.	3.4	3.4	7.8	11.0
Other DOE	29.7	22.6	20.9	20.5
Work for Others	30.5	35.0	36.7	37.5
Total	**229.0**	**234.3**	**254.7**	**270.6**

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.

- The Laboratory's contribution to national efforts in the Basic Energy Sciences (BES) includes constructing the Advanced Light Source (ALS) and developing advanced user facilities to support scientists in chemistry, biology, materials research, physics, and other fields.
- In the context of an advancing national program in Health and Environmental Research, LBL is initiating a human genome program and will strengthen structural biology programs and programs in atmospheric and subsurface environment research. The biomedical program will improve diagnostic imaging systems and elucidate the metabolic basis of disease.
- LBL scientists and users from throughout the world will continue the vigorous research program at the 88-Inch Cyclotron and the Bevalac. The 88-Inch Cyclotron with its new Electron Cyclotron Resonance (ECR) ion source provides the highest flux of heavy ions of any low-energy accelerator in the U.S. The planned exotic beam facility would open up new research opportunities. The Bevalac will continue its pioneering studies of nuclear matter and contribute to advances in atomic physics, biomedical research, and related fields. The relativistic heavy-ion research program will be pursued with lead beams at CERN and with a major experiment at the Relativistic Heavy-Ion Collider (RHIC).
- High-energy physics research will continue with sophisticated detectors at forefront facilities, including the Mark II at the Stanford Linear Collider (SLC), and the D-Zero and Collider Detector at Fermilab (CDF). New detector programs for the SSC, research in particle astrophysics, and planning activities for a B factory will potentially expand in the near term.

- In support of the national fusion research goals, base programs may potentially expand in heavy-ion-fusion accelerator research for inertial-confinement fusion and in neutral-beam development for magnetic-confinement fusion. LBL's 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. Expanded program activity in CAM is anticipated in thin-film research, studies of wear and mechanical properties of surfaces, electronic device packaging, 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 atomic resolution and analytical studies are proposed to maintain the nation's research leadership.

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	1989	1990	1991	1992
Basic Energy Sciences	63.7	69.3	71.5	67.8
Nuclear Physics	38.7	37.1	41.3	47.7
High-Energy Physics	25.6	22.2	22.3	23.3
Biological & Environ. Res.	13.5	17.5	17.9	18.8
Magnetic Fusion	2.6	2.2	2.3	2.4
Univ. Research Support	1.4	1.8	1.8	1.9
General Purpose Facilities	4.6	5.3	7.7	12.1
Supercond. Super Collider	0.0	2.6	6.0	8.1
Total	**150.1**	**158.0**	**170.8**	**182.1**
Percent of LBL Total	**65.5**	**67.4**	**67.1**	**67.3**

Basic Energy Sciences

LBL has become one of the world's leading centers of research on 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.

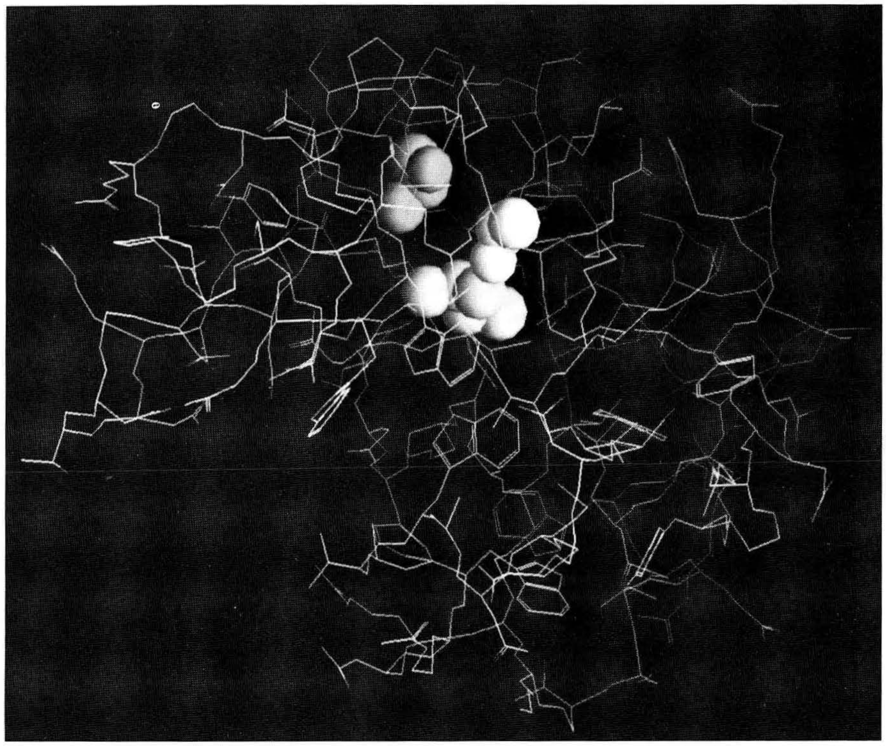
Materials Science

BES programs in Materials Sciences will continue to emphasize forefront research projects that analyze existing materials, develop and characterize advanced materials such as high-temperature superconductors, and explore materials-processing systems. Expanded areas include design and construction of advanced sources of synchrotron radiation and advanced materials development. Leading programs continue in x-ray optics, electron microscopy, solid-state physics, surface science, metallurgy and ceramics, and materials chemistry. The ALS, a third-generation synchrotron radiation facility that will produce the world's brightest beams of ultraviolet and soft x-ray radiation, will be completed in FY 1993. The ALS, CAM, Center for X-Ray Optics, NCEM, and the Superconductivity Research Center for Thin-Film Applications 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, beam-line optical systems, and magnet systems. At the Center for X-Ray Optics, research is conducted on advanced optical-system components for the utilization of high-brightness photon beams.

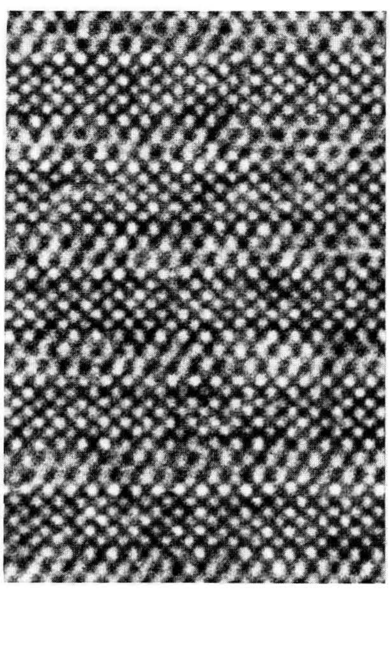
The Center for Advanced Materials will continue major research efforts that are vital to U.S. industrial strength. Six research programs are continuing, including the new research program on high-temperature superconductors: the Surface Science and Catalysis Program focuses on the synthesis and molecular-level understanding of heterogeneous catalysts, including zeolites and related compounds; the Electronic Materials Program addresses technical obstacles to industrial development of very-large-scale gallium arsenide integrated circuits; the Polymers and Composites Program investigates relationships between processing and microstructure, focusing on enzymatic synthesis, anisotropic materials, surface interactions between polymer liquids and metals, and computational tools; the High-Performance Metals Program advances the development of light alloys, including low-density aluminum alloys (primarily in aerospace systems) and new alloys for advanced energy needs; and the Ceramics Science Program supports research on the design and processing of ceramic materials with enhanced properties. In addition, superconductivity research at LBL is a CAM program that includes the Center for Thin-Film Applications (described below) and related research programs. Programs on high-temperature superconducting materials includes synthesis and characterization, fabrication, theoretical studies, and studies of physical properties.

At the Center for X-Ray Optics, the development of high-brightness, partially coherent sources of x-ray and vacuum-ultraviolet (VUV) radiation will continue to inspire new means for transporting, focusing, dispersing, and detecting radiation with photon energies from approximately 10 eV to 10 keV. Continuing research programs involving collaboration with university, industry, and other national laboratories include: diffractive x-ray optics for x-ray lenses to scan and image materials; highly reflective multilayer coatings for hard x-ray spectroscopy; monochromator and spectrometer development; high-brightness x-ray source development; and x-ray holography research for three-dimensional imaging. The Center conducts



Enzyme engineering at CAM is providing the basis for increasing the thermal stability of biologically derived catalysts. Three amino acid substitutions, shown in space-filling form, have led to a corresponding threefold increase in the lifetime of lysozyme.

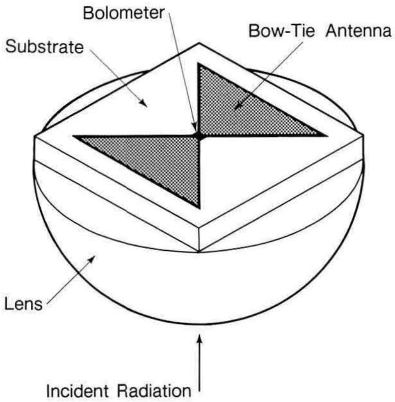
Stacking and edge defect structure of pulsed laser-deposited thin films have been observed directly by atomic resolution electron microscopy. The defects, resulting from nonequilibrium processing, may be responsible for higher critical currents compared to single crystals.



research on the fundamental interactions of x-rays with matter and develops advanced beam lines at national synchrotron facilities. Efforts include ALS insertion devices and beam lines, a VUV branchline at Stanford Synchrotron Radiation Laboratory, a soft x-ray photoelectron microscopy beam line at the University of Wisconsin Synchrotron Radiation Center, and coherent optics for an undulator beam line at National Synchrotron Light Source.

The National Center for Electron Microscopy, a user-oriented national facility, is part of the DOE Metallurgy and Ceramics Program and 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. Significant improvements in equipment are being proposed to maintain U.S. leadership in electron microscopy (Section 4).

Research on high-temperature superconducting materials is coordinated with the Superconductivity Research Center for Thin-Film Applications and includes studies of the microstructure of new oxides, such as structural changes near grain boundaries and analysis of stacking sequences. Research on the structure and properties of transformation interfaces has the goal of determining the atomic configurations at structural boundaries and the relationships between structure and properties at the interface. Research at NCEM is carried out on a wide range of materials, such as gallium arsenide (GaAs), amorphous silicon semiconductor materials, structural materials, magnetic materials, and ceramics.



A novel high-T_c thin-film microbolometer has been invented by LBL scientists. Infrared radiation is coupled efficiently to the bow-tie antenna through the lens and substrate. Such high-T_c bolometers may offer order-of-magnitude improvement in sensitivity compared to commercially available detectors.

LBL's Superconductivity Research Center for Thin-Film Applications serves as a focal point for research and information on thin-film applications of high-temperature superconductors. The Center assists in coordinating research conducted in several LBL units, including the Center for Advanced Materials, the Applied Science Division, the Accelerator and Fusion Research Division, and the National Center for Electron Microscopy. These activities include thin-film research on devices such as dc Superconducting Quantum Interference Devices (SQUIDS) and a conservation research program supported by DOE's Office of Conservation and Renewable Energy (see following sections). The thin-film program has produced high-quality thin films and devices that can be used for measuring instruments, radiation detectors, and electronic devices. A technology transfer effort for several devices is underway.

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.

Metallurgy and Ceramics

LBL projects on advanced alloys are directed at improving strength, failure resistance, and wear resistance. Projects include development of advanced metal alloys for energy and aerospace needs and studies of the effect of high magnetic fields and low temperature. The Laboratory's alloy theory program complements studies of alloy design and related research on permanent magnetism, mechanical properties, corrosion, and physical metallurgy.

Studies of high-temperature reactions focus on the kinetics and thermodynamics of solid-state decomposition reactions, which result in materials with a high energy content due to extremely large surface area. Several projects are oriented toward ceramic materials in an effort to understand particle consolidation and densification. The mechanical reliability of structural ceramics at high temperatures is investigated, with emphasis on the reasons for failure, such as creep rupture.

A new research program in magnetic materials is being proposed to provide information on structure, composition, and processing, with the objective of developing novel magnetic materials. The experimental approaches will emphasize quantitative magnetic characterization using unique imaging techniques, diffraction, and spectroscopy at high resolution.

Solid-State Physics

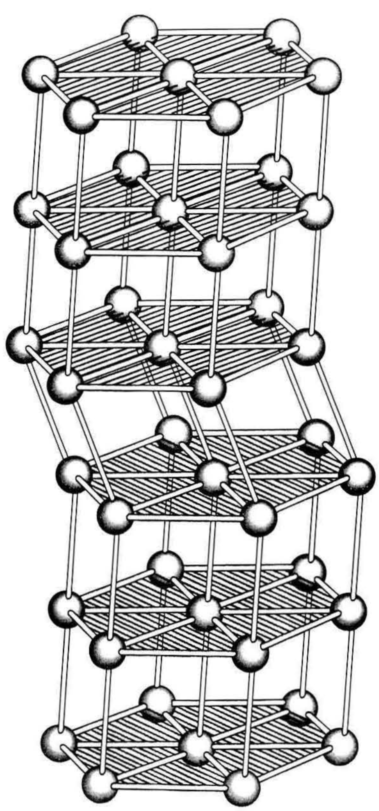
Solid-state physics research at LBL will continue with strong programs in both experimental and theoretical physics. Experimental research includes new far-infrared spectroscopy systems to develop technology to increase sensitivity of infrared measurements, including the use of high- critical-temperature superconducting films. Studies on optical second-harmonic generation further the understanding of lasers as probes of surface and interface systems. The properties of materials under pressure and structural phase transitions are studied using diamond-anvil techniques. Theoretical research has focused on applications of quantum-mechanical theory to study the properties of solids, clusters, and molecules.

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 extensively used.

Materials Chemistry

LBL will continue its strong contributions to materials chemistry, including studies of low-temperature properties of materials, 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, 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.

LBL scientists have predicted that, at high pressure, hydrogen gas is transformed into a monatomic metal with three repeating planes, as indicated in this diagram. Such a metastable metal may be superconducting at relatively high temperatures (230 K).



Chemical Sciences

DOE's Chemical Sciences Division supports focused research in several LBL divisions. Programs in the Chemical Sciences Division (CSD) emphasize chemical physics and catalysis, atomic physics, chemical-energy research, theoretical chemistry, and nuclear chemistry. Programs in the Applied Science Division focus on advanced combustion processes and the mechanisms for minimizing combustion emissions and improving fuel efficiency. In the Chemical Biodynamics Division, programs in photochemistry and the chemistry of electronically excited molecules are conducted.

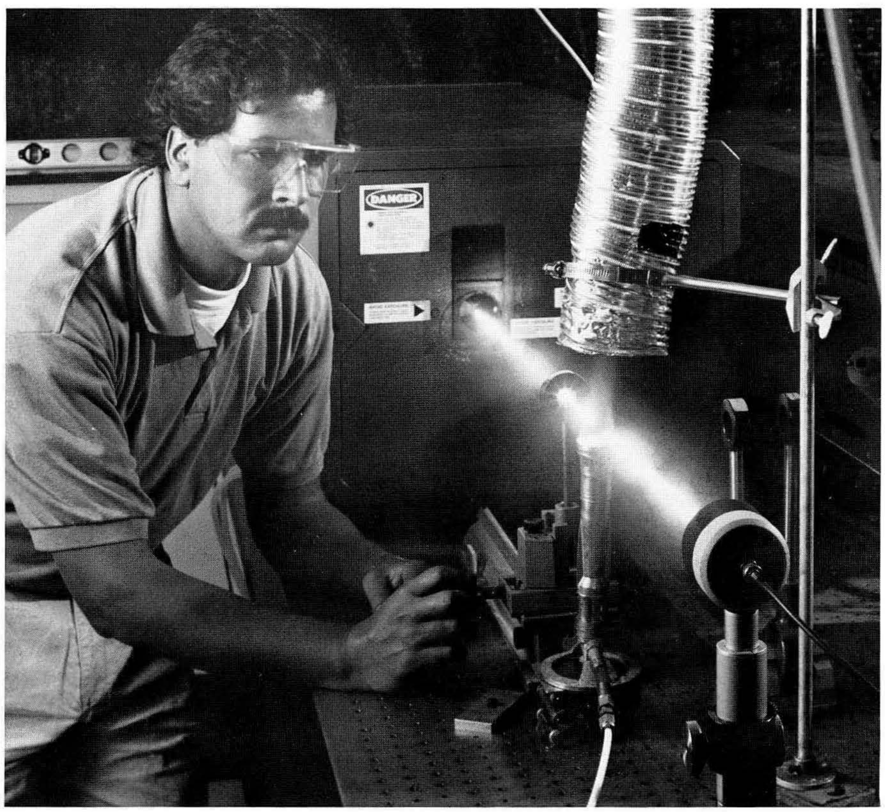
In CSD, the extensive chemical-physics research includes several major programs. In one, a study of the spectroscopy and structures of reactive intermediates, laser magnetic resonance is used to study reactive molecules, such as molecular ions and free radicals, that may be important in combustion processes, reactive plasmas, and astrophysical processes in interstellar space. 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.

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 nuclear chemistry in CSD focuses on the synthesis and safe handling of actinide materials. The program will continue its two thrusts: design and synthesis of sequestering agents for treatment of actinide poisoning and for possible application to spent reactor fuels, and the preparation of new compounds incorporating actinides.

Research in the Applied Science 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. Other areas of research include catalytic processes that could selectively remove nitrogen and sulfur from hydrocarbons, and laser-materials interactions for chemical analysis.

Research in LBL's Chemical Biodynamics Division is directed at a fundamental understanding of electronically excited molecules, with attention to features that relate to the storage of photon energy in the form of high-free-energy chemical bonds. Projects focus on the manganese catalytic function in artificial photosynthesis, the photoinduced reduction of CO_2 into



LBL's Combustion Research Group, sponsored by Basic Energy Sciences and the National Institute of Environmental Health Sciences, utilizes laser photofragmentation—laser-induced fluorescence techniques to measure toxic species that can be formed during the incineration of hazardous waste.

organic products, and polyelectrolyte interfaces for increasing quantum efficiency in photosynthetic processes. Other projects include infrared spectroscopy as a diagnostic tool, tuned laser excitation to map electronic-reaction hypersurfaces, and the storage of long-lived electronically excited molecules.

Engineering and Geosciences

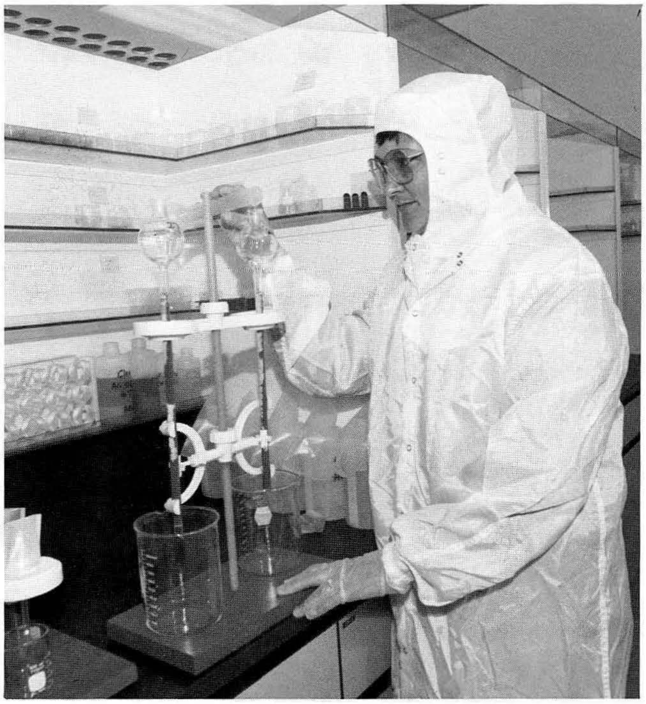
The Geosciences Program at LBL is strengthening its multidisciplinary effort to expand the scientific basis of many energy-related technologies, including safe disposal of radioactive and toxic chemical wastes, exploitation of geothermal energy, and development of petroleum and strategic-mineral resources. 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.

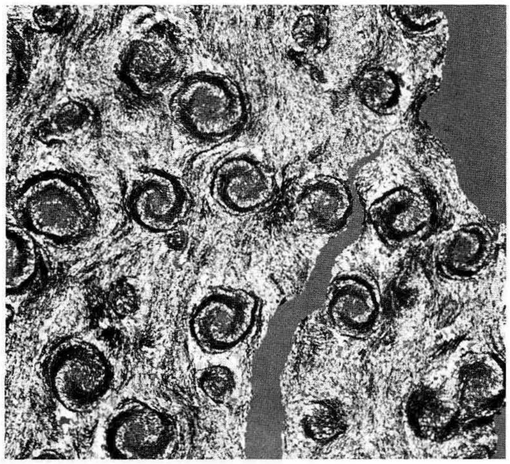
LBL is a key participant in the multiagency Continental Scientific Drilling Program (CSDP), with studies, either completed or underway, at the Valles caldera in New Mexico, the Salton trough, the Cajon Pass in southern California, and the Long Valley caldera in eastern California. Research at these sites has led to conceptual models of their structure and hydrothermal systems. The DOE-NSF-USGS interagency agreement for CSDP responsibilities emphasizes DOE's leadership in thermal-regime investigations.

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.

Evidence for the asteroid-impact hypothesis for biological extinctions through definition of trace-element time markers continues to accumulate. The possibility of several widespread extinctions with a periodicity of about 27 million years is being investigated, as is a related hypothesis that there is a dim companion star to the sun. These projects and a sky search to determine whether such a companion star can be observed are being conducted under collaborative BES support.

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.





Graduate students in LBL's Center for Isotope Geochemistry separate strontium from rock (top left) and prepare the strontium for isotopic analysis (top right) to reveal the age of rock formations, including the crystal growth rate of rotated garnet crystals in rocks deformed more than 400 million years ago (bottom). Ultraclean operation is required in order to precisely analyze small samples for unprecedented spatial resolution.

Geochemical studies focus on the properties of magmas and electrolytes, the generation and migration of petroleum compounds, the occurrence of abiogenic methane, 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.

Combustion research funded through DOE's Engineering and Geosciences Office has the objective of gaining fundamental knowledge for advanced controlled combustion systems for power plants and internal-combustion engines. Such systems offer improved thermal-energy conversion efficiency, minimized pollutant emissions, and optimized tolerance to a wide variety of fuels. Specific projects are directed toward eliminating local flame quenching, which is a source of undesirable combustion by-products, and advanced flame-jet ignition systems.

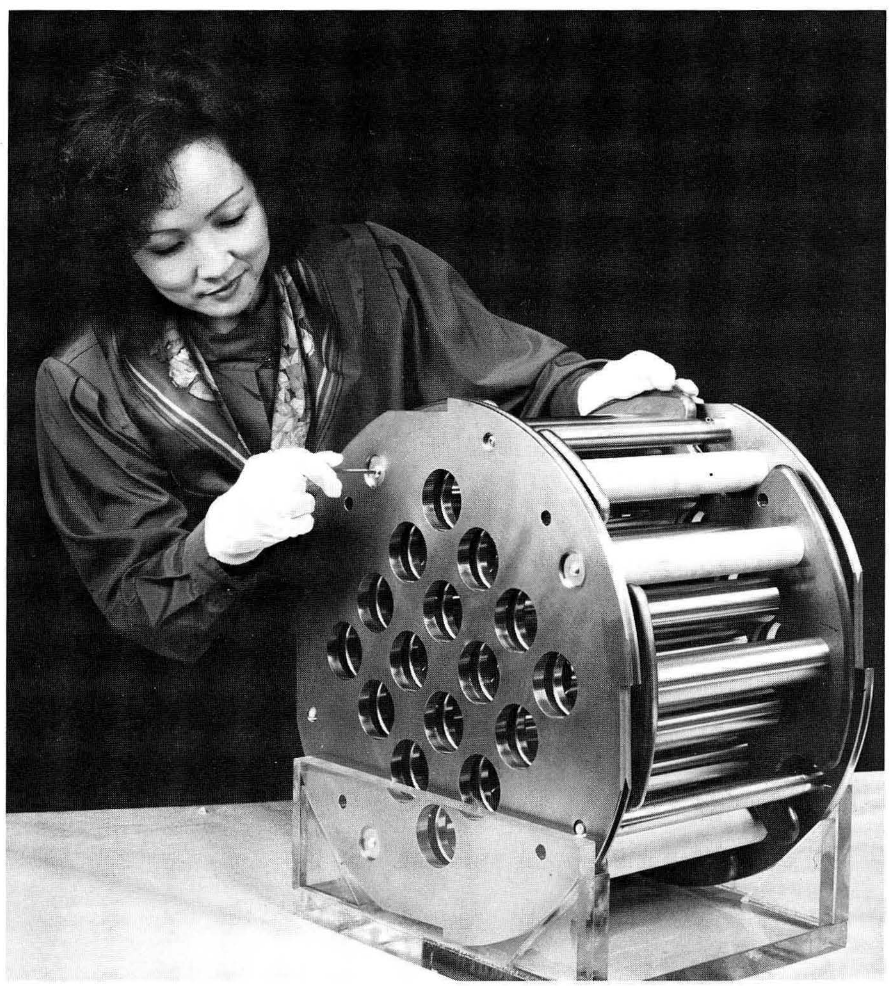
Energy Biosciences

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.

Advanced Energy Projects

Research projects supported at LBL by DOE's Advanced Energy Projects provide for generic, long-term support of the heavy-ion fusion-accelerator research program. The LBL Heavy-Ion Fusion Accelerator Research (HIFAR) Group has focused its attention on exploring the physics and technology of the single-pass induction linac as the means for accelerating 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. The National Academy of Sciences review of inertial fusion in 1989–90 has made preliminary recommendations to expand the HIFAR program, with the potential for enhanced LBL activity. This may lead to an Induction Linac Systems Experiment (ILSE), as described in Section 4.



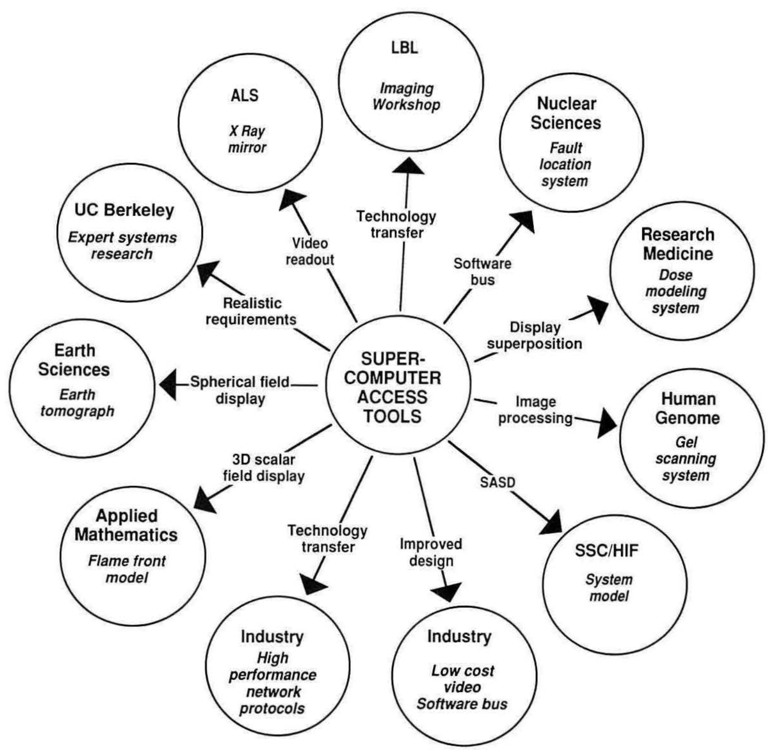
A prototype of the 16-beam electrostatic quadrupole assembly for the low-energy section of ILSE. The electrostatic quadrupole design provides cost and performance advantages for beam focusing and is being tested in preparation for the ILSE project.

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.

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



The Supercomputer Access Tools Program has developed new protocols, processing methods, display methods, and bus structures to open supercomputers, and OER's computing resources, to new users and new applications. LBL is leading this effort with other national laboratories, universities, and industry.

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.

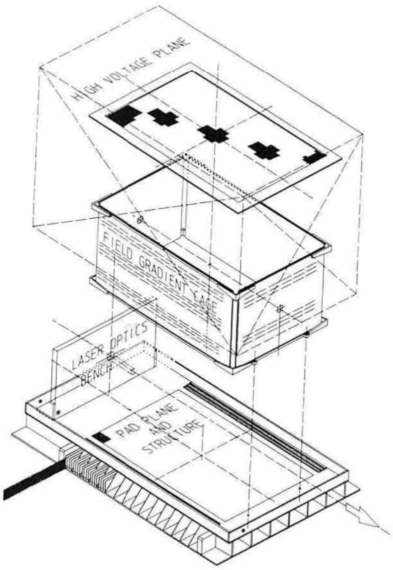
Nuclear Physics

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.

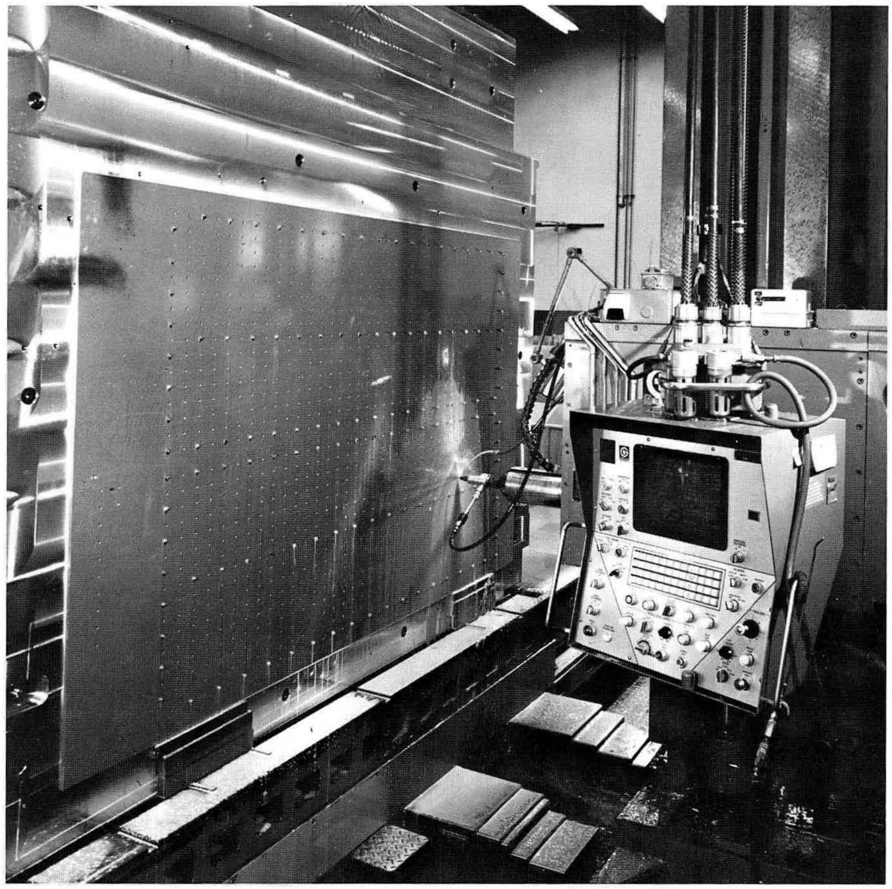
Relativistic Heavy-Ion Physics

LBL's Bevalac has played a pioneering role in relativistic heavy-ion physics. Use of heavy-ion beams of up to 2.1 GeV/nucleon (960 MeV/nucleon for uranium) has enabled scientists to probe new phases of nuclear matter by making high-temperature (100 MeV or 10^{12} K) compressed matter and measuring the size of the "hot spots" created when heavy nuclei collide. There are many opportunities for new experiments at the Bevalac—the energy region obtained by bombarding fixed targets with heavy ions at several GeV will allow definition of the nuclear equation of state and exploration of new relativistic concepts of nuclear structure, exotic unstable nuclei, and atomic physics with highly stripped heavy ions. Upgraded detectors for the Dilepton Spectrometer (DLS) and the Heavy-Ion Superconducting Spectrometer (HISS) will allow full exploitation of these scientific opportunities. A new Time Projection Chamber (TPC) is being built at the HISS facility to provide unprecedented resolution of all charged particles produced in central nucleus-nucleus collisions. These new and improved detectors, along with the continuing upgrade of computing capacity and accelerator capability, will allow researchers at the Bevalac to aggressively pursue forefront studies of the nuclear equation of state, of dilepton production, of neutron and pion production, and of fragmentation, as well as the pioneering research program with radioactive beams.

The Nuclear Science Division is also pursuing the study of heavy-ion collisions at even higher energies using ^{16}O and ^{32}S beams at the Super Proton Synchrotron (SPS) at CERN. Although it is too early to confirm the observation of a quark-gluon plasma in nuclear collisions at these energies, some of the necessary conditions, such as nuclear stopping, thermalization, and appropriate energy densities, have been observed. It is probable that a new injection system for the SPS will be built so that beams up to lead can be accelerated by 1994. Nuclear Science Division scientists recently submitted a letter of intent for a lead beam experiment.



The pad plane of the HISS TPC carries 15,000 charge-sensitive pads that read out the particle tracks moving through the gas column, providing outstanding resolution for high-multiplicity heavy-ion collisions. The detector is scheduled for installation at the Bevalac next year.



LBL researchers will also participate in the use of beams of unique characteristics at Brookhaven's Alternating Gradient Synchrotron (AGS) and are planning for a major experiment at RHIC. LBL also proposes to initiate the detector R&D effort required to support future ultrarelativistic heavy-ion experiments (see Section 4).

Low-Energy Nuclear Physics

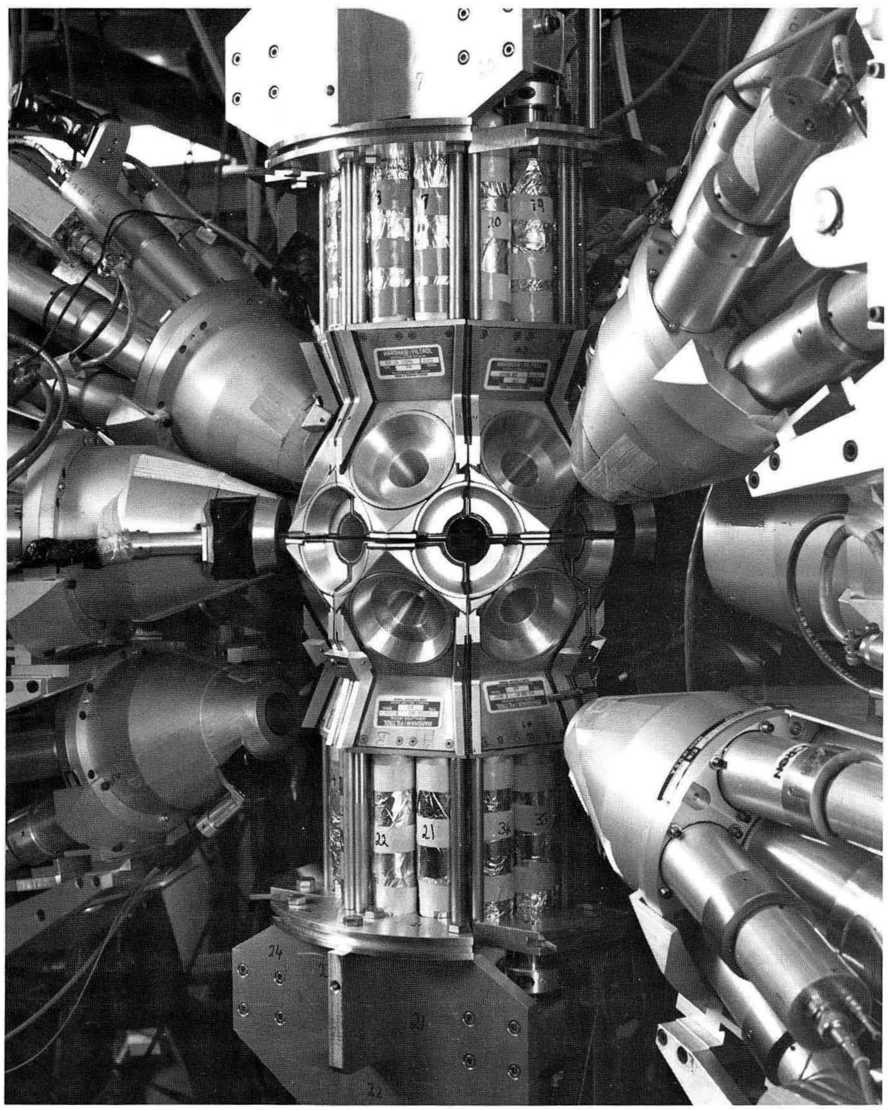
The broad and diversified low-energy nuclear physics research program will continue at the 88-Inch Cyclotron and the Bevalac. At the 88-Inch Cyclotron, new research opportunities have been made possible by ECR ion source; both heavy-ion and light-ion beams are used to study nuclear structure, nuclear reaction mechanisms, exotic nuclei, and nuclear astrophysics. The proposed exotic beam facility would provide proton-rich beams for unique new experiments at the 88-Inch Cyclotron.

Nuclear-structure studies at the 88-Inch Cyclotron are aimed mainly at understanding nuclei with large angular momenta. Results from the 21-element Compton-suppressed Ge gamma-ray High-Energy Resolution Array (HERA)—used in the study of these high-spin states—have been particularly rewarding. Researchers have observed and studied superdeformed bands and measured lifetimes of individual states in very-high-spin nuclei. The recent addition of a central bismuth germanate (BGO) ball to HERA is extending these studies.

GAMMASPHERE is currently the major initiative of the nuclear structure community in the U.S. Since the GAMMASPHERE siting decision has been reopened, the Laboratory is proposing that initial siting of this facility will be at the 88-Inch Cyclotron. Of the sites considered, the 88-Inch Cyclotron has the widest variety of beams available now (including light-ion polarized beams), is highly reliable, and can provide the most beam time.

Heavy-ion reaction-mechanism studies in the intermediate-energy region (5–100 MeV/ nucleon) will be advanced by continued upgrading of detector systems, by use of higher-energy beams from the new advanced ECR source, and by exploitation of the Bevalac's unique capability to provide the heaviest ions in this intermediate-energy range.

The 88-Inch Cyclotron is 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 High Energy Resolution Array (HERA), a system of 21 gamma-ray detectors with Compton suppression shields, has been upgraded with a 40-element central BGO ball, allowing measurement of the number and total energy of the gamma rays emitted. The device permits determination of high spin states of rapidly rotating nuclei, greatly expanding the knowledge of superdeformed nuclei.

The nuclear astrophysics group is participating in the Sudbury (Ontario, Canada) Neutrino Observatory collaboration to detect solar and supernova neutrinos using a large D_2O detector. Other activities in the rapidly developing nuclear astrophysics program include measurements of cross sections and studies of electromagnetic and beta-decay properties of importance to nucleosynthesis and astrophysical processes. A series of experiments related to the problem of nuclear cosmochronology has been proposed in conjunction with the UC Center for Particle Astrophysics.

Nuclear Theory

LBL's nuclear-theory program covers many of the major topics in nuclear physics, reflecting and extending the broad range of experimental programs. A substantial effort is already being devoted to theoretical studies in support of physics at the Bevalac and at the higher, ultrarelativistic energies available at CERN, the AGS, and, in the future, RHIC.

Over the next several years, the theory program will have a strong emphasis on the forefront area of ultrarelativistic nuclear collisions, while the long-standing effort at intermediate energies will be maintained. The activities in the areas of chaos in nuclei and dense-matter astrophysics are expected to develop further.

Data Evaluation

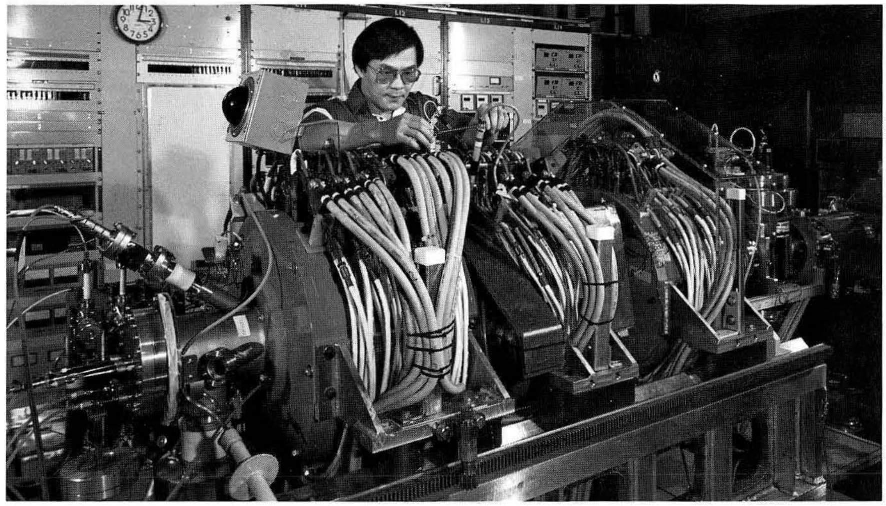
The Isotopes Project of the Nuclear Science Division will continue to provide evaluated nuclear-structure and decay data for the world nuclear physics community. In addition to its mass-chain evaluation activities, the group produced the *Table of Radioactive Isotopes*, a comprehensive reference intended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

Accelerator Improvements

Aimed at maximizing the Bevalac's scientific productivity, a modernization program has, as its long-range goals, improvements in beam spill quality, duty factor, flexibility and reproducibility of operation, and intensity. New controls are being installed to help assure the desired beam emittance and cleanliness, and new main guide-field power supplies will provide for quieter spills and extended flattop and duty factor. New control systems are improving response, tune reproducibility, and flexibility of operations for enhanced overall performance of the accelerator.

Following installation of the ECR source at the 88-Inch Cyclotron, a wide range of new beams and energies has been developed and used in nuclear science experiments. This versatile combination of the ECR source and cyclotron makes an extremely reliable and cost-effective accelerator. Three beam lines for atomic physics and materials research extend directly from the ECR source. Based on the success of this source and its emulation at other accelerator facilities, construction of an advanced ECR source has been completed with a greater than five-fold increase in beam intensity for many ions, making the 88-Inch Cyclotron the highest-intensity cyclotron in its energy range. Design efforts for a next-generation, gyrotron-driven ECR source are also underway.

The Advanced Electron Cyclotron Resonance (AECR) ion source at the 88-Inch Cyclotron is breaking previous energy and intensity records. For example, an $^{86}Kr^{23+}$ beam was successfully accelerated to an energy of 1.0 GeV. A postdoctoral fellow, who assisted in the development of the source, is adjusting a detector used to monitor x-ray levels inside the source.



High-Energy Physics

In high-energy physics, the Laboratory continues its 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 Superconducting Super Collider (SSC) and an asymmetric B factory at the Positron Electron Project (PEP). LBL maintains close interactions with the SSC Laboratory through R&D on superconducting magnets and through the SSC Solenoidal Detector Collaboration initiative (see Section 4).

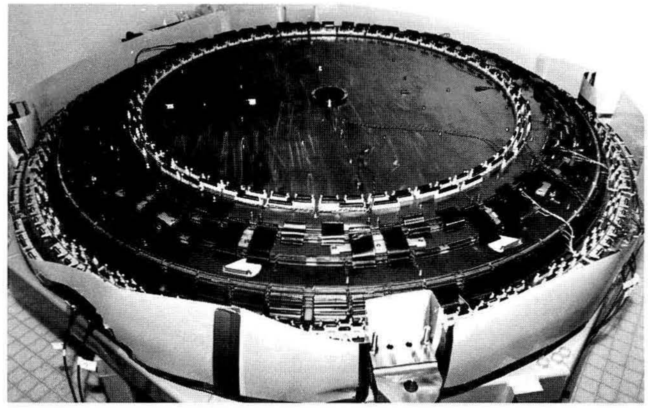
Experimental Programs

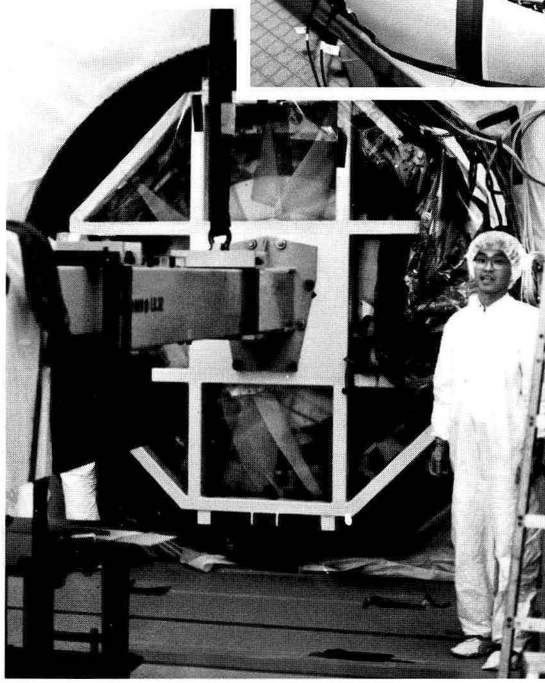
The Laboratory's experimental programs in high-energy physics focus on the properties of quarks and leptons, the basic constituents of matter. Their interactions are mediated through the gauge bosons, namely, massless photons and gluons and massive W and Z particles. Efforts at studying these particles 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 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 CDF is also underway. LBL has major responsibilities in the D-Zero detector collaboration, as well as 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. In addition to these large detector programs, there are smaller ongoing experimental efforts in both high-energy physics and selected areas of astrophysics.

At SLAC, the MARK II Detector has successfully recorded the first high-energy electron-positron collision experiments at the (SLC), and the endcap calorimeter, constructed at LBL, is taking data. An ultrahigh-resolution drift

Completed assembly of the D-Zero end-cap electromagnetic calorimeter, showing electrical gang connections and some of the uranium absorber plates. The assembly is also shown being installed in the test-beam cryostat at Fermilab, where the theoretically predicted high resolution and uniformity of response have been demonstrated.





chamber is also being developed in a collaborative effort with SLAC. The TPC installed at the PEP storage ring at SLAC continues to be the most-sophisticated detector in any collider in the world. Its three-dimensional pattern-recognition capability, excellent precision in ionization measurement, and lepton identification over a large solid angle provide an unsurpassed level of detail in the analysis of electron-positron annihilation in the PEP energy range.

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 the SSC project, including the organization of workshops.

The Particle Data Group performs a service to the world high-energy physics community through its compilations of particle properties. Its recent strengthening includes making data bases 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 such as the SSC. 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. There are also cooperative efforts between LBL engineers and high-energy physicists to develop improved data-acquisition electronics suitable for experiments at high-luminosity hadron colliders as a part of LBL's SSC detector development initiative (Section 4).

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 are being 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

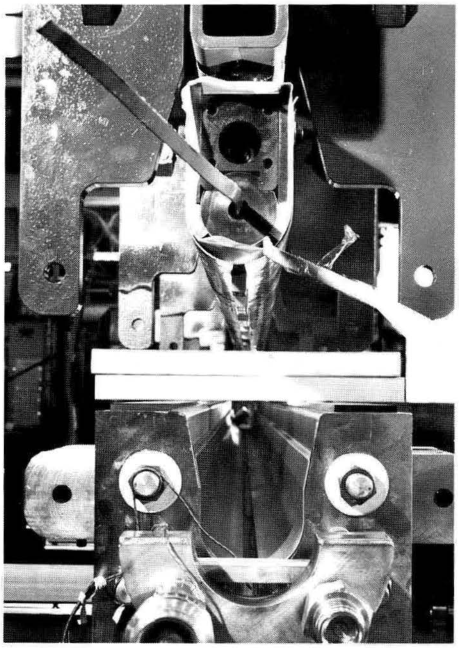
LBL accelerator physicists play a leading national role in solving major high-energy accelerator physics issues. Their experience with beam-cooling systems has resulted in successful systems at the Tevatron I and is being utilized to develop beam-control electronics for major hadron colliders, including the SSC. Such systems generally employ feedback of information from beam sensors to correct effects of noise and collective instabilities. LBL studies have shown that the SSC must use such systems to achieve economy and optimum performance.

LBL's magnet-research efforts will emphasize continued development of superconducting wire for high-current densities, improved cable design, and high-field magnets. LBL will pursue research on superconducting cables with very small filaments (2–3 μm diameter). If successful, this project will eliminate problems of field distortion at low fields and the need for distributed field-correction windings in hadron colliders. In the next year or two, LBL plans to resume a low-level effort on magnets using other superconductors and to explore application of high-temperature superconducting ceramics to magnet design (see Section 4). The design, fabrication, and testing of SSC quadrupole magnets with a Nb-Ti superconductor continues at LBL.

Other plans include accelerator design studies for a B factory (see Section 4). The B factory is a concept developed at LBL to use asymmetric e^+e^- collisions to produce beams of B mesons in a well-defined quantum state. This technique could be implemented by colliding the beam from the PEP storage ring with the beam from a new 2.5-GeV storage ring.

High accelerating gradients, generated by efficient sources of high-frequency microwaves, would open the door to a next-generation high-energy electron collider. The Two-Beam Accelerator (TBA), a concept pioneered at LBL, would use either a free-electron laser or relativistic klystrons to generate the needed microwaves. Studies are underway on a 35-GHz high-gradient accelerating structure, on the coupling of energy into such a structure, and on the power sources.

The SSC quadrupole magnets are being designed and fabricated at LBL. Stages in magnet assembly include winding the layers of superconducting cable, then compressing and heating this assembly inside a precision mold (equipment shown), and finally installing collars. The resulting stable assembly maintains several thousand psi of pressure on the windings.



Office of Health and Environmental Research

Life-sciences-related research activities include six research program areas: genome mapping and expression; structural biology; research medicine; carcinogenesis 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, and environmental science.

Genome Mapping and Gene Expression

Important research growth areas for LBL are studies on human genome structure and gene expression of cell systems. Research at the Human Genome Laboratory, described in Section 4, is resulting in the advancement of mapping and sequencing techniques. Examples of the research in gene expression include: (1) control of tissue-specific secretory activity; (2) differentiation in blood-forming cells; and (3) genetic regulation of lipoprotein production and circulatory-system disease. This research has already resulted in the determination of key exogenous and endogenous factors controlling cell development and steps involving carcinogenesis.

LBL molecular biologists are studying cancer induction by specific protein growth factors and the role of RNA that mediates the flow of information within the cell. This micrograph taken following growth-factor induction shows the white grains (radiotracer probes) that indicate the widespread presence of Rous Sarcoma Virus mRNA in a chicken tumor, indicating the importance of the growth factor.

LBL's Cell & Molecular Biology 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 expression and chemical- and radiation-induced carcinogenesis and are now also providing vehicles for production of genetically engineered foreign genes. LBL has identified hemopoietic 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

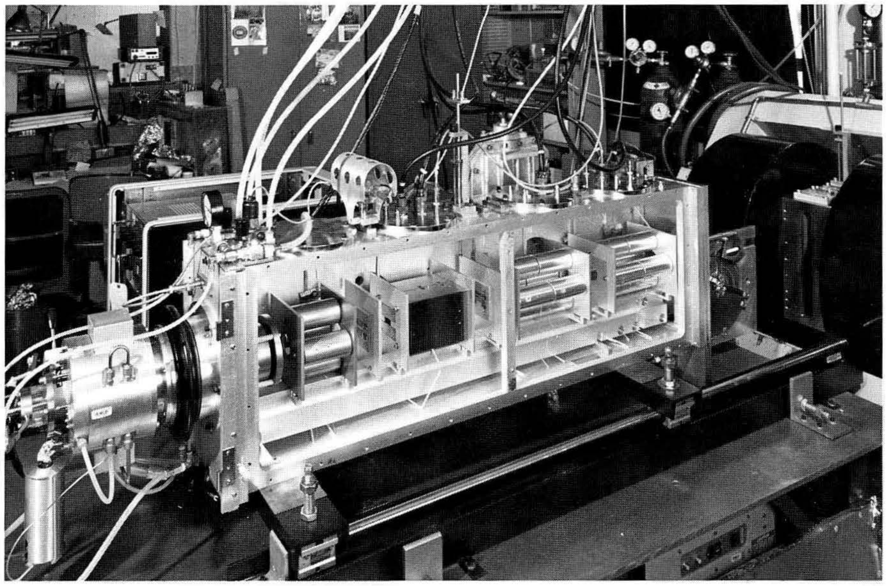
One thrust of LBL' structural biology program is directed toward x-ray-based research at the proposed ALS Life Sciences Center, as described in Section 4. Research on advanced techniques in x-ray microholography focuses on subcellular structures, and x-ray crystallography and NMR spectroscopy focus on protein, nucleic-acid structure, and protein-DNA complexes. Several of these studies are aimed at determining the basic structure of how secondary structures within the molecules regulate the functioning of genes, using advanced imaging techniques, including x-ray diffraction and scanning tunneling microscopy.

Studies in 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 high-resolution electron diffraction and imaging of crystalline sheets of membrane proteins, structural studies will be pursued on growth-factor receptors, chemotaxis receptors, and receptors for extracellular matrices. Related work will exploit circular dichroism microscopy, electron microscopy, and novel microscopic imaging capabilities from the UV and soft x-ray beams of the ALS.

Research Medicine

Research in nuclear medicine will continue to involve both diagnostic 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 the most-advanced NMR instrumentation, including the design and evaluation of a 10-T whole-body imaging spectrometer.

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,



A prototype biomedical "cyclotrino," conceived and initially constructed by LBL physicists, is now being adopted for use in biomedical tracer applications. The cyclotrino can enhance detection sensitivity to isotopes such as ^{14}C by a thousandfold, making feasible a new realm of human metabolic studies.

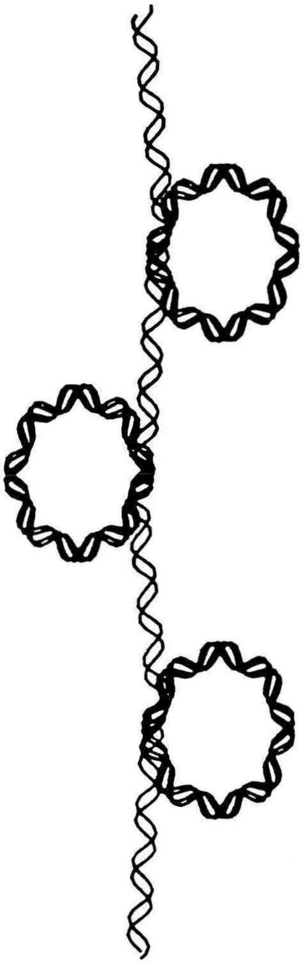
absorbers, and elution techniques that favor the production of short-lived radionuclides.

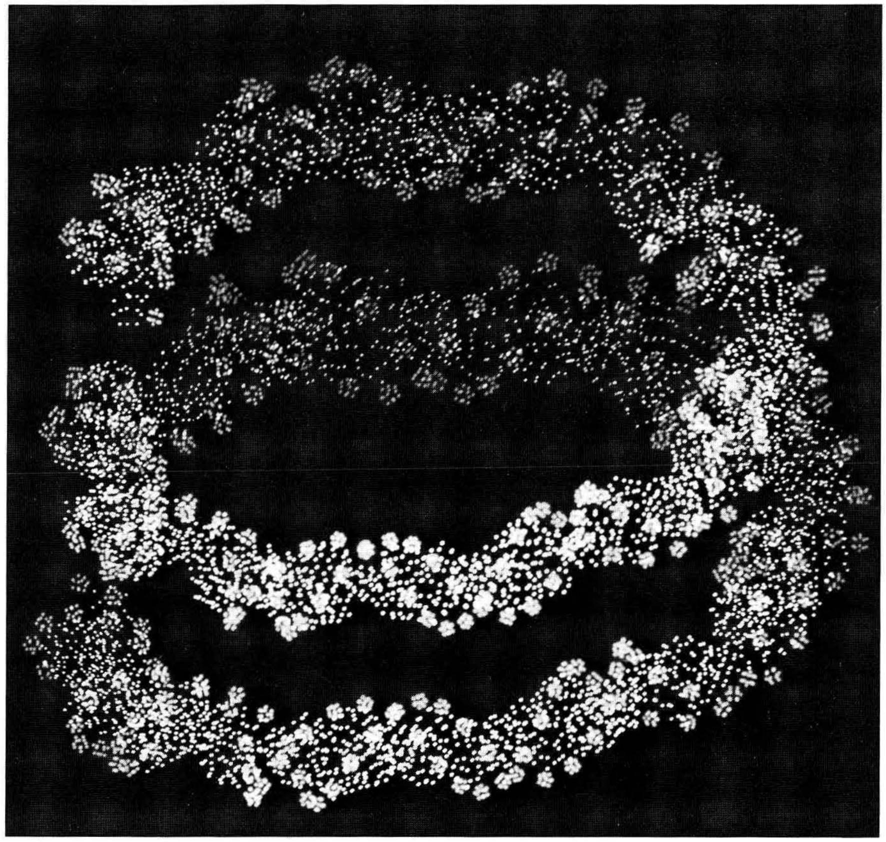
Basic studies of the biological effects of heavy-ion beams from the Bevalac are being coupled with research on optimum methods for heavy-ion radiosurgery. Research on the treatment of arteriovenous malformations (AVMs) in the brain will build on the established clinical research successes and on basic biological studies of the effects of heavy ions. Tracer studies with radioactive beams have the goal of placing the radiation dose in the tumor or target volume with the highest accuracy possible.

Carcinogenesis, Mutagenesis, and Radiation Biology

LBL plans increased research emphasis on DNA damage and repair, the role of oncogenes in cancer induction and embryogenesis, and an integrated program in cancer initiation, promotion, and progression. 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.

LBL researchers are using accelerated ions as controlled probes to answer specific questions regarding the cellular and molecular effects of radiation. Such work will enable continued progress in radiation medicine and the assessment of radiation hazards. The central research theme is to understand the cellular and molecular events in radiation-induced mutagenesis and carcinogenesis. 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. Because of the importance of measuring the consequences of low-dose exposure, a new project on single- and multiple-particle exposure is being developed. 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 radon exposure, accidental exposure to neutrons, space radiation, and other occupational hazards.





LBL computer modeling indicates how DNA forms loops, or nucleosomes, around clusters of proteins. These models indicate that higher-order DNA structures tend to protect DNA from damage by hydroxyl radicals.

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. It also includes analytical-methods development and statistical studies of environmental and epidemiological factors.

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.

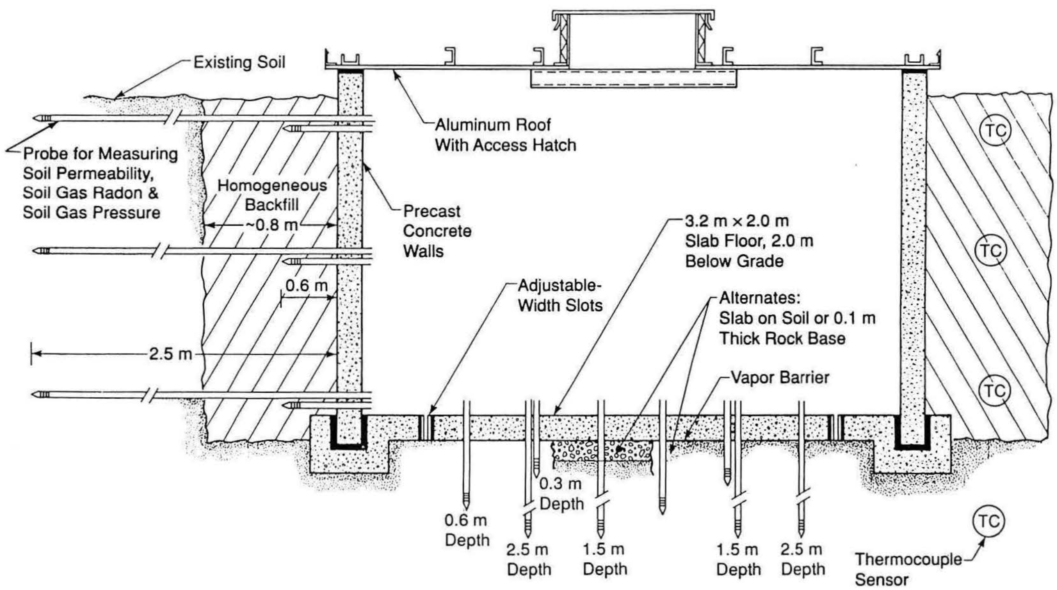
LBL is developing an interdisciplinary program to investigate the processes that lead to changes in the physical and chemical characteristics of the atmosphere and other potential changes in the ecosystem (Section 4). Initial research subjects include atmospheric processes that are involved in the generation 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 atmospheric-ecosystem interactions.

LBL continues to play an important national role in radon research, with indoor air-quality research on monitoring, diagnosing, and controlling radon levels in buildings and biological research on cancer induction by alpha particles, conducted in concert with research projects at other national laboratories and universities. LBL's program includes experimental and theoretical investigations of radon availability, transport in soils, airborne concentrations, and interactions with other gaseous pollutants and studies of cell transformation by radon progeny.

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.

LBL has established a radon study site in California with experimental "mini-basements" to evaluate parameters of radon ingress into homes. By determining soil characteristics and gas movement, the mechanisms of radon entry and radon control strategies can be effectively developed.

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.



Measurement Technology

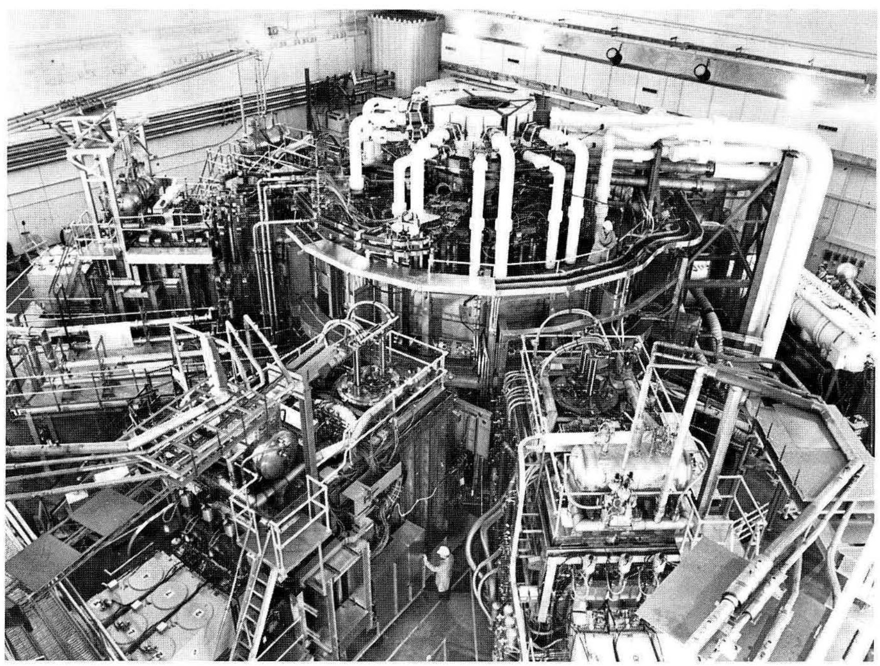
Excellence in measurement technology is key to the success of OHER programs. Refinements in sensors and analytical techniques have been developed at LBL for a number of years. Improvements in radiation detectors and materials for detectors, and the development of increasingly sensitive and specific x-ray and atomic-absorption analytical methods are the major thrusts. Research and development of the associated electronic signal-processing techniques complement this work.

Office of Fusion Energy

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 Toroidal Ignition and Burn Reactor study conducted at LLNL, have identified neutral beams as the leading candidate for driving current in a long-pulse reactor. This study is continuing as part of the International Thermonuclear Experimental Reactor (ITER) program. As a result, research and development of high-energy (≥1-MeV) beams for heating and current drive in ITER are increasing. These systems will be based on the production and acceleration of negative deuterium ions. These efforts will be partially supported from other sources to maintain a reasonable level of effort in negative-ion-source, accelerator, and neutralizer development.

An additional contribution to the magnetic fusion program in the Materials Sciences Division is research on alloys and weldments for conventional 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.



LBL has been a leader in neutral-beam injection systems for magnetic fusion energy, such as the systems surrounding the Tokamak Fusion Test Reactor at Princeton. These injectors provide the supplemental heating and confinement necessary to achieve break-even conditions.

University and Industry 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 foster productive relationships with industry. These programs, currently undergoing significant expansion in response to strategic national goals for investment in human resources and long-term economic development, include science education and technology-transfer initiatives described in Section 4.

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, and geothermal systems.

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

Major Program	1989	1990	1991	1992
Buildings & Community Systems	7.6	7.4	8.6	9.0
Energy Storage	2.8	3.2	3.5	3.7
Electric Energy	0.9	0.4	1.0	1.0
Geothermal	0.9	0.8	0.8	0.8
Solar Energy	0.8	0.7	0.8	0.8
Multisector	0.4	0.6	1.7	1.9
State & Local Assistance	0.1	0.2	0.1	0.1
Transportation	0.1	0.5	0.2	0.2
Total	**13.6**	**13.8**	**16.7**	**17.6**
Percent of LBL Total	**5.9**	**5.9**	**6.6**	**6.5**

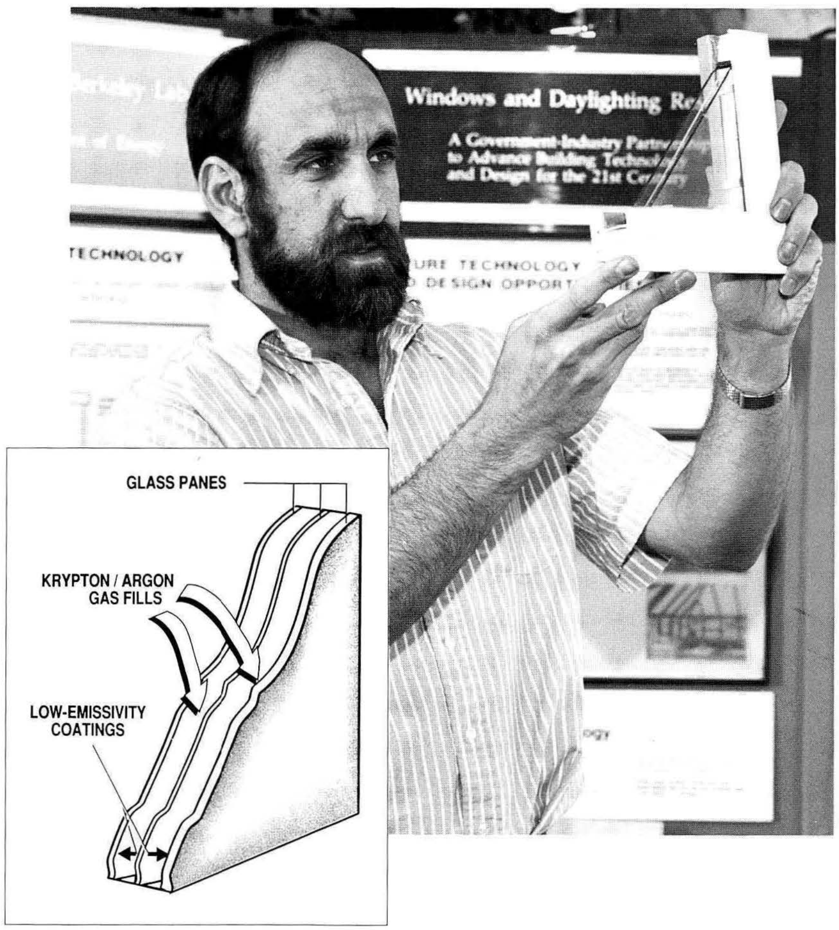
[a] Does not reflect DOE-CRE reorganization of April 1990.

Buildings and Community Systems

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 (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 information that allows identification 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, analysis of federally assisted housing; residence analysis and performance studies; building-retrofit studies and evaluation of thermal storage; analysis of appliance energy efficiency; and site-planning studies to minimize summer heat-island effects.

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. Considerable effort is devoted to analyzing the effects of conservation on electric utilities, including least-cost utility planning studies.



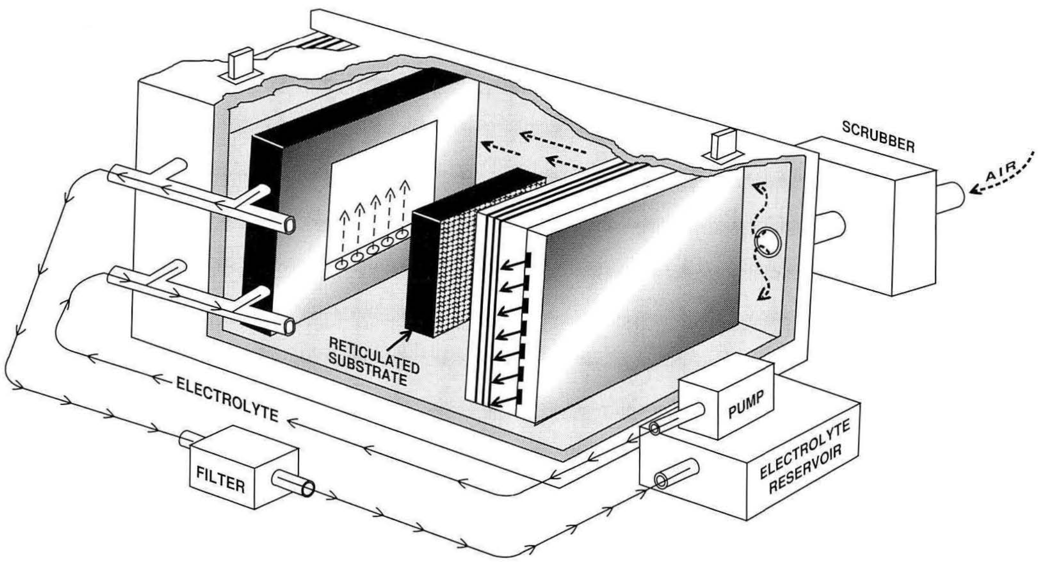
LBL scientists are developing low-emissivity, highly insulating windows. These "superwindows," with coatings, gas fills, and other design elements, are capable of thermal and daylighting performance that can provide more energy savings in some applications than well-insulated opaque walls.

Energy Storage and Distribution

LBL manages the Technology Base Research Project for DOE's Electrochemical Energy Storage program. The applications of present fundamental research include advanced batteries for both electric vehicles and stationary energy storage, fuel cells, and other efficient electrochemical energy-conversion devices. The general objectives are to identify technologies with the greatest potential for satisfying economic and performance requirements and to transfer them to industry-related DOE programs. LBL also pursues research in surface morphology of metals in electrodeposition, engineering analysis of electrolytic gas evolution, surface layers on battery materials, analysis and simulation of electrochemical systems, electrode kinetics and electrocatalysis, and electrochemical properties of solid electrolytes.

The goal of the program in high-temperature superconductors is to advance the technology for electric-power applications by developing superconducting films suitable for the fabrication of high-current tapes (see Section 4). The program currently emphasizes the exploration of methods of producing thin films: magnetron sputtering and laser ablation. As warranted by progress on the films, the design and fabrication of tape conductors and prototype magnets will be phased in. The program is coordinated through LBL's Superconductivity Research Center for Thin-Film Applications.

Exploded view of a cell in a rechargeable zinc-air battery developed at LBL. The battery features a sponge-like zinc electrode substrate encased in a frame through which electrolyte flows. The potential for low weight, high energy density, quick recharge, and long lifetime of the design has led industry efforts toward commercialization.



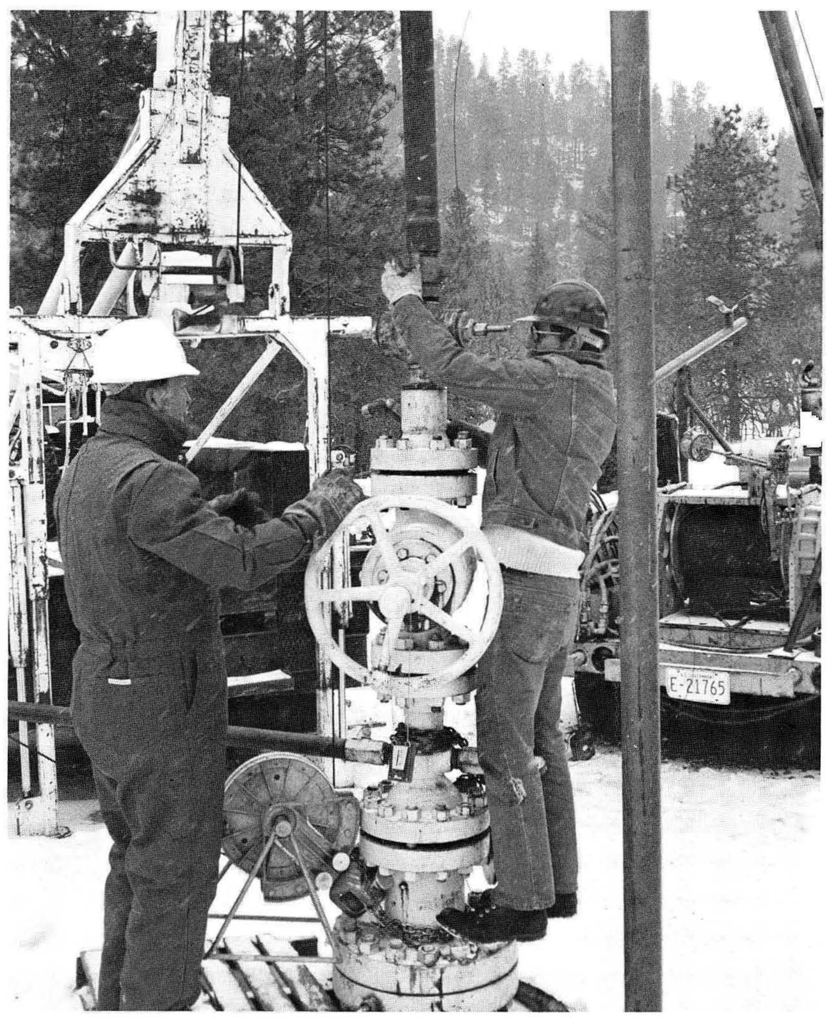
Energy Utilization Research

In the Energy Utilization Research program, premixed lean-engine combustion is studied because it holds the promise of reduced pollutant emissions, improved engine efficiency, and extended fuel tolerance. Three aspects of the combustion process are investigated: ignition of lean mixtures, lean-limit flame propagation, and wall heat transfer. Other efforts include research on energy-efficient chemical separations and on the opacitization of aerogels for insulation in nonview applications (e.g., refrigerators).

Geothermal Energy

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.



LBL scientists are conducting field work in connection with other national laboratories to obtain downhole fluid samples to evaluate the hydrothermal system of the Valles caldera in New Mexico.

Solar Heat Technology

In solar energy, LBL conducts research on innovative conversion techniques and provides basic information as input to evaluations of solar options. Passive-solar approaches that treat the cooling, heating, and daylighting requirements of nonresidential buildings in an integrated fashion are devised and analyzed. Further work funded by Solar Energy is for the development of advanced aperture materials that allow, for example, greater thermal insulation in buildings while retaining window clarity.

State and Local Assistance

The DOE Office of State and Local Assistance Programs administers energy-conservation grants to the institutional-buildings sector, such as schools and hospitals. Based on its expertise in buildings research, LBL is assisting the Office in evaluating programs to date and enhancing the effectiveness of future institutional conservation efforts.

Office of Fossil Energy

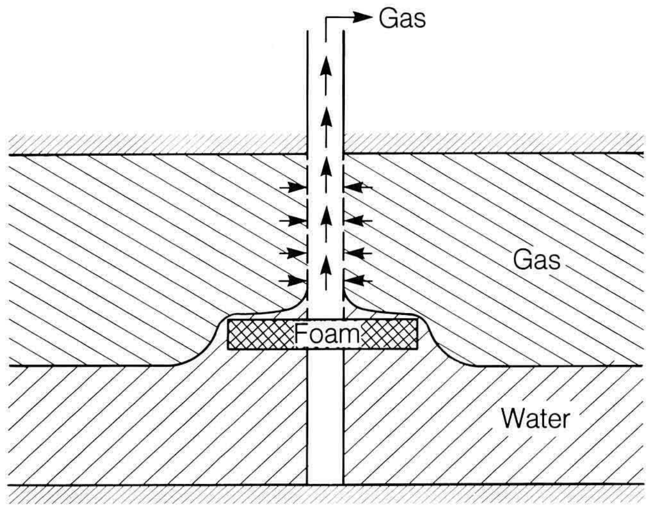
LBL conducts research directed toward making coal more usable, including studies on conversion to gaseous and liquid fuels and reduction of emissions. One current effort focuses on the low-temperature catalytic gasification of graphite and other forms of carbon. A flue-gas chemistry project is directed 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.

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

Major Program	1989	1990	1991	1992
Coal	1.4	1.2	1.3	1.3
Petroleum	0.3	0.3	0.5	0.5
Total	**1.7**	**1.5**	**1.8**	**1.8**
Percent of LBL Total	**0.7**	**0.6**	**0.7**	**0.7**

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 data base and processes for microbial degradation of organic waste materials.

A method to reduce water coning (water intrusion) into gas reservoirs has been developed by LBL geohydrologists. The technique involves the use of foams, which act as a barrier between different fluid media.



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 Sections 4 and 8, the existing and budgeted site projects address specific conditions at the Laboratory, including facilities and operating programs, soils, water, and air emissions. In addition, LBL is conducting a science education program and is proposing a research initiative for near-term technology development and demonstration projects (see Section 4).

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

Major Program	1989	1990	1991	1992
Environmental Management	3.4	3.4	7.8	11.0
Percent of LBL Total	**1.5**	**1.5**	**3.1**	**4.1**

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	1989	1990	1991	1992
Civilian Radioactive Waste Management	4.1	2.9	3.6	3.8
Policy, Planning, & Analysis	0.8	0.4	0.5	0.5
Administration and Human Resource Management	0.3	3.1	2.2	1.6
Other DOE Contractors	24.5	16.2	14.6	14.6
Total	**29.7**	**22.6**	**20.9**	**20.5**
Percent of LBL Total	**13.0**	**9.6**	**8.2**	**7.6**

Civilian Radioactive Waste Management

LBL continues a strong multidisciplinary program of interrelated geoscience and geological engineering research important to the 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 various thermal, mechanical, and hydrochemical 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, and instrumentation engineering.

Policy, Planning, and Analysis

LBL also undertakes studies in support of particular policy issues of concern to DOE. Recent efforts include analysis of methanol-compatible vehicle transportation strategies, energy markets and demand in China, and combustion pollution exposure indoors.

In support of DOE's interest in developing a comprehensive understanding of factors that influence the release of "greenhouse" gases, LBL is undertaking studies on global energy demand and related issues. Studies will include demand by less-developed countries (LDCs) residential energy use, improved data on combustion, and biogenic emissions.

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

The Laboratory has been host to the Central Design Group (CDG) for the SSC. This work, supported through the Universities Research Association, has phased down with the CDG move to the SSC site in Texas, although it continues in support of accelerator and detector R&D studies. Collateral SSC research conducted by LBL's Accelerator and Fusion Research Division and the Physics Division is described in the section on High Energy Physics.

LBL contributes to the research programs at other DOE national laboratories and facilities through such activities as laser-material interactions for LLNL, assistance to ORNL in assessing renewable energy applications in developing countries, 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	1989	1990	1991	1992
Department of Defense	3.7	3.1	3.0	3.0
Department of the Interior	1.5	0.8	0.8	0.8
Environmental Protection Agency	0.7	1.1	1.3	1.3
National Aeronautics & Space Adm.	1.8	2.5	2.3	2.3
National Institutes of Health	12.7	15.6	15.9	16.4
Other Federal Agencies	1.5	0.7	2.3	2.6
State and Private	8.6	11.2	11.1	11.1
Total	**30.5**	**35.0**	**36.7**	**37.5**
Percent of LBL Total	**13.3**	**15.0**	**14.4**	**14.3**

Agency for International Development

The Agency for International Development is supporting a multiyear effort in which LBL will perform research in support of policy development for Southeast Asian nations to reduce commercial building energy use.

Department of Defense

The Army Strategic Defense Command is supporting neutral-beam research related to magnetic fusion energy. The Air Force Office of Scientific Research is supporting research in x-ray microscopy, sources of high-brightness x-rays, and work in the magnetic fusion energy program. The Office of Naval Research supports LBL research on performance of oxide scales on aluminides, on quantum Monte Carlo calculations, on the properties of thin film superconductors, and on 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 Research Projects Agency is supporting research on photothermal imaging. The Defense Nuclear Agency is supporting research on smoke measurements to evaluate the "nuclear winter" hypothesis.

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 practices. 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, and gathering information on the potential effect of global climate change on U.S. natural resources.

National Aeronautics and Space Administration

LBL is conducting biomedical 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. LBL collaborates with NASA groups to develop gamma and x-ray detector systems for various space applications, such as for the WIND Spacecraft. 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.

National Institutes of Health

Programs sponsored by the 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. Lipoproteins and their relationship to cardiovascular disease are studied, as is 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.

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 and on the development of chemical "mimics" of natural enzymes for methane conversion. In health-effects research, EPRI supports projects on human exposure to magnetic fields involving dosimetry and effects from superconducting magnetic-energy storage.

The Gas Research Institute supports data bases on heating and cooling loads in single-family and multifamily buildings to analyze advanced gas energy-use technology. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers is sponsoring accurate determination of solar-heat gain through fenestration. 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 (see Section 4). 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 advance energy information systems, and Pacific Gas and Electric Company supports a demonstration of advanced lighting control techniques and analysis of energy pricing policies.

The California Association for Research in Astronomy has supported mirror support and control-system development for the LBL-designed Keck 10-m telescope, the world's largest optical instrument. In the life sciences, research on human lipoprotein function and genetics is supported by the National Dairy Research Board. Research on the accurate expression of foreign genes is pursued in collaboration with the Monsanto Company.

Chapter

6

Education and Technology Transfer Programs

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 this area.

SCIENCE AND ENGINEERING EDUCATION

LBL's educational programs advance pre-university, undergraduate, graduate, and minority educational opportunities (Table 6-1). These programs support the objectives of the emerging National Energy Strategy and the Math/Science Education Action Conference Report. Through the Center for Science and Engineering Education, LBL has developed programs with a strong focus on the following:

- Opening doors for all K–12 science students and teachers,
- Developing education partnerships for outreach and impact, and
- Delivering programs specifically for women and minorities.

There are approximately 3,000 visitors to LBL who are exposed to LBL's frontier science and technology and many more through the partnership with the UC Lawrence Hall of Science (LHS), an acclaimed education research center and science museum. To plan and conduct the educational programs effectively, the Center for Science and Engineering Education (CSEE) was established in 1987 in the Office of Environment and Laboratory Development. 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, pre-college (K–12), community college, and technical training through undergraduate and graduate education. CSEE serves as the LBL center for science and engineering education programming and coordination. The goals of the CSEE education 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 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.

Table 6-1. Science Education and Training Participants at LBL

Program Area	FY 1990 Participants
Pre-university	
Teacher Research Associates *(Teachers)*	31
Horizon — Berkeley High School Project *(Students)*	250
High School Honors Program Life Sciences *(Students)*	64
High School Science Symposium *(Students)*	275
Updating Science Knowledge for Instruction *(Teachers)*	300
National Science & Technology Week *(All)*	300
Undergraduate Students	
Science and Engineering Research Semester	18
Laboratory Co-op Program	18
Minority Student Programs	20
Research Assistants	178
Community College Transfer	6
Faculty/Student Research Teams *(Faculty)*	3
Graduate Training	
Graduate Student Research Associates	493
Postgraduate Activity	
Minority College Faculty	10
Postdoctoral Fellows	98
Faculty Visitors	350
Public Programs	
Tours and Seminars	~3,000

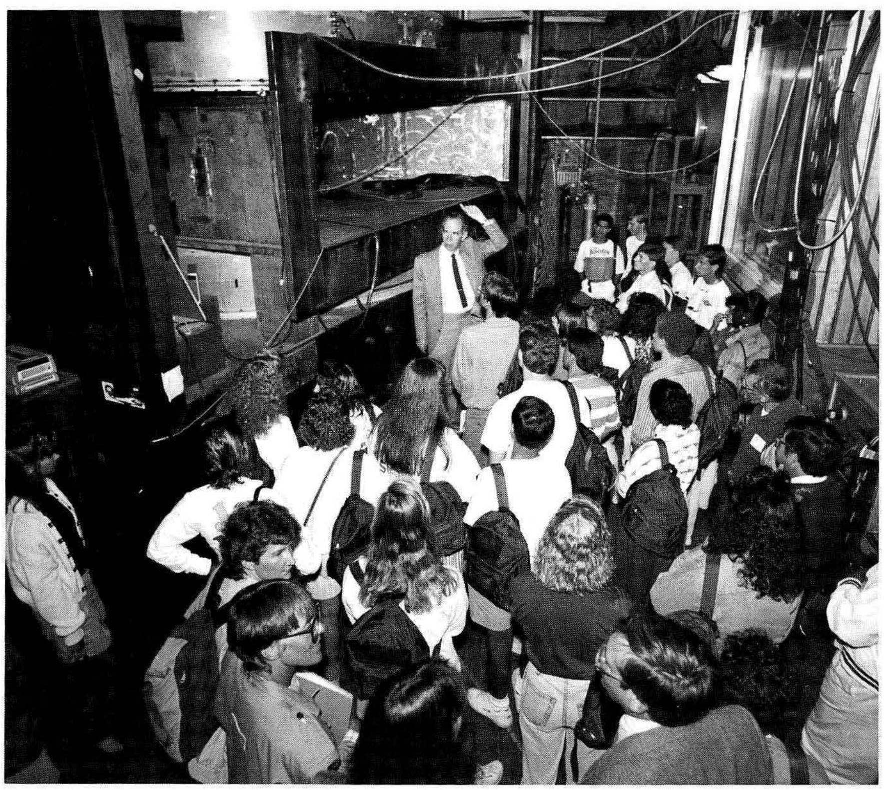
By consolidating pre-university, undergraduate, and minority programs, CSEE provides a foundation for expanding and enhancing LBL's educational efforts.

Pre-university Programs

Since 1983 LBL has provided over 130 community college, high school, and junior high school science and mathematics teachers with summer research positions. 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.

An outgrowth of the LBL teacher summer research participation program is the DOE TRAC (Teacher Research Associates) program. This national program has placed over 140 high school teachers at over 10 national laboratories in FY 1990 and was piloted as the Residence in Science and Technology program in 1985 as a consortium of LBL, ANL, and BNL. LBL's TRAC Program has a strong national focus, with teachers reporting from 31 of the 50 states.

The High School Honors Program in the Life Sciences, started in 1987, brings over 60 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 two weeks of frontier lectures and hands-on laboratory experiences. LBL's focus on Life Sciences not only gives students an opportunity to develop skills in recombinant DNA technology, but also prepares them for the social and ethical issues in science and technology.



During their orientation at LBL, visiting students from DOE's High School Honors program are introduced to nuclear science and radiotherapy research at the Bevalac. The Coordinator of Accelerator Research describes the Heavy Ion Superconducting Spectrometer (HISS), explaining how the large HISS magnet (above left) and detector array (above right) can be used to explore the structure and properties of the nucleus.

A new program to improve math and science retention among inner city minority students (Horizon) was started this past year. Horizon develops school leadership, works with parents, and provides to students weekend academic activities in exciting scientific breakthrough areas. Several hundred middle and high school students are being reached through Berkeley High School and the Berkeley Mathematics Engineering Science Achievement programs. In addition, LBL cosponsors activities with LHS to promote public understanding of science and technology and to enrich teaching in local schools. An annual National Science and Technology Week program honoring teachers is planned with LHS. 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. This past year 2000 "Frontiers in Science at LBL" teacher materials packets were sent to K–12 schools. Topics range from scanning tunneling microscopy to earthquakes.

Students participating in undergraduate research programs at LBL also had the opportunity to teach at-risk pre-college students. LBL students taught several hands-on workshops to junior and senior high school students at a national IMAGE conference for Hispanic youths.

Undergraduate Programs

Through the Scientific Divisions almost 400 undergraduate students were research assistants or guests in FY 1990. 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, 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.

Since its beginning in 1969, the Lab Co-op Program has sponsored undergraduate students in engineering and fundamental science studies. The introduction of the Science and Engineering Research Semester (SERS) in 1987 expanded LBL's undergraduate educational commitment substantially. 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 is expanding and provides faculty from predominantly minority universities and colleges with an opportunity to develop collaborative research programs. These ongoing collaborations serve as a pipeline for minority students to work at LBL. This is the second year LBL has provided community college transfer students entering UC Berkeley with an opportunity for research and academic year mentorship at the Laboratory.

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 graduating 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. In FY 1990 an aggressive five-year plan was developed by the Science Consortium. The original Memorandum of Understanding establishing the Science Consortium set forth the following goals: to improve (1) faculty research opportunities; (2) the quality of research seminars; (3) academic support systems for minority students; (4) undergraduate and graduate programs in the natural sciences, mathematics, computer science, engineering, and other math-based disciplines; (5) pre-university programs that better prepare minority students for college programs; (6) the number of graduates from math-based programs; and (7) institutional capabilities to engage in competitive research and academics.

Teachers from around the country participate in DOE's Teacher Research Associate (TRAC) program. Each teacher is assigned to an LBL scientist for eight weeks during the summer, such as this Washington, D.C. teacher (left) working on subcloning the insulin gene with an LBL scientist (right).

During the summers of 1989 and 1990, a total of 10 AGMEF faculty worked on collaborative research projects at LBL. A special environmental research campaign was held and led by LBL researchers for JSU and AGMEF faculty and students in Puerto Rico in 1989 and at JSU in 1990.

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.

Future Educational Program Plans

As articulated in the Interim Report on the Development of a National Energy Strategy, DOE has a growing commitment to science education, and LBL expects to continue to expand its activities. The Faculty/Student Experiment and Teaching Laboratory initiative is proposed by LBL to provide new access and support for teachers and students primarily in the greater Bay Area (see Section 4). The new initiative for LBL in FY 1991 will be the Bay Area Science and Technology Education Collaboration (BASTEC).

The BASTEC initiative involves four national laboratories (LBL, LLNL, SLAC, and Sandia) and the Oakland Unified School District and was announced by DOE Secretary Watkins in April 1990. BASTEC will contribute to a district-wide math, science, and technology education reform effort.

LBL scientists will participate in K–12 curriculum development, teacher education, and special student programs. BASTEC provides long-term commitment to Bay Area school district science education improvement.

Integration of the minority education programs with other activities has resulted in over 51% minority participation in undergraduate research appointments. Research participation programs are being further developed for science and engineering faculty from community colleges and from small colleges and universities. Currently, much of the educational effort is at the undergraduate level devoted to the undergraduate programs that provide research participation opportunities for outstanding science and engineering students who have completed their sophomore year of college.

CSEE's activities at the pre-university level are expected to increase in FY 1991. These activities will continue the research participation by community college, middle-school, and high-school teachers through DOE teacher research associate appointments. Identifying, motivating and challenging students with high potential but low career horizons will remain important dimensions of pre-university programs.

The Science Consortium (LBL, JSU, and AGMEF) will shift resources to strengthen precollege programs at JSU and AGMEF. Faculty and student development through collaboration with LBL scientists will continue with the goal of developing centers of research excellence.

NATIONAL USER FACILITIES

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

- The Bevalac—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 88-Inch Cyclotron—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 National Center for Electron Microscopy—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.
- The National Tritium Labeling Facility—provides advanced instrumentation to investigators needing high specific activities of tritiated compounds as tracers in chemical and biomedical research.
- The Advanced Light Source—will provide photon beams of unprecedented brightness and coherence and with picosecond time structure. An active users' group has participated in the design, the development of beam lines, and support facilities. This facility will be completed in FY 1993.

In addition to the 675 users at LBL's existing national user facilities (Table 6-2) in FY 1990, there are already 580 voting members of the ALS Users Association. Considerable growth in membership is expected during the next few years, with many users expected at the ALS following its commissioning in 1993.

In addition to these national facilities, other research facilities are made available to collaborating investigators, including the Center for Computational Seismology (see cover), the Sky Simulator, the Mobile Window Thermal Test Facility, the Low Background Counting Facility, and the Heavy Charged Particle Treatment Facility. Scientific information on the capabilities and access to these facilities is in the *Guide to User Facilities at the Lawrence Berkeley Laboratory* (PUB-426), which is available upon request.

Table 6-2. Experimenters at National User Facilities (FY 1990)[a]

Facility	Laboratory	University	Industry	Total
Bevalac	62	124	3	189
88-Inch Cyclotron	96	49	54	199
National Center for Electron Microscopy	25	10	10	45
National Tritium Labeling Facility	6	6	12	24
Total	**189**	**189**	**79**	**457**

[a] "Laboratory" includes the University of California at Berkeley. "Experimenters" do not include additional users of research results at home institutions.

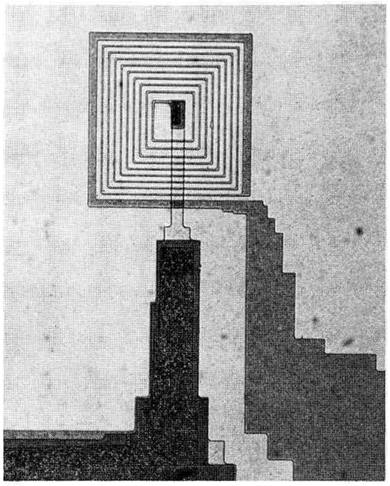
TECHNOLOGY TRANSFER

LBL promotes technology transfer and interactions with industry through its newly established Technology Transfer Office, the Patent Office, and the Office of Sponsored Research Administration, by licensing LBL technology and by specific collaborative research projects. Technology transfer is also facilitated through research centers and through industry involvement in advisory committees, panels, and review groups.

Collaborative Research 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 Superconductivity Research Center for Thin-Film Applications, the Human Genome Center, the Center for X-Ray Optics, the Center for Computational Seismology, and the Center for Building Sciences.

In addition, procurements are awarded for a range of capital projects and operating activities, including specialized engineering studies and instrumentation. LBL engaged in more than 300 industrially sponsored research agreements in FY 1990 and is currently involved in 18 industry cooperative research agreements (Table 6-3).



Scientists in LBL's Superconductivity Research Center for Thin Film Applications have developed unique, patented processes for fabricating high-temperature superconducting devices, such as this flux transformer. The development of these devices is also being supported by the California Competitive Technology Program, in collaboration with Stanford University and Conductus, Inc., a Bay Area firm specializing in new high-T_c devices.

Table 6-3. Selected Technology Transfer Activities and Staffing

Category	FY 1989	FY 1990	FY 1991
Activity			
Industry Cooperative Agreements	4	16	18
Agreement Value ($M)	0.2	1.6	2.9
Personnel Exchanges	8	9	10
Patent Applications	14	20	23
Patents Issued	17	16	17
Licensing Royalties ($k)	0	50	50
Staffing (Administrative)			
Technology Transfer Office	2.5	2.5	2.5
Patent Department	4	2	3
Office of Sponsored Research	2	2	2
Total	**8.5**	**6.5**	**7.5**

The Center for Advanced Materials (CAM) supports the goals of increasing U.S.-based industry in DOE research and has established research collaborations with close user 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 Advanced Light Source, will provide a wide range of research opportunities and further extend these collaborations.

LBL and Industry Interaction

LBL supports strategic national goals to rapidly transform the Laboratory's research into economically practical technologies for U.S. industry. These efforts include licensing, research participation, and active involvement in DOE's Laboratory Technology Exchange Program. Through this program, DOE provides financial assistance needed to support extended visits by senior American industry scientists to the national laboratories. These visits are highly productive, and the Laboratory has requested further funding to expand the program to other areas.

Several research participation programs are being initiated to develop and improve the transfer of emerging technology for the energy industry. The California Institute for Energy Efficiency, a research unit coordinated by the University of California, has formed to provide a vehicle for improved technology transfer and cooperative research support. The Center is expected to develop more efficient end-use technologies that will improve national energy security and benefit users, utility companies, and manufacturers. Other technology transfer initiatives include the program on Cooperative Approach to Software Advancement and the Advanced Computer-Based Building Design.

The East Bay Emerging Technology Advisory Board (EBETAB) was established in 1989 to promote early-stage technologies for first-round, start-up ventures. The board plans to hold annual briefings to showcase new technologies to venture capitalists. LBL works with EBETAB to present LBL's latest promising technologies that have strong potential to form start-up companies. As a result of the first annual briefing, two spin-off companies were formed:

- PolyPlus was established to manufacture and market solid-state lithium batteries, initially for use in small-scale electronics applications;
- Contemporary Physics Education Project, Inc., a nonprofit company, was formed to distribute educational material teaching modern nuclear physics at the high school and college level.

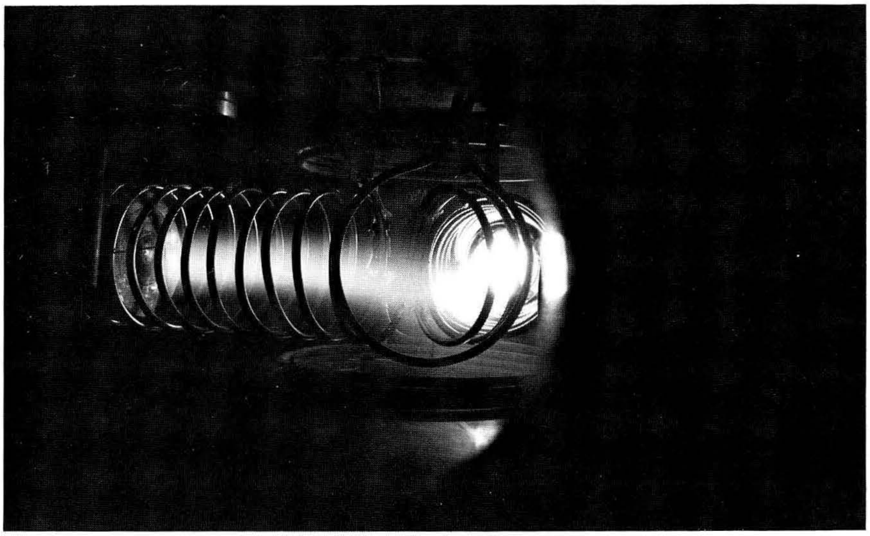
LBL scientists are actively involved in transferring other technology to the private sector, also through the formation of new companies as a spin-off of LBL research. These new companies include:

- ISM Technologies, Inc., was formed specifically to develop a metal vapor vacuum arc (MEVVA) ion source for ion implantation.
- Thermolux, Inc., is developing a cfc-free insulator for refrigeration and heating applications.
- Hettrick Scientific was formed to develop a high-resolution erect-field spectrometer (HIREFS) for use in research by industry, government, and university laboratories for spectroscopy of plasmas.

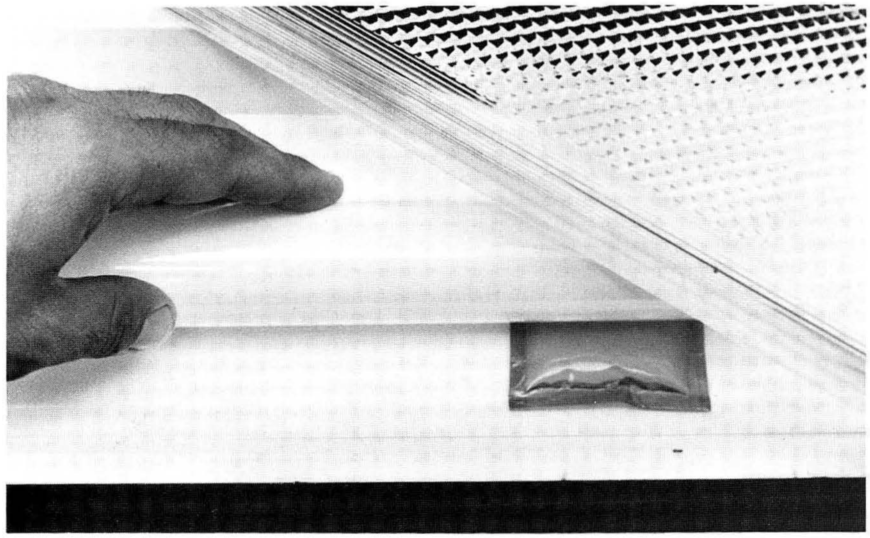
LBL will continue to expand the mechanisms for DOE-developed technology transfer. A new marketing program has been developed to package intellectual property so that it is attractive to U.S. companies. LBL-developed technology will be identified, evaluated, and selected for licensing activities. Examples of technology areas identified for transfer include:

- Ion implantation technologies,
- Software for mapping of surface chemical properties,
- Rechargeable, high-power, and long-life batteries,
- Secretory cell cultures for biotechnology,
- New scintillators for gamma-ray detection and measurement,
- Efficient fluorescent lighting technology, and
- Amorphous silicon detectors.

An outreach program has been established to inform LBL scientists of the Laboratory's technology transfer options. As part of this program, LBL initiated a technology transfer newsletter that describes the many technology



LBL investigators, in cooperation with Extrion, a division of Varian Associates, are improving the delivery of electrons for neutralizing positive charge that accumulates during ion implantation. The electron-beam charge neutralization system (developed for magnetic fusion research) has potential applications in electron, plasma, or ion sources for such uses as semiconductor wafer fabrication.



LBL's Lighting Systems Research Group has developed a low-cost system for spot cooling fluorescent lamps that will maximize efficiency and increase light output by 15-20%. The thermally conductive liquid within a thin flexible membrane provides a conformable thermal bridge between the lamp and the fixture, maintaining optimum temperatures. The technology is currently available for licensing from LBL.

transfer approaches and services available to the LBL investigator. The newsletter will also feature an ongoing series that details patent, copyright, and licensing procedures. In 1989, the LBL Technology Transfer Employee Recognition Program was established to acknowledge the accomplishments the Laboratory staff has made toward technology development and transfer to industry or other parts of the private sector. LBL plans to award investigators on a yearly basis for their technology transfer endeavors. LBL's highest honor for accomplishments in technology transfer is the Technology Transfer Excellence Award. Certificates of merit will also be awarded annually for technology transfer efforts.

As part of the marketing program to promote LBL technology, the Technology Transfer Office is planning a collaborative effort with UC Berkeley's "Management of Technology" joint program between the School of Business Administration and the College of Engineering.

LBL is developing policies that protect proprietary interest to maximize usefulness to U.S. industry by protecting legal rights to the technology. These policies will advance the commercial usefulness of a new technology while continuing the free flow of information early in development stages. As a part of the process to improve these operations, the Laboratory will review invention disclosures for commercial potential and target specific licensees.

Procurements for a range of capital projects and operating activities, including specialized engineering and instrumentation, leads to extensive transfer of technology as LBL scientists work with engineers from the participating companies. In 1990, procurement was $83.9 M from all sources, including $10.9 M from universities (Table 6-4). Increased expenditures over FY 1989 were due to $20 M for new construction projects ($14 M over FY 1988) and the inclusion of procurement from state and local governments, nonprofit organizations, and work outside of U.S. (categories not previously included). About half of the Laboratory's procurement is from small, disadvantaged, and/or women-owned businesses (Table 6-5).

Table 6-4. Subcontracting and Procurement ($M)

Recipient	FY 1988	FY 1989	FY 1990
Universities	5.9	8.0	10.9
All Other	71.3	93.9	72.3
Other DOE	0.6	2.4	0.7
Total	**77.8**	**104.3**	**83.9**

Table 6-5. Procurement from Disadvantaged, Women Owned, and All Small Businesses

	FY 1989			FY 1990		
Business Category	Transactions	$M	(%)[a]	Transactions	$M	(%)[a]
Disadvantaged	3,160	8.0	(8.3)	3,177	8.7	(11.6)
Women Owned	2,867	3.4	(3.6)	3,856	5.0	(6.7)
All Small	28,081	44.4	(46.4)	27,850	38.4	(51.5)

[a] Percentage of total non-University and non-DOE procurement.

Chapter

7

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 3420 employees, almost two-thirds with baccalaureate or advanced degrees (Table 7-1). The part-time employees include 467 graduate and 253 undergraduate students, important components that contribute to LBL's education and training mission. In addition, 224 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, the most recent being Yuan T. Lee, who received the 1986 Nobel Prize in Chemistry. Of its present staff, 54 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.

High retention rates have been reflected in a mid-1980s trend toward an increase in overall professional staff age. LBL's overall population is now stable, and the Laboratory has an active recruitment program, including divisional fellows and postdoctoral associates, 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.

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. Comprehensive and scheduled on-site training and programs are conducted in environmental safety and health and in computer and workstation skills.

Table 7-1. Laboratory Staff Composition (Full- and Part-Time Personnel)

Group	Doctoral	Master's	Bachelor	Other	Total
Staff Scientists	636	153	152	34	975
Students/Postdoctoral	96	123	408	205	832
Management	20	42	71	31	164
Administrative	3	25	104	273	405
Technical	6	66	199	773	1044
Total	**761**	**409**	**934**	**1316**	**3420**

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

The Laboratory maintains an active Equal Employment Opportunity Program. An Affirmative Action Plan is prepared annually and reviewed by the DOE. LBL's Equal Employment Opportunity Officer reviews each division's performance in the implementation of the Compliance Program. An Equal Employment Opportunity Council, with laboratory-wide representation, reviews LBL performance and advises the Laboratory Director. The program goals include active recruitment outreach, training, and retention activities. In addition, a workforce diversity management program is being initiated. Elements of this program include supervisor and management seminars to increase:

- Awareness of an effective diverse workforce;
- Skills for successful personnel management; and
- Development of highly competitive recruitment and retention programs.

Twenty-two short courses and workshops are offered by LBL's Occupational Health Division to meet training needs, such as the Hazardous Communication course shown here, and to improve other environment, health, and safety programs. In addition, 20 courses are offered by the Personnel Department to improve management, productivity, and employee well-being.

Special employment and internship programs are maintained to increase employment opportunities, which include summer employment programs, student employment programs, youth employment programs, and minority education programs. Educational aid and tuition assistance is available for full-time employees.

Special employee assistance programs promote retention, personal well-being, and effective job performance. These resources and programs are available through the Personnel Employee Relations Group and the Medical Department. Included are on-site consulting services for emotional problems and substance abuse. Off-site referral services are also available when needed.

EXPLORATORY RESEARCH AND DEVELOPMENT PROGRAM

The Exploratory Research and Development Program was established in 1984 following the issuance of DOE guidance to allocate a portion of LBL's operating budget to encourage staff to explore innovative research (Table 7-2). These allocations are subject to the approval of the Laboratory's Overhead Budget Task Force, the Laboratory Director, and DOE.

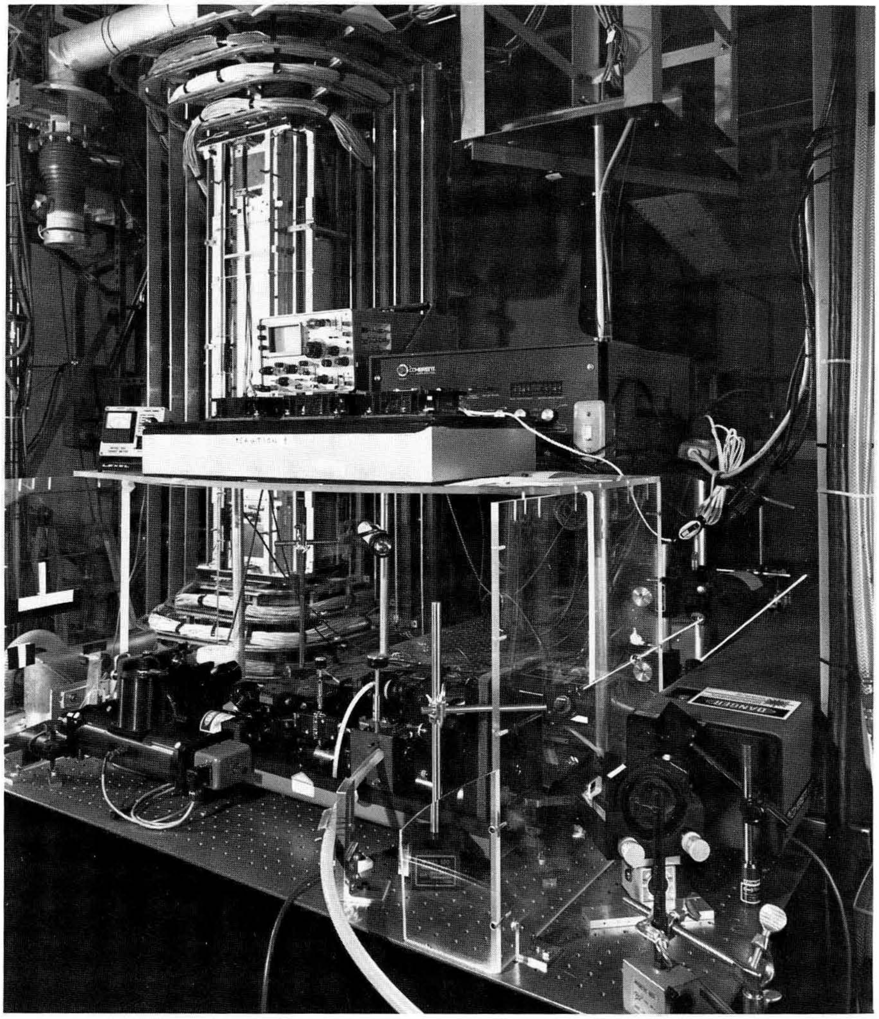
Table 7-2. Exploratory Research and Development Program

Category	FY 1989 Actual	FY 1990 Actual	FY 1991 Estimated
Funding ($M)	3.29	4.10	3.5
Projects Approved	46	51	30

This program contributes to scientific staff capability and vitality through the support of interesting 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 program include the elucidation of noise characteristics in thin-film high-temperature superconducting devices, development of scanning-tunneling microscopy capability for studying surfaces under aqueous solutions, evaluation of foam solution technologies for aquifer restoration, and the determination mechanisms of heavy atom scintillators. An *Annual Report on the LBL Exploratory Research and Development Fund* is available from the Office of Environment and Laboratory Development.



LBL's Exploratory Research and Development program has supported this unique multidisciplinary experiment to search for the electric dipole moment (EDM) of the electron. The experiment has set an upper limit to the EDM of the electron of 1×10^{-26} cm $\times$ e. This is the best limit ever achieved.

Chapter

8

Site and Facilities

The Laboratory prepares long-range 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 building resources. Recent department-wide planning efforts such as the Five-Year Non-defense Facilities Modernization Plan and the Environmental Restoration and Waste Management Site Specific Plan are integrated with this planning process (see Sections 4 and 5).

Resources to maintain and improve the Laboratory's existing facilities are provided through operating expenses, General Plant Projects (GPP), Multiprogram Energy Laboratory Facilities Support (MEL-FS), Environmental Restoration Site Specific Plan, In-House Energy Management, Strategic Facilities Initiative, and General Purpose Equipment (GPE). Adequate funding in these areas will provide DOE with a multiprogram Laboratory capable of efficiently meeting the Laboratory's mission, in full compliance with environment and safety standards.

LBL's facilities planning is coordinated through specific Laboratory management activities and DOE initiatives. The *Long Range Site Development Plan,* will be reviewed and updated periodically. DOE's Strategic Facilities Initiative seeks to optimize the Laboratory's capital investment through evaluation of building and infrastructure conditions. The Environmental Safety and Health Long-Range Plan identifies needs for full compliance in operations and facilities. The Laboratory's ten-year In-House Energy Management Plan represents significant opportunities for cost savings. Institutional planning acts to couple these management activities closely to program planning and other strategic management processes.

SITE DESCRIPTION AND STATUS

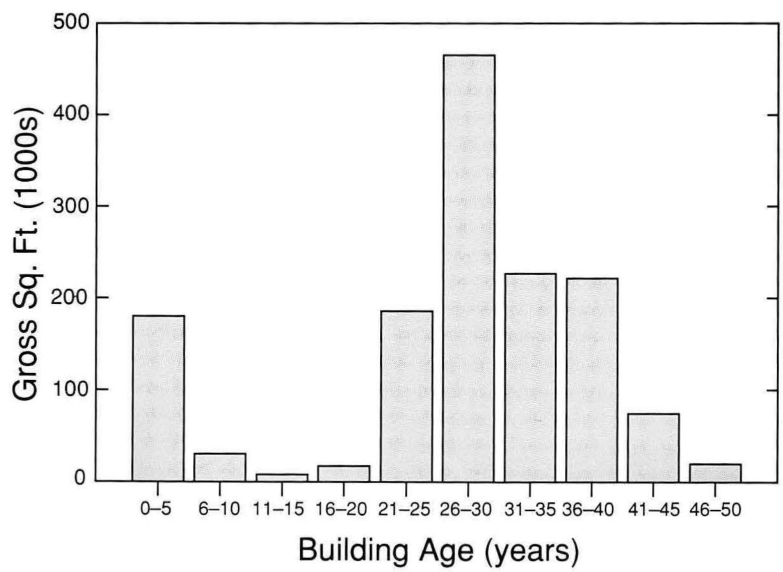
The first building on the LBL site was constructed in 1940. In FY 1990 over 70% of the gsf of permanent buildings is greater than 25 years old. As financial resources have become available, the basic structures, utilities, and interiors of many buildings have been rehabilitated or upgraded. During the late 1980s the first major new laboratories since the mid-1960s have been completed and ALS construction was initiated. The existing facilities and the currently funded construction at LBL constitute 2.08 Mgsf located on the main site, the UC campus, and leased off-site locations. Although new programmatic facilities are planned, the total space associated with the proposed modernization (MEL-FS) projects remains constant as construction projects are offset by demolition of obsolete facilities. The space distribution upon completion of current projects in FY 1990 is shown in Table 8-1.

Table 8-1. LBL Space Distribution[a]

Location	Area (Mgsf)	% of Total
Main site	1.601	77
On campus	0.331	16
Off-site leased	0.146	7
Total	**2.078**	**100**

[a] Includes funded and budgeted projects.

Age distribution of permanent main-site building.



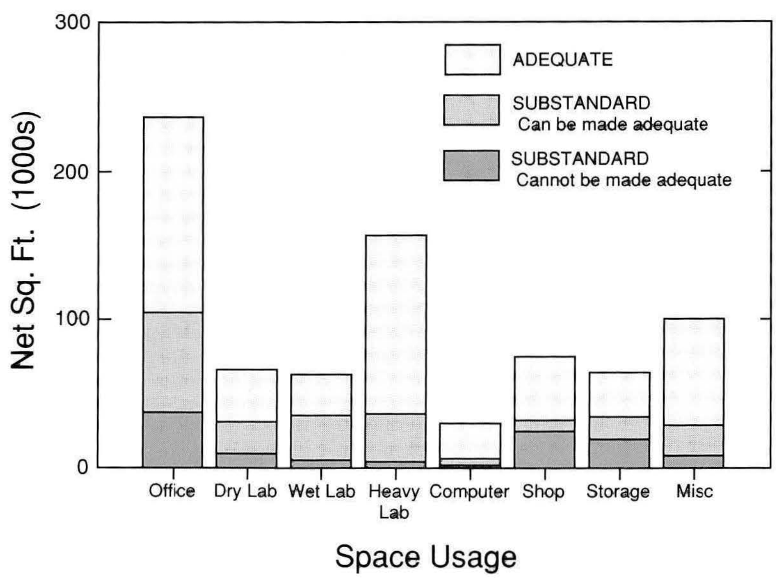
LBL space in campus buildings is available to DOE on a long-term arrangement. The off-site leased buildings provide space for essential research and support functions. In the long term, 30,600 gsf of off-site leased office and laboratory space are planned to be vacated. Of the 1.6 Mgsf on the main site, about 60,000 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, is more than $425 M (Table 8-2). The inventory of building space, including funded construction, is:

- Adequate: 622,800 gsf that require maintenance such as painting, repairs, and minor alterations;
- Substandard, can be made adequate: 797,400 gsf that do not meet existing standards—about 20% gsf require minor rehabilitation (in electrical, structural, and mechanical systems), and the balance major rehabilitation (for existing or projected program requirements); and
- Substandard, cannot be made adequate: 207,350 gsf that cannot be upgraded or rehabilitated at a cost less than new construction.

Table 8-2. Facilities Replacement Value

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

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



Significant modernization is required in laboratory buildings to meet current standards and to provide improved systems for materials handling, as an example. Temporary structures that need to be removed provide primarily office, shop, and storage space. As described below, mechanical and electrical utilities are inadequate and are undergoing partial replacement. Electrical-power substations and distribution systems also require improvements. Two critical programs for modernization and environmental protection are the Multiprogram Energy Laboratories Facilities Support Program and the Environmental Restoration and Waste Management Program.

FACILITIES PLANS AND REQUIREMENTS

Multiprogram Energy Laboratory Facilities Support

To initiate the 15-year MEL-FS modernization plan, an overall increase from $8.0 M in FY 1991 to $12.1 M in FY 1992 is required. The total MEL-FS (FY 1990–2005) needs represent an investment of $201.9 M (Table 8-3). Many of the buildings and utilities are 20 to 40 years old and need improved mechanical and electrical systems to meet current design standards.

Table 8-3. MEL-FS Construction Projects FY 1990–2005

Category	TEC ($M)	Period
Safety and roofs	59.4	1990–2005
Mechanical utilities[a] safety	48.8	1990–2004
Electrical utilities[a] safety	29.3	1990–2003
Building rehabilitation[a]	40.2	1990–2004
Building replacement[a]	24.2	1993–1999
Total	**201.9**	

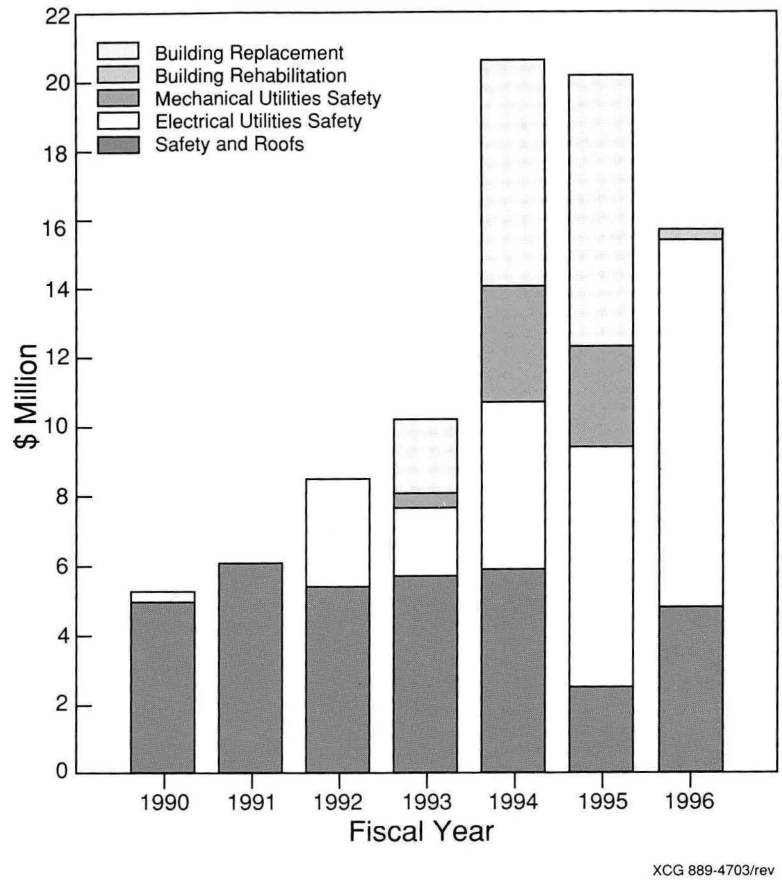
[a] Also includes health- and safety-related building and utility improvements.

Safety Improvements

Health and safety improvements are needed in safety services, medical services, building illumination, radiation protection and monitoring, and in other safety systems. Many of these projects were initiated as MEL-FS projects in FY 1988. Slope and seismic stabilization (required in the Bevalac and Shops Areas), the Original Labsite Substation Project, and Instrument Support Laboratory Rehabilitation have been scheduled for FY 1990. The Building 90 Seismic Rehabilitation is an important proposed project for FY 1991.

A Safety and Support Services Facility and road safety improvements are required for safe and efficient operations and movement of staff and materials throughout the site. Roads need widening, base materials need to be

The backlog of MEL-FS projects provides essential support for the laboratory's needs in environment, health and safety, utilities, and building rehabilitation.



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: one each in FY 1993, FY 1995, and FY 1998.

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 has improved critical mechanical systems, but nearly 60% of existing equipment is over 20 years old and beyond its useful service life. Full implementation of the Mechanical Utilities Rehabilitation Plan minimizes the possibility of accidents and the possibility that programs can be disrupted by loss of essential utilities and equipment.

Electrical Utilities/Safety

LBL's power-distribution system consists of 60 substations and 20 miles of 12-kV primary distribution cable. Most transformers and distribution cables are beyond their expected service lives, resulting in periodic power outages and increased maintenance. The electrical rehabilitation projects have been prioritized based on the expected failure rates of equipment and importance to sitewide facilities demands. The Original Labsite Substation Project replaces electrical facilities in the oldest part of the Laboratory and complements the electrical capability included in programmatic projects under construction in this area. The Switching Station Replacement Project will provide increased reliability for the facilities in the Central Research and Administration Area.

Building Rehabilitation and Replacement

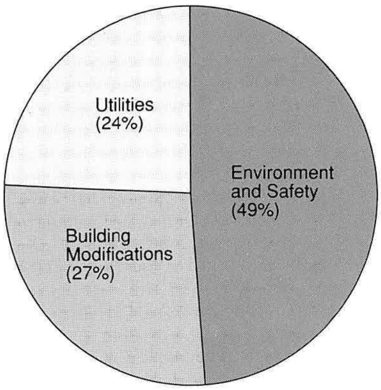
The nonprogrammatic construction projects include 171,800 gsf of new on-site projects through FY 2005. The new construction responds to the needs for safety and supply services infrastructure and general-purpose mechanical- and electrical-engineering facilities. Included in the long-range plan is the removal of substandard facilities that cannot be made adequate. An important priority for FY 1992 construction funding in the MEL-FS program is the Safety and Supply Services Building, which will provide essential space for support services, and the consolidation of functions, resulting in increased efficiency, improved safety services, and cost reductions. An important project for FY 1991 is the Seismic Rehabilitation of Building 90. Seismic analysis of the building has identified structural deficiencies intensified by foundation settling.

Environmental Restoration and Waste Management (ERWM)

LBL environmental management site projects (Table 8-4) 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 exposure and risk levels to chemicals in soils and groundwater, in discharges to sewers, and in laboratory buildings. The environmental restoration program for facilities and operations includes the assessment and characterization of chemical contamination and the closure of the existing hazardous-waste-handling facility. The waste-management program strengthens waste minimization and enables an assessment of sewer systems integrity and potential soil contamination, and supports the construction of a new hazardous-waste-handling facility. These projects provide for full compliance with DOE and other federal regulations and for meeting requirements established by state and local agencies.

Table 8-4. Environmental Restoration and Waste Management (Budgetary Authority $M)

Category	1990	1991	1992	1993	1994	1995	1996
Corrective Activities	0.4	2.1	4.9	2.7	2.8	2.7	0.0
Environmental Restoration	0.0	4.6	1.6	4.7	3.0	2.5	0.0
Waste Management	2.3	1.5	4.5	3.3	3.6	4.9	3.3
Total	**2.7**	**8.2**	**11.0**	**10.7**	**9.4**	**10.1**	**3.3**



GPP backlog by category.

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 (Table 8-5 and accompanying figure). The Chemical Dynamics Research Laboratory, Human Genome Laboratory, and ALS Life Sciences Center are significant resources for programs supported by the DOE's Chemical Sciences Division and Office of Health and Environmental Research. An ALS Improvement Project, to optimize utilization of the ALS, is in the initial planning stages.

General Plant Projects

LBL's GPP funds are provided by DOE's Nuclear Physics Division to fund priority construction projects of a smaller scale; however, the funds received have been inadequate to meet the Laboratory's needs in a timely schedule. This program includes a backlog of 132 projects totaling $36 M. Roughly a third of this backlog is for environmental, health, and safety needs; a third is for other utilities safety and reliability and building maintenance and standards compliance; and a third would be used for multiprogram support facilities and small programmatic rehabilitation projects and additions. These funds have also supported small programmatic initiatives that required minor capital additions. Increasing GPP funding to $6.0 M annually and increasing the ceiling from $1.2 M to $2.0 M for individual projects are important to the success of the Laboratory's safety rehabilitation program.

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 sitewide 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.

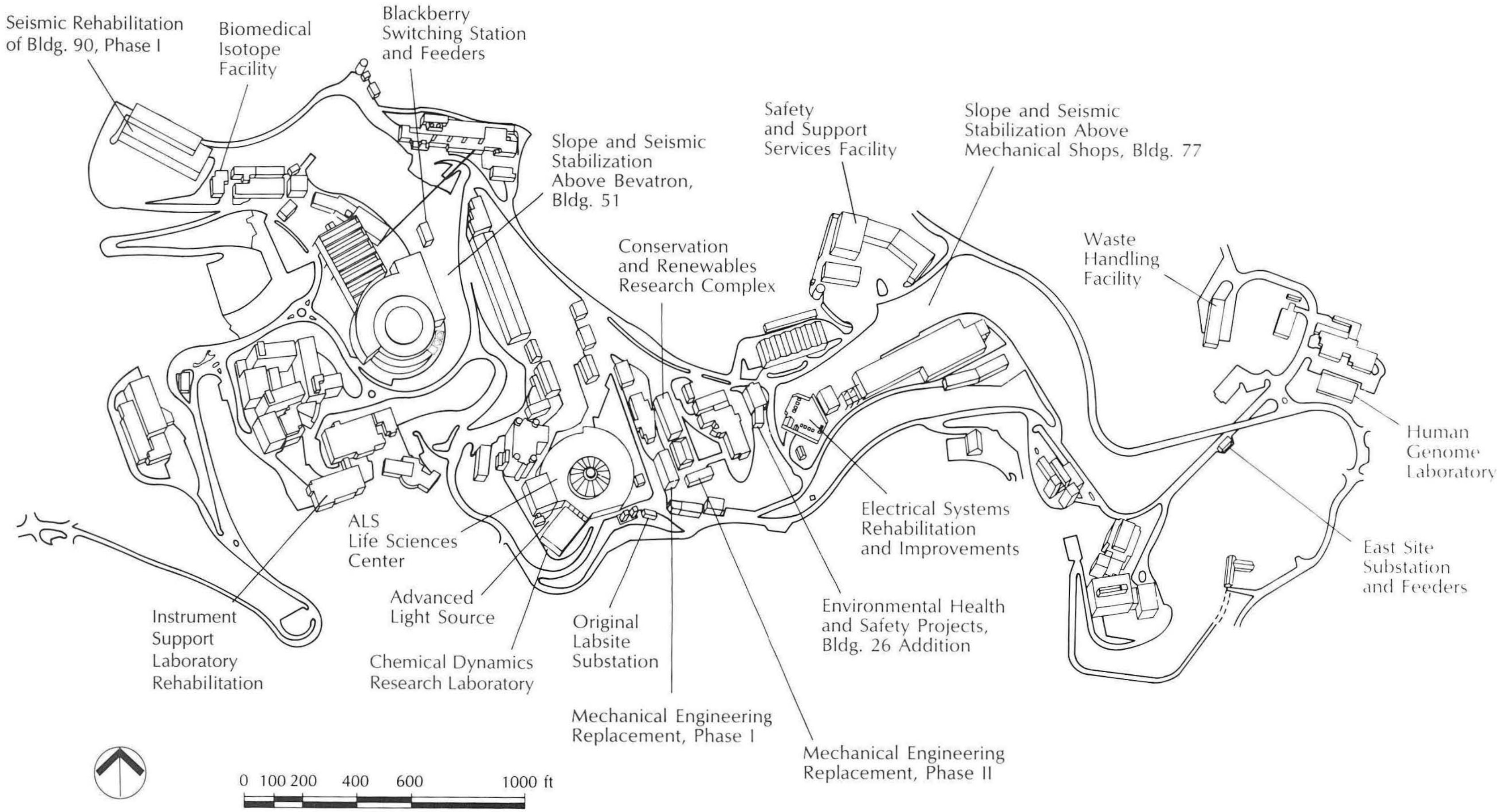
As discussed in the MEL-FS and ERWM sections above, long-range site modernization also addresses many of the major maintenance issues. The reroofing, road safety projects, slope and seismic stabilization, general-purpose-facilities replacement projects, and other environmental and safety improvements 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.

Table 8-5. Long-Range Plan for Programmatic and General Purpose Facilities, Including Funded, Budgeted and Proposed Construction (FY BA,$M)

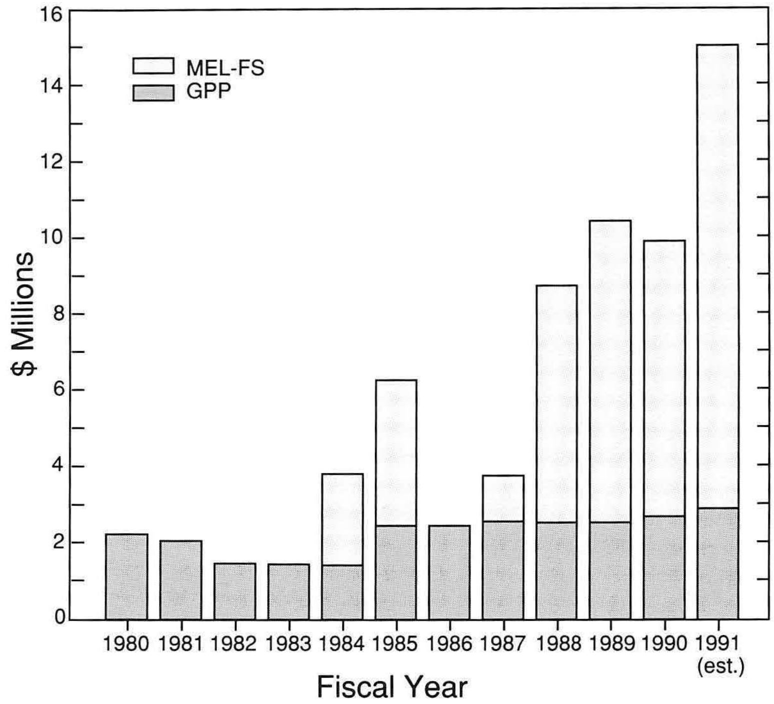
Project	TEC	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
FUNDED PROGRAM RELATED PROJECTS:																		
Advanced Light Source (KC)	99.5	25.0	25.6	23.0	6.4													
FUNDED MEL-FS PROJECTS (KG):																		
Electrical Systems Rehabilitation & Improvements	2.6	0.5																
Mechanical Utilities Rehabilitation, Phase I	5.5	1.6																
Environmental Health & Safety Project	9.2	2.5	4.3	1.6														
SUBTOTAL - FUNDED MEL-FS PROJECTS	**17.3**	**4.6**	**4.3**	**1.6**	**0.0**													
FUNDED ERWM PROJECTS (EX)*:																		
Hazardous Waste Handling Facility	6.2	2.8	1.3	0.0	1.6													
Environmental Health & Safety Project	1.1	0.6	0.5															
SUBTOTAL - FUNDED ERWM PROJECTS	**7.3**	**3.4**	**1.8**	**0.0**	**1.6**													
TOTAL FUNDED	**124.1**	**33.0**	**31.7**	**24.6**	**8.0**													
BUDGETED MEL-FS PROJECTS (KG)																		
Original Labsite Substation	3.0		0.3	0.0	2.7													
Instrument Support Laboratory Rehabilitation	2.1		0.2	0.0	1.9													
Slope and Seismic Stabilization	3.7		0.5	2.4	0.8													
Building 90 Seismic Rehabilitation	6.8			3.7	2.7	0.4												
TOTAL BUDGETED MEL-FS PROJECTS	**15.6**	**0.0**	**1.0**	**6.1**	**8.1**	**0.4**												
TOTAL FUNDED and BUDGETED	**139.7**	**33.0**	**32.7**	**30.7**	**16.1**	**0.4**												
PROPOSED PROGRAM RELATED PROJECTS:																		
Human Genome Laboratory (KP)	20.3				1.7	6.6	6.0	6.0										
Life Sciences Center (KP)	28.6				4.7	14.8	9.1											
Chemical Dynamics Research Laboratory (KC)	69.8				14.5	35.4	13.6	5.8	0.5									
Advanced Light Source Improvements (KC)	40.0					6.0	13.0	14.0	7.0									
Conservation & Renewables Energy Lab. (EC)	26.4					1.8	23.4	1.2										
SUBTOTAL - PROPOSED PROGRAM RELATED	**185.1**				**20.9**	**64.6**	**65.1**	**27.0**	**7.5**									
PROPOSED MEL-FS PROJECTS (KG):																		
East Canyon Electrical Safety Project	3.9				0.4	1.5	2.0											
Roof Replacements, Phase I	3.0				3.0													
Safety & Support Services Facility	8.3				0.6	3.0	4.7											
Fire & Safety Systems Upgrade Proj., Phase I	2.5					0.4	1.2	0.9										
Mechanical Utilities Rehabilitation, Phase II	3.5					0.6	2.9											
Roadway Safety & Stabilization, Phase I	1.9					1.9												
Blackberry Switching Station Replacement	5.4					0.5	2.8	2.1										
Mechanical Engineering Replcmt Proj., Phase I	12.0					1.5	2.7	7.8										
Buildings 50E & 50F Second Fl. Additions	4.2					0.4	3.8											
Sitewide Mechanical Equipment Replcmt, Ph I	3.5						0.5	3.0										
Roadway Safety & Stabilization, Phase II	3.5							1.3	2.2									
Replace Central Switch & Feeders	4.6							0.8	1.6	2.2								
Fire & Safety Systems Upgrade Project, Phase II	3.0							0.4	2.6									
Electrical Engineering Replacement, Phase I	11.0							1.5	6.0	3.5								
Upper Blackberry Switch Replacement	5.9							2.5	3.0	0.4								
Rehabilitation of Bldg. 46	3.2								0.3	1.9	1.0							
Mechanical Engineering Replcmt. Proj., Phase II	8.0									1.0	2.0	5.0						
Cooling Towers & Chillers Replacement	4.3									0.5	3.8							
Sitewide Electrical Equipment Replcmt., Phase I	4.0									1.0	3.0							
Roof Replacements, Phase II	4.4									0.6	2.3	1.5						
Roadway Safety & Stabilization, Phase III	4.3										0.4	3.9						
Mechanical Utilities Rehabilitation, Phase III	6.0											0.8	3.4	1.8				
Electrical Engineering Replacement, Phase II	11.0											1.6	7.4	2.0				
Mechanical Utilities Rehabilitation, Phase IV	5.0												0.5	2.7	1.8			
Rehabilitation of Bldg. 90	4.0												0.4	3.6				
Rehabilitation of Bldg. 64	6.0													0.6	3.0	2.4		
Mechanical Utilities Rehabilitation, Phase V	7.0													0.8	5.2	1.0		
Rehabilitation of Bldg. 50	6.0														0.7	3.6	1.7	
Rehabilitation of Bldg. 70	7.0														0.8	2.9	3.3	
Rehabilitation of Bldg. 70A	7.0															0.8	2.8	3.4
Rehabilitation of Bldg. 62	7.0															0.8	2.7	3.5
Roof Replacements, Phase III	5.0																0.5	4.5
Roadway Safety & Stabilization, Phase IV	5.0																0.5	4.5
SUBTOTAL - PROPOSED MEL-FS PROJECTS	**180.4**	**0.0**	**0.0**	**0.0**	**4.0**	**9.8**	**20.6**	**20.3**	**15.7**	**11.1**	**12.5**	**12.8**	**11.7**	**11.5**	**11.5**	**11.5**	**11.5**	**15.9**

Escalated at 4.3%, FY 1990; 4.7%, FY 1991; 5.5%, FY 1992; 5.7%, FY 1993; 5.8%, FY 1994; 6.0%, FY1995; 6.1%, FY 1996; 6.2%, FY 1997; and 6.3, FY 1998. Beyond 1998 in constant dollars.
* Table 8-4 provides the ERWM resource projection for outyears.



Current and proposed major construction projects.

Recent trends in General Plant Projects and Multiprogram Energy Laboratory Facilities Support. A large backlog of MEL-FS projects has occurred due to limited funding in the early and mid-1980s.



General-Purpose Equipment

GPE funds are essential for the Laboratory to replace worn-out and obsolete plant-maintenance equipment, vehicles, administrative equipment, shop equipment, environmental monitoring and safety equipment, and information processing equipment. The Laboratory requires GPE funding to maintain its complement of general-purpose equipment at a level adequate to serve the research and support programs. For example, LBL currently has a backlog of GPE needs totaling $38 M, primarily for computing, telecommunications, shop, laboratory, environmental safety, and vehicle equipment. With FY 1990 funding at $1.5 M, the backlog cannot be reduced. GPE support at $3 M/year would provide a basis for reducing this backlog incrementally.

INFORMATION TECHNOLOGY RESOURCES

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 (Table 8-6), 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;
- 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.

Table 8-6. Summary of Computing Resources and Activities

Characteristic	FY 1989 Actual	FY 1990 Actual	FY 1991 (Estimated)
LBLnet (million packets/mo)	833	2,700	7,500
Workstations	2,395	2,570	2,725
Central processor (MIPS)	57	297	443
Central storage (Gbytes)	51	68	171

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.

Chapter

9

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 1989 BA and estimated FY 1990 BA for comparison. These tables include:

- Resource Summaries (Tables 9-1 and 9-2);
- Secretarial Level Resources (Tables 9-3 and 9-4);
- Program Office Resources (Tables 9-5 through 9-7); and
- Work for Others Resources (Table 9-8).

The FY 1991 estimate is based on FY 1991 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 1992 and beyond, operating cost projections are in FY 1992 dollars and construction costs are in actual-year dollars (as indicated in the DOE Guidance). For FY 1992 to FY 1996, the growth assumptions in program areas described in the detailed tables range from 0% to 2.0% per year. These growth assumptions are based on the general direction indicated by DOE program personnel. Specific trend levels were established within each major program activity.

The resource projections that follow include all funded and budgeted construction projects, the MEL-FS program, Environmental Restoration and Waste Management, and construction and operational costs for the Advanced Light Source. Other initiatives are only included to the extent that programmatic support is a part of ongoing efforts. The new initiative costs are indicated in Section 4. Proposed construction project costs are provided in Section 8.

Table 9-1. Funding Summary (Fiscal Year Budgetary Authority, $M)

Category	1989	1990	1991	1992	1993	1994	1995	1996
DOE Operating	141.6	141.0	157.9	171.3	177.1	178.1	179.3	180.9
WFO Operating	29.2	33.2	35.6	36.3	36.4	36.5	36.6	36.6
Total Operating	**170.8**	**174.2**	**193.5**	**207.6**	**213.5**	**214.6**	**215.9**	**217.5**
Capital Equipment	20.0	18.8	21.1	22.6	24.4	24.3	24.4	23.7
Program Construction	26.2	30.0	26.3	13.5	5.3	5.3	5.3	5.3
General Purpose Facilities	4.6	5.3	7.7	12.1	10.2	20.6	20.3	15.7
Environmental Restoration	3.4	1.8	1.2	5.8	5.9	5.2	6.2	0.0
General Plant Projects	2.6	2.7	2.9	6.0	6.0	6.0	6.0	6.0
General Purpose Equipment	1.4	1.5	2.0	3.0	3.0	3.0	3.0	3.0
Total Lab Funding	**229.0**	**234.3**	**254.7**	**270.6**	**268.3**	**279.0**	**281.1**	**271.2**

Table 9-2. Personnel Summary (Fiscal Year FTE)

Category	1989	1990	1991	1992	1993	1994	1995	1996
DOE Effort	1574	1571	1577	1614	1604	1590	1604	1618
WFO	275	284	283	275	276	276	277	277
Total Direct	**1849**	**1855**	**1860**	**1888**	**1879**	**1867**	**1881**	**1895**
Total Indirect	**729**	**715**	**712**	**716**	**716**	**715**	**718**	**720**
Total Lab Personnel	**2578**	**2570**	**2572**	**2604**	**2596**	**2581**	**2599**	**2615**

Table 9-3. Secretarial Office Funding Summary (Fiscal Year Budgetary Authority, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
Office of Energy Research								
Operating	101.8	107.4	117.9	131.9	138.3	139.8	141.4	143.0
Capital Equipment	15.1	15.6	18.1	20.1	21.7	21.7	21.7	21.7
Construction	33.2	35.0	34.8	30.1	20.5	30.9	30.6	26.0
Total	**150.1**	**158.0**	**170.8**	**182.1**	**180.5**	**192.4**	**193.7**	**190.7**
Conservation and Renewable Energy								
Operating	12.8	13.5	15.5	16.4	16.4	16.4	16.4	16.4
Capital Equipment	0.8	0.3	1.2	1.2	1.2	1.2	1.2	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.6**	**13.8**	**16.7**	**17.6**	**17.6**	**17.6**	**17.6**	**17.6**
Fossil Energy								
Operating	1.7	1.5	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.7**	**1.5**	**1.8**	**1.8**	**1.9**	**1.8**	**1.9**	**1.8**
Environmental Restoration and Waste Management								
Operating	0.0	1.6	6.6	4.7	4.2	3.6	3.3	3.3
Capital Equipment	0.0	0.0	0.0	0.5	0.6	0.6	0.6	0.0
Construction	3.4	1.8	1.2	5.8	5.9	5.2	6.2	0.0
Total	**3.4**	**3.4**	**7.8**	**11.0**	**10.7**	**9.4**	**10.1**	**3.3**
Civilian Waste Management								
Operating	4.1	2.9	3.5	3.7	3.7	3.7	3.7	3.7
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**4.1**	**2.9**	**3.6**	**3.8**	**3.8**	**3.8**	**3.8**	**3.8**
Administration and Human Resource Management								
Operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.2	3.0	2.1	1.5	1.0	1.0	1.0	1.0
Total	**0.3**	**3.1**	**2.2**	**1.6**	**1.1**	**1.1**	**1.1**	**1.1**
Policy, Planning and Analysis								
Operating	0.8	0.4	0.5	0.5	0.5	0.5	0.5	0.5
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	**0.8**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Work for Other DOE Contractors								
Operating	20.3	13.6	12.1	12.1	12.1	12.1	12.1	12.1
Capital Equipment	4.2	2.6	2.5	2.5	2.5	2.5	2.5	2.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**24.5**	**16.2**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**
Total DOE								
Operating	141.6	141.0	157.9	171.3	177.1	178.1	179.3	180.9
Capital Equip. (inc.GPE)	20.1	18.5	22.0	24.4	26.2	26.1	26.2	25.5
Construction (inc. GPF)	36.8	39.8	38.1	37.4	27.4	37.1	37.8	27.0
Total	**198.5**	**199.3**	**218.0**	**233.1**	**230.7**	**241.3**	**243.3**	**233.4**
Work for Others	30.5	35.0	36.7	37.5	37.6	37.7	37.8	37.8
Total Lab Funding	**229.0**	**234.3**	**254.7**	**270.6**	**268.3**	**279.0**	**281.1**	**271.2**

Table 9-4. Personnel By Assistant Secretary Level Office (Fiscal Year FTE)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
Office of Energy Research	1257	1270	1257	1283	1271	1260	1274	1288
Conservation and Renewable Energy	130	129	139	141	141	141	141	141
Fossil Energy	17	16	19	19	19	19	19	19
Civilian Waste Management	42	30	34	34	34	34	34	34
Environmental Restoration and Waste Management	0	5	13	13	13	13	13	13
Administration and Human Resource Management	3	3	3	3	3	3	3	3
Policy, Planning and Analysis	9	6	6	6	6	6	6	6
Other DOE Contractors	116	112	94	89	89	89	89	89
Total DOE	**1574**	**1571**	**1564**	**1588**	**1576**	**1565**	**1578**	**1592**
Work for Others	275	284	283	275	276	276	277	277
Total Direct	**1849**	**1855**	**1847**	**1863**	**1852**	**1841**	**1855**	**1869**
Total Indirect	**729**	**715**	**709**	**710**	**710**	**709**	**711**	**713**
Total Personnel	**2578**	**2570**	**2556**	**2573**	**2561**	**2549**	**2566**	**2583**

Table 9-5. Office of Energy Research Funding and Personnel (FY BA, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
AT Magnetic Fusion								
Operating	1.6	1.7	1.8	1.9	1.9	1.9	1.9	1.9
Capital Equipment	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.6**	**2.2**	**2.3**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**
Direct FTE	25	25	25	25	25	25	25	25
KA High Energy Physics								
Operating	22.1	19.4	19.6	20.6	20.9	21.3	21.6	21.9
Capital Equipment	3.5	2.8	2.7	2.7	2.7	2.7	2.7	2.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**25.6**	**22.2**	**22.3**	**23.3**	**23.6**	**24.0**	**24.3**	**24.6**
Direct FTE	220	174	168	168	171	173	176	179
KB Nuclear Physics								
Operating	30.9	28.7	32.5	34.2	34.2	34.2	34.2	34.2
Capital Equipment	4.2	4.3	4.7	5.7	5.7	5.7	5.7	5.7
Construction	3.6	4.1	4.1	7.8	7.8	7.8	7.8	7.8
Total	**38.7**	**37.1**	**41.3**	**47.7**	**47.7**	**47.7**	**47.7**	**47.7**
Direct FTE	339	310	328	338	338	338	338	338
KC 02 Materials Sciences								
Operating	15.5	20.3	26.4	34.5	39.5	40.1	40.7	41.3
Capital Equipment	2.9	3.3	2.5	2.5	3.5	3.5	3.5	3.5
Construction	25.0	25.6	23.0	10.2	2.5	2.5	2.5	2.5
Total	**43.4**	**49.2**	**51.9**	**47.2**	**45.5**	**46.1**	**46.7**	**47.3**
Direct FTE	315	371	363	370	348	326	331	336
KC 03 Chemical Sciences								
Operating	7.5	7.3	7.0	7.4	7.5	7.6	7.7	7.9
Capital Equipment	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**8.4**	**8.2**	**7.9**	**8.4**	**8.5**	**8.6**	**8.7**	**8.9**
Direct FTE	97	97	88	88	90	91	92	94
KC 04 Engineering, Math and Geosciences								
Operating	2.6	2.7	2.6	2.7	2.8	2.8	2.9	2.9
Capital Equipment	0.4	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**3.0**	**2.9**	**2.9**	**3.0**	**3.1**	**3.1**	**3.2**	**3.2**
Direct FTE	26	27	25	25	25	25	26	26
KC 05 Advanced Energy Projects								
Operating	5.0	5.0	4.8	5.1	5.2	5.2	5.3	5.4
Capital Equipment	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5.6**	**5.8**	**5.4**	**5.7**	**5.8**	**5.8**	**5.9**	**6.0**
Direct FTE	47	49	45	45	45	46	47	47
KC 06 Energy Biosciences								
Operating	1.3	1.1	1.1	1.2	1.2	1.2	1.2	1.2
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.5**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
Direct FTE	15	12	11	11	12	12	12	12

Table 9-5 (continued). Office of Energy Research Funding and Personnel (FY BA, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
KC 07 Applied Math Sciences								
Operating	1.7	1.9	2.1	2.2	2.3	2.3	2.3	2.4
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.8**	**2.0**	**2.2**	**2.3**	**2.4**	**2.4**	**2.4**	**2.5**
Direct FTE	17	17	18	18	18	19	19	19
KC Basic Energy Sciences (Total)								
Operating	33.6	38.3	44.0	53.0	58.4	59.3	60.2	61.1
Capital Equipment	5.1	5.4	4.5	4.6	5.6	5.6	5.6	5.6
Construction	25.0	25.6	23.0	10.2	2.5	2.5	2.5	2.5
Total	**63.7**	**69.3**	**71.5**	**67.8**	**66.5**	**67.4**	**68.3**	**69.2**
Direct FTE	517	573	549	558	538	519	527	535
KE University Research Support								
Operating	1.4	1.8	1.8	1.9	1.9	1.9	1.9	1.9
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	**1.4**	**1.8**	**1.8**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**
Direct FTE	12	8	7	7	7	7	7	7
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	4.6	5.3	7.7	12.1	10.2	20.6	20.3	15.7
Total	**4.6**	**5.3**	**7.7**	**12.1**	**10.2**	**20.6**	**20.3**	**15.7**
Direct FTE	10	7	9	12	12	14	14	14
KP Biological and Environmental Research								
Operating	12.2	16.8	16.7	17.6	17.9	18.3	18.7	19.0
Capital Equipment	1.3	0.7	1.2	1.2	1.2	1.2	1.2	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.5**	**17.5**	**17.9**	**18.8**	**19.1**	**19.5**	**19.9**	**20.2**
Direct FTE	134	162	156	157	160	163	166	170
KS Superconducting Super Collider								
Operating	0.0	0.7	1.5	2.7	3.0	3.0	3.0	3.0
Capital Equipment	0.0	1.9	4.5	5.4	6.0	6.0	6.0	6.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**2.6**	**6.0**	**8.1**	**9.0**	**9.0**	**9.0**	**9.0**
Direct FTE	0	11	14	18	20	20	20	20
Total OER								
Operating	101.8	107.4	117.9	131.9	138.3	139.8	141.4	143.0
Capital Equipment	15.1	15.6	18.1	20.1	21.7	21.7	21.7	21.7
Construction	33.2	35.0	34.8	30.1	20.5	30.9	30.6	26.0
Total	**150.1**	**158.0**	**170.8**	**182.1**	**180.5**	**192.4**	**193.7**	**190.7**
Direct FTE	**1257**	**1270**	**1257**	**1283**	**1271**	**1260**	**1274**	**1288**

Table 9-6 . Conservation and Renewable Energy Funding and Personnel (FY BA, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
AK Electric Energy Systems								
Operating	0.9	0.4	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.9**	**0.4**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Direct FTE	10	4	7	7	7	7	7	7
AL Energy Storage								
Operating	2.8	3.2	3.4	3.6	3.6	3.6	3.6	3.6
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.8**	**3.2**	**3.5**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**
Direct FTE	26	26	26	26	26	26	26	26
AM Geothermal								
Operating	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.9**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Direct FTE	7	6	6	6	6	6	6	6
EB Solar Energy								
Operating	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.8**	**0.7**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Direct FTE	8	7	7	7	7	7	7	7
EC Building & Community Systems								
Operating	7.0	7.2	8.0	8.4	8.4	8.4	8.4	8.4
Capital Equipment	0.6	0.2	0.6	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**7.6**	**7.4**	**8.6**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**
Direct FTE	71	76	77	77	77	77	77	77
EE Transportation								
Operating	0.1	0.5	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
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.1**	**0.5**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Direct FTE	1	2	1	1	1	1	1	1
EF State/Local								
Operating	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
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	**0.1**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Direct FTE	1	1	1	1	1	1	1	1
EG Energy Conversion Technology								
Operating	0.4	0.6	1.5	1.7	1.7	1.7	1.7	1.7
Capital Equipment	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.4**	**0.6**	**1.7**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**
Direct FTE	6	7	15	16	16	16	16	16
Total Conservation and Renewable Energy								
Operating	12.8	13.5	15.5	16.4	16.4	16.4	16.4	16.4
Capital Equipment	0.8	0.3	1.2	1.2	1.2	1.2	1.2	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.6**	**13.8**	**16.7**	**17.6**	**17.6**	**17.6**	**17.6**	**17.6**
Direct FTE	130	129	139	141	141	141	141	141

Table 9-7. Fossil Fuel and Other DOE Program Funding and Personnel (FY BA, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
AA Coal								
Operating	1.4	1.2	1.2	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.4**	**1.2**	**1.3**	**1.3**	**1.4**	**1.3**	**1.4**	**1.3**
Direct FTE	11	11	10	10	10	10	10	10
AC Petroleum								
Operating	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5
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	**0.3**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	6	5	8	8	8	8	8	8
Total Fossil								
Operating	1.7	1.5	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.7**	**1.5**	**1.8**	**1.8**	**1.9**	**1.8**	**1.9**	**1.8**
Direct FTE	17	16	19	19	19	19	19	19
DB Civilian Waste Management								
Operating	4.1	2.9	3.5	3.7	3.7	3.7	3.7	3.7
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**4.1**	**2.9**	**3.6**	**3.8**	**3.8**	**3.8**	**3.8**	**3.8**
Direct FTE	42	30	34	34	34	34	34	34
EX Environmental Restoration and Waste Management								
Operating	0.0	1.6	6.6	4.7	4.2	3.6	3.3	3.3
Capital Equipment	0.0	0.0	0.0	0.5	0.6	0.6	0.6	0.0
Construction	3.4	1.8	1.2	5.8	5.9	5.2	6.2	0.0
Total	**3.4**	**3.4**	**7.8**	**11.0**	**10.7**	**9.4**	**10.1**	**3.3**
Direct FTE	0	5	13	13	13	13	13	13
WB Administration and Human Resource Management								
Operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.2	3.0	2.1	1.5	1.0	1.0	1.0	1.0
Total	**0.3**	**3.1**	**2.2**	**1.6**	**1.1**	**1.1**	**1.1**	**1.1**
Direct FTE	3	3	3	3	3	3	3	3
PE Policy, Planning and Analysis								
Operating	0.8	0.4	0.5	0.5	0.5	0.5	0.5	0.5
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	**0.8**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	9	6	6	6	6	6	6	6
Work for Other DOE Contractors								
Operating	20.3	13.6	12.1	12.1	12.1	12.1	12.1	12.1
Capital Equipment	4.2	2.6	2.5	2.5	2.5	2.5	2.5	2.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**24.5**	**16.2**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**
Direct FTE	116	112	94	89	89	89	89	89

Table 9-8. Work for Others Funding and Personnel (FY BA, $M)

Office/Program	1989	1990	1991	1992	1993	1994	1995	1996
Other Federal Agencies								
AID	0.5	0.3	0.5	0.5	0.5	0.5	0.5	0.5
Direct FTE	2	2	3	3	3	3	3	3
Defense	3.7	3.1	3.0	3.0	3.0	3.0	3.0	3.0
Direct FTE	32	28	26	24	24	24	24	24
DOI	1.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Direct FTE	9	6	6	5	5	5	5	5
EPA	0.7	1.1	1.3	1.3	1.3	1.3	1.3	1.3
Direct FTE	6	8	9	9	9	9	9	9
NASA	1.8	2.5	2.3	2.3	2.3	2.3	2.3	2.3
Direct FTE	15	17	15	14	14	14	14	14
NIH	12.7	15.6	15.9	16.4	16.4	16.5	16.5	16.5
Direct FTE	112	117	113	111	111	112	112	112
NRC	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE	2	1	1	1	1	1	1	1
Miscellaneous	0.8	0.3	1.7	2.0	2.0	2.0	2.0	2.0
Direct FTE	5	2	11	13	13	13	13	13
Total Other Federal Agencies								
Operating	21.1	22.6	24.9	25.6	25.6	25.7	25.7	25.7
Capital Equipment	0.8	1.2	0.7	0.8	0.8	0.8	0.8	0.8
Total	**21.9**	**23.8**	**25.6**	**26.4**	**26.4**	**26.5**	**26.5**	**26.5**
Direct FTE	183	181	184	181	181	181	181	181
State/Private								
Operating	8.1	10.6	10.7	10.7	10.8	10.8	10.9	10.9
Capital Equipment	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**8.6**	**11.2**	**11.1**	**11.1**	**11.2**	**11.2**	**11.3**	**11.3**
Direct FTE	92	103	99	94	95	95	96	96
Total Work for Others								
Operating	29.2	33.2	35.6	36.3	36.4	36.5	36.6	36.6
Capital Equipment	1.3	1.8	1.1	1.2	1.2	1.2	1.2	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**30.5**	**35.0**	**36.7**	**37.5**	**37.6**	**37.7**	**37.8**	**37.8**
Direct FTE	275	284	283	275	276	276	277	277

Acronyms & Abbreviations

AECR	Advanced Electron Cyclotron Resonance
AEDOT	Advanced Energy Design and Operation Technologies
AGMEF	Ana G. Méndez Educational Foundation
AGS	Alternating Gradient Synchrotron
ALS	Advanced Light Source
AVMs	arteriovenous malformations
BA	budgetary authority
BASTEC	Bay Area Science and Technology Education Collaboration
BES	Basic Energy Sciences (Office)
BGO	bismuth germanate
BNL	Brookhaven National Laboratory
CAD	computer-aided design
CAM	Center for Advanced Materials
CASA	Cooperative Approach to Software Advancement
CDF	Collider Detector at Fermilab
CDG	Central Design Group
CDRL	Chemical Dynamics Research Laboratory
CERN	European Organization for Nuclear Research
CFCs	chlorinated fluorocarbons
CP	charge parity
CRE	Conservation and Renewable Energy
CSD	Chemical Sciences Division
CSDP	Continental Scientific Drilling Program
CSEE	Center for Science and Engineering Education
DLS	Dilepton Spectrometer
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EBETAB	East Bay Emerging Technology Advisory Board
ECR	electron cyclotron resonance
EH&S	Environmental Health and Safety Department
EKS	Energy Kernal System
EM	Environmental Management
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERWM	Environmental Restoration and Waste Management
FEL	free-electron laser
FSETL	Faculty-Student Experiment and Teaching Laboratory
FTE	full-time equivalent
FY	fiscal year
GaAs	gallium arsenide
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
HIREFS	high-resolution erect-field spectrometer
HISS	Heavy-Ion Superconducting Spectrometer
ILSE	Induction Linac Systems Experiment

IRFEL	infrared free-electron laser
ITER	International Thermonuclear Experimental Reactor
JSU	Jackson State University
LBL	Lawrence Berkeley Laboratory
LDCs	less-developed countries
LEAP	Large Einsteinium Activation Program
LET	linear energy transfer
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
MEL-FS	Multiprogram Energy Laboratory Facilities Support
MEVVA	metal vapor vacuum arc
Mgsf	million gross square feet
NCEM	National Center for Electron Microscopy
NIH	National Institutes of Health
NMR	nuclear magnetic resonance
NSAC	Nuclear Science Advisory Committee
NSF	National Science Foundation
OER	Office of Energy Research
OFA	other federal agencies
OHER	Office of Health and Environmental Research
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PEP	Positron Electron Project
R&D	research and development
RHIC	Relativistic Heavy-Ion Collider
SERS	Science and Engineering Research Semester
SLAC	Stanford Linear Accelerator Center
SLC	Stanford Linear Collider
SNL	Sandia National Laboratories
SQUIDs	Superconducting Quantum Interference Devices
SPS	Super Proton Synchrotron
SSC	Superconducting Super Collider
TBA	Two-Beam Accelerator
TEC	total estimated cost
TPC	Time Projection Chamber
TRAC	Teacher Research Associates (DOE)
UC	University of California
URA	Universities Research Association
USGS	U.S. Geological Survey
VUV	vacuum ultraviolet
WFO	Work for Others

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