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Lawrence Berkeley Laboratory Preliminary Institutional Plan FY 1990-95

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LAWRENCE BERKELEY LABORATORY

Institutional Plan

FY 1990–1995

Lawrence Berkeley Laboratory
University of California
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PREFACE

The FY 1990–1995 Institutional Plan provides an overview of the Lawrence Berkeley Laboratory (LBL) mission, strategic view, scientific initiatives, research programs, educational and technology transfer activities, human resources, and facilities needs.

The Laboratory 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 a major long-term opportunity 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 section on Education and Technology Transfer Programs identifies current and planned interactions with industry, universities, and the broader science-education community. The Human Resources section identifies 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 Laboratory Mission Statement and Strategic View reflect the research divisions grouped in the Energy Sciences, General Sciences, and Life Sciences. The Initiatives and Scientific and Technical Programs sections are organized to parallel sponsoring Department of Energy (DOE) program offices.

Preparation of the plan is coordinated by the Office for Planning and Development from information contributed by the Laboratory's scientific and support divisions through an annual planning and review process.

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1 DIRECTOR'S STATEMENT

Charles V. Shank, LBL Director

At Lawrence Berkeley Laboratory, the Institutional Plan has become an important vehicle for charting and assessing the Laboratory's scientific opportunities: it provides a process by which our mission, initiatives, and environment can be critically evaluated on a continuing basis. As the new Director of LBL, I will use this opening statement for the 1990–1995 Institutional Plan to express my views on the mission and future directions for the Laboratory.

Simply stated, the mission of the Laboratory is to employ our unique resources to execute programs in fundamental and applied research and to be a technological resource for the Department of Energy (DOE) and the nation. To help our country face the next decade of global competition and interdependence, it is imperative that the Laboratory pursue well-defined research efforts that bring the cutting edge of science to bear on problems of national importance.

Scientific excellence is the Laboratory's fundamental goal as it contributes to the DOE's national programs in basic research and energy technology. These programs form a knowledge base that will enhance our understanding of the world around us and provide the underpinning for strengthening our technologically based economy.

To exploit fully LBL's potential for contributing to the national scientific program, our scientists collaborate broadly in developing and using forefront facilities. At LBL we operate a user facility, the National Center for Electron Microscopy, that is a vital resource for both industrial and academic communities. In addition, we are constructing the Advanced Light Source, which will be a national user facility. We are also continuing to participate in such national projects as the Superconducting Super

Collider. Beyond the development and use of central facilities, the Laboratory leads major interdisciplinary research programs such as the Human Genome Project.

National laboratories have a special obligation to contribute to the economic health of our country. One way to do this is through the process of transferring technology developed in the research laboratory to industries where it might be used. A more important role is to identify, while in their embryonic state, new technologies that will require long-term commitments before commercial applications can be determined. It is in this precompetitive stage that a national laboratory can be a point of focus for new knowledge and industrial collaboration. As research clarifies market opportunities, our industrial collaborators will move the technology to the commercial sector. The Laboratory can make a unique contribution through our graduate students and postdoctoral fellows. When the technology is ready for the marketplace, the human resources will be there as well. A key challenge for the Laboratory is to select the areas with the most promise for economic development.

As members of the scientific community in a national laboratory, we have a social responsibility to set an example for the larger community. The Laboratory must be an innovator in using our scientific and organizational resources to attack difficult social problems. The Laboratory must lead the way in including and developing underrepresented groups on the staff. Early and effective mathematics and science education is crucial for the creation of a technically flexible work force to meet the needs of the country in the next century. The frontier research teams at LBL, in partnership with the University of California at Berkeley and the Lawrence Hall of Science, can provide the full range of enriched scientific experiences for students and teachers.

The Laboratory faces other challenges as well. We have always taken pride in the general view of LBL as a safe and environmentally benign site. We can no longer take this view for granted. Public standards for hazardous materials and effluents are tightening, and public scrutiny is increasing. The local community requires assurance that the Laboratory is a thoughtful and responsible neighbor, and the DOE must also be confident of the excellent operation of this facility. At the Laboratory, our primary goal is to create science, but the world will not condone research if the environment is defiled or if people are injured. I place a high priority on the continued safety and environmental acceptability of site operations and on communicating this plan to the Laboratory staff.

The initiatives and scientific programs presented in this Institutional Plan are an impressive agenda for action. This is the world as seen by an excellent professional staff deeply excited by scientific opportunities and the need to meet national challenges. In the coming years, new initiatives will be built on this foundation.

Charles V. Shank, LBL Director

2 LABORATORY MISSION

The Lawrence Berkeley Laboratory, operated by the University of California for the Department of Energy, provides national scientific leadership and supports 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 DOE goals.

ENERGY SCIENCES

- **Applied Science**—building energy efficiency, environmental effects of technology, energy storage and distribution, fossil-energy conversion, solar for heating/cooling building systems, and national and international energy policy studies.
- **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 and Chemical 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; dynamics of chemical reactions; and atomic structure of heavy ions.

- **Engineering**—technical support for scientific programs and research facilities, development of advanced electronic and mechanical instrumentation systems, design of detectors, and fabrication of experimental systems.

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.

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

LIFE SCIENCES

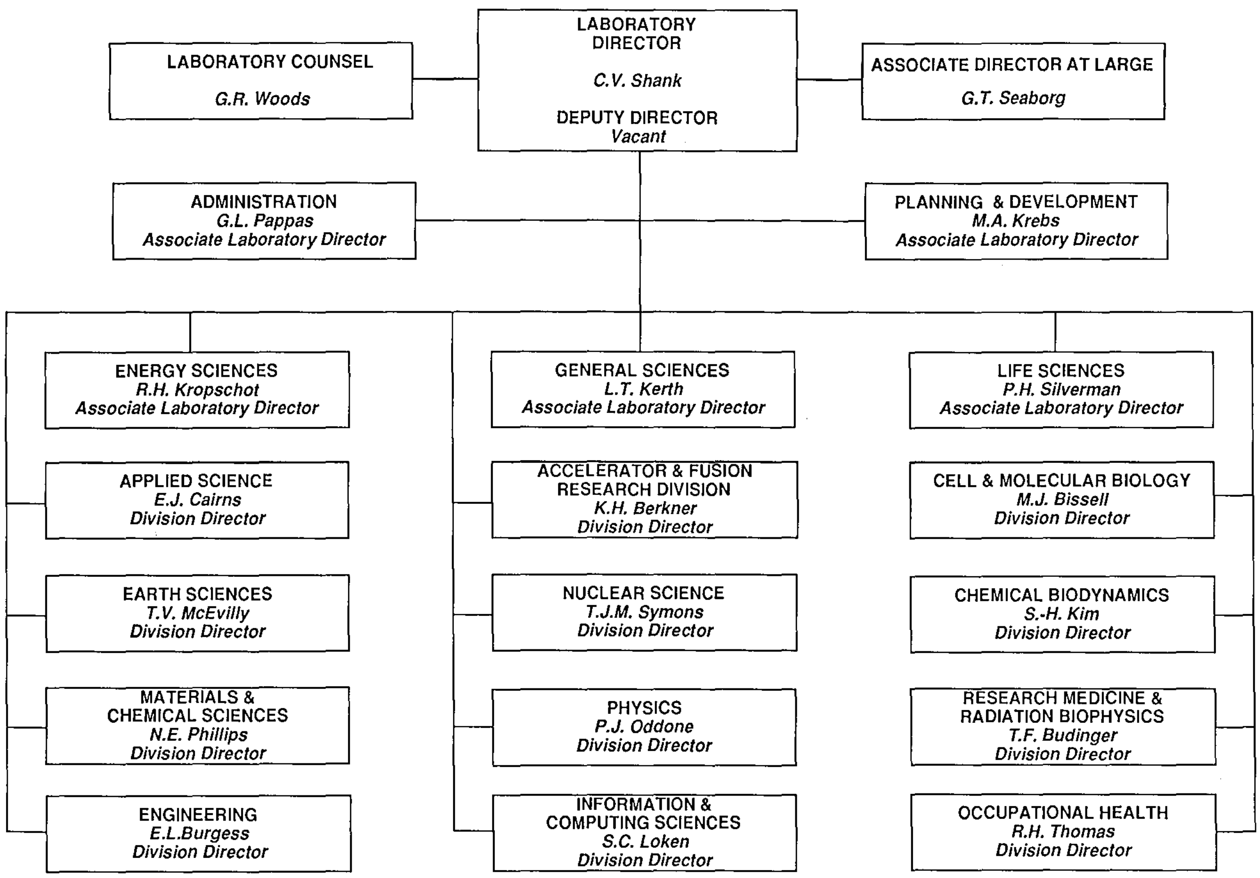
- **Cell and Molecular Biology**—gene expression and molecular genetics, cellular differentiation (including hemopoiesis) and carcinogenesis, structural and theoretical biology, DNA repair and recombination, cell and molecular biology of radiation, and the Human Genome Center.

- **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.

- **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, effectively, and efficiently.



LBL Organization Chart.

3 LABORATORY 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

FEDERAL RESEARCH ENVIRONMENT

The Laboratory is strongly affected by national economic, political, and environmental conditions that influence energy policies and research programs. These conditions include a strengthened technical base for domestic energy production and use, the increasing need for U.S. industrial innovation, and the protection of health and the environment.

Energy Resources and Fundamental Research

To take 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 alternate energy-supply technologies, renewables, and end use.

Basic research will continue to be supported strongly at the national level during an era of expanding programs in physics, space, environment, and health. Since LBL primarily serves the 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 the DOE through their basic-research capability and their plans to develop and build new facilities that serve university and industrial research communities.**

Economic Competitiveness and Education

Federal laboratories will be increasingly seen as sources of new ideas and technology to improve the competitiveness of U.S. industries. LBL's continued commitment to fundamental research, broadly guided by the Department's missions in energy, general, and life sciences, is also the foundation for the Laboratory's interaction with other 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 work force will be essential 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.**

Environment 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 will structure its plans to allocate the necessary resources to implement DOE policies in safety, environmental restoration, and waste management.**

RESEARCH AND DEVELOPMENT ASSUMPTIONS

The following sections identify important conditions affecting LBL's Energy Sciences, General Sciences, and Life Sciences programs. These programs will be limited by fiscal constraints associated with efforts to decrease the Federal budget deficit, and the overall size of Laboratory staff is not expected to grow significantly.

Energy Sciences

Research activities in LBL's Energy Sciences programs have been influenced by national research needs, patterns of energy use and supply, and related economic and environmental policies. The development of new, efficient 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, alternate 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:

- **Chemistry of inorganic and 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 and studies of the structure and function of macromolecules, including artificial enzyme catalysis and materials synthesis, are also critical for success.

- **Materials science research** will grow in areas involving investigation of electronic, structural, and other properties of thin films, surfaces, interfaces, and bulk materials; development of the science of wear, fracture, 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, including magnetic optical materials.

- **Earth sciences research** will include comprehensive studies of geological systems, including petroleum and geothermal reservoirs, groundwater systems, and repositories for energy-related wastes. Additional attention will be given to subsurface environmental restoration and waste-management problems. Important themes will be the dynamics of transport processes and the composition and evolution of the continental lithosphere.

- **Energy-use 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.

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

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, with the materials research community involving accelerator-based user facilities, and with Federal program directions in fusion research. LBL's national scientific outlook in these program areas includes the following developments:

- **Nuclear physics research** will emphasize techniques that probe or alter the state of nuclei to explore nucleonic, hadronic, and quark-gluon matter. 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. The 88-Inch Cyclotron, with its advanced Electron Cyclotron Reasonance (ECR) 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.

- **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 the 1990s and onto the 21st century. The growing interrelationship between astrophysics and particle physics will lead to experimental programs for measuring cosmological parameters, dark matter, diffuse radiation, and large-scale structure. These emerging programs 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.

- **National fusion research** 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. A major review by the National Academy of Sciences, requested by Congress and conducted during 1989–90, will examine the 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 are an option for driving toroidal currents in the next-generation steady-state tokamak—the International Thermonuclear Experimental Reactor.

- **Research in information and computing sciences** will continue to be needed to improve the ability to access, transfer, store, and retrieve research results, at unprecedented data rates, in distributed computing facilities. These studies will involve the introduction of new control and data-acquisition systems and powerful workstations to provide scientists with flexibility in the access, manipulation, and visualization of complex data. Emphasis will be placed on interoperable software systems.

Life Sciences

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 study, diagnose, and treat human disease. 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 hemopoiesis, radiation biology, and the search for bioassays to detect low-level radiation are expected to expand. Technology transfer in the areas of gene expression and accelerator-related biomedical research will be emphasized.

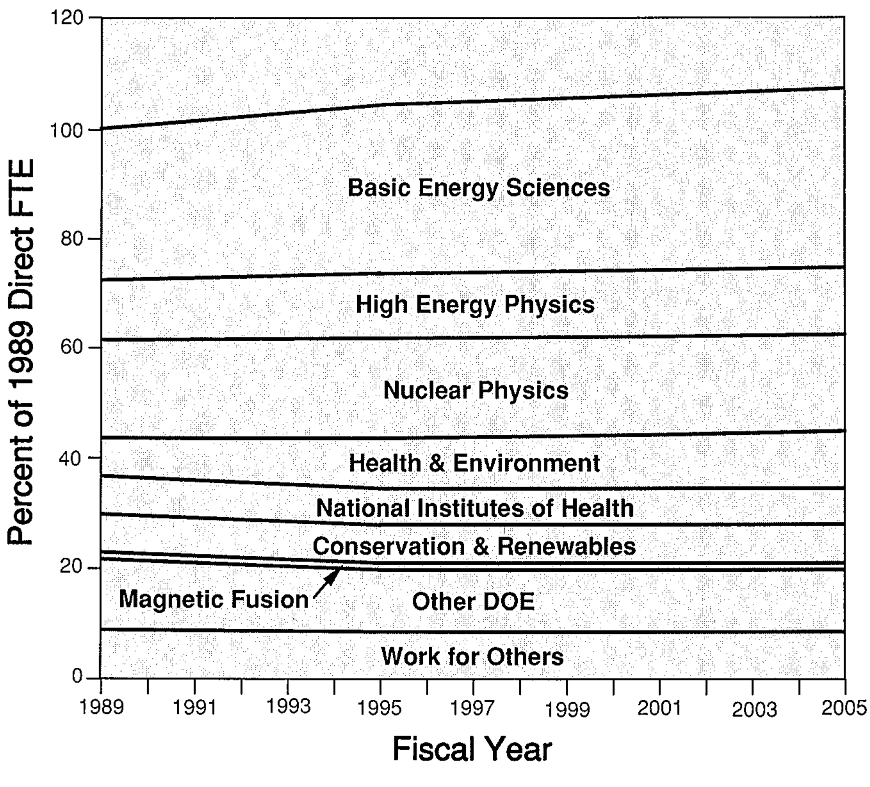
ACTIVITY TRENDS

The Laboratory is projected to remain generally stable in overall size but with selected growth in several initiatives, including those involving 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. After FY 1990, operating levels of existing programs are capped at between 1.0 and 2.0% annual growth until FY 1995. Following FY 1995, 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 1990–1995 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.

Energy Sciences

- **Basic Energy Sciences research will grow.** An important component of this growth for LBL will be the Advanced Light Source. Construction began in FY 1987, and the facility will be operational in FY 1993. To capitalize on the capabilities of the light source, a Combustion Dynamics Facility is being proposed, including a dedicated infrared



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.

free-electron laser for the chemical sciences. A 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 science 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. The level of research activity and the training of graduate students in the chemical and materials sciences are expected to expand.

- **Geosciences research on containment and remediation of subsurface pollutants; on the safe disposal of radioactive, mixed, and other hazardous wastes; and on definition of hydrocarbon reservoirs 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). Modest growth is expected also in association with LBL's Center for Isotope Geochemistry.

- **Research on the emissions 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 will include combustion chemistry and control, heterogeneous chemical processes in cloud formation, the relationship between particulates and climate models, and carbon dioxide assimilation by ecosystems.

- **Energy conservation, supply, and use research has the potential for increased activity over the 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.

General Sciences

- **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.** The Bevalac will continue to provide the nation with a high-intensity heavy-ion accelerator emphasizing the energy range between 500 MeV and 2 GeV per nucleon. This will be complemented by the low-energy nuclear science research conducted at the 88-Inch Cyclotron.

- **An SSC detector development program at LBL will contribute significantly to research, engineering, and construction of the nation's next generation high-energy physics detector.** 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.

- **Particle astrophysics is an expanding field that offers a range of observational and theoretical opportunities.** An example is the study of phenomena at higher energies and densities than those available in terrestrial particle accelerators. Expanded research and educational activities at LBL will include studies of cosmological parameters (such as patterns of primordial nucleosynthesis), detection of dark matter, and the development of detectors for microwave, x-ray, and gamma-ray cosmic backgrounds.

- **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 and enhancement of PEP.

- **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 of activity, including engineering research on various comparative technologies such as room temperature vs. superconducting linacs for free-electron lasers. 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.

- **Induction linear accelerators have the potential for providing intense and focused kinetic energy from heavy ions 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 review will affect the course 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 1-MeV test facility for ITER neutral-beam systems R&D.

Life Sciences

- **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 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 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.

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.

- **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 is initiating an active marketing and licensing program for the Laboratory's intellectual property and works with LBL's Office of Sponsored Research Administration to draft effective collaborative research contracts with industry. Creative approaches to protecting DOE/LBL intellectual property rights, while responding to industry's needs, are being developed in coordination with DOE.

- **LBL's energy, general, and life sciences programs require advanced engineering and computational support to achieve DOE's national programmatic goals.** Leadership in instrumentation engineering and computer networking systems calls for adequate programmatic and general-purpose resources to respond to research initiatives and to replace obsolete systems. The Laboratory is committed to working with DOE to provide adequate general-purpose equipment, to maintain safe and efficient engineering facilities, and to train and develop the human resources for technical support to safely achieve DOE program objectives.

- **The Institutional Plan will continue to give priority to modernization and restoration of facilities because these sustain national programs while providing 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 decades will see innovative use of new and rehabilitated facilities, including new probes and detection systems, dramatic advances in the understanding of complex physical and biological systems, and new collaborations that promote the transfer of research results to industry.

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 (in constant FY 1989 dollars) and construction costs (in actual-year Budgetary Authority) 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 Facility
- Heavy-Ion Fusion Accelerator Research
- ALS Source User Participation Programs
- Advanced Transmission Electron Microscopes

High Energy and Nuclear Physics

- SSC Detector Program
- Particle Astrophysics
- B Factory at PEP
- Relativistic Heavy-Ion Collider Participation

Health and Environmental Research

- Human Genome Center
- ALS Life Sciences Center
- Structural Biology Research Program
- Biomedical Isotope Facility
- Global Change Research Program

Conservation and Renewable Energy

- Advanced Computer-Based Building Design
- Superconductivity Research and Technology Program

Fusion Energy

- 1.3-MeV Neutral-Beam Injector

Multilaboratory Collaboration

- Environmental Restoration Research Program
- Large Einsteinium Activation Program

Education/Technology Transfer Initiatives

- Faculty/Student Experiment and Teaching Laboratory
- California Institute for Energy Efficiency
- Cooperative Approach to Software Advancement
- Biomedical Research Accelerators

General-Purpose Facilities

- Safety and Support Services Facility
- Mechanical Engineering Replacement Projects

BASIC ENERGY SCIENCES

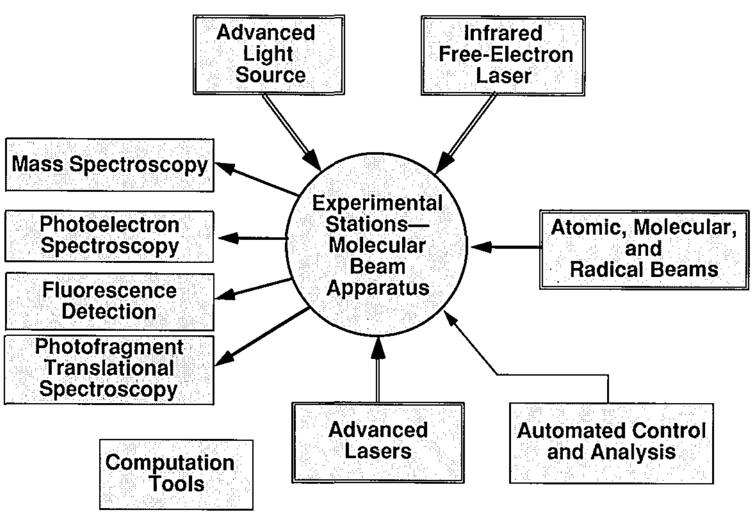
COMBUSTION DYNAMICS FACILITY

In support of DOE's national role in combustion research and chemical reaction science, LBL and the Sandia National Laboratories (SNL) have proposed a major Combustion Dynamics Initiative. The initiative advances DOE's energy sciences mission to enhance the efficiency of combustion processes while minimizing the undesirable effects, such as the production of pollutants. The LBL effort will focus on fundamental advances in structure and reactivity of critical reaction intermediates and transients and dynamics of elementary chemical reactions. The Sandia effort will emphasize complementary optical diagnosis of combustion, chemical kinetics, and reacting flows.

The Combustion Dynamics Facility (CDF) will offer unparalleled experimental resources for national users to enable new investigations of fundamental and applied combustion processes. At LBL, a new advanced Infrared Free-Electron Laser (IRFEL), molecular beam machines, dedicated chemical physics synchrotron-radiation beam lines and advanced lasers would 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 combustion systems and control technology industries. Application of this knowledge will be accelerated by the partnership with SNL through the availability of CDF experimental resources for applied research.

Some of the most obvious applications of this basic research are to model and predict accurately reaction processes and to develop advanced controlled combustion systems. This requires understanding the chemical behavior of molecular species that are highly reactive and severely strained or unstable, as well as molecules in excited electronic and vibrational states. This knowledge is not available from conventional chemical experiments. The CDF'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 picosecond lasers in the VUV region, as well as molecular-beam apparatus for the investigation of radicals and transient species. The proposed facilities at LBL include:

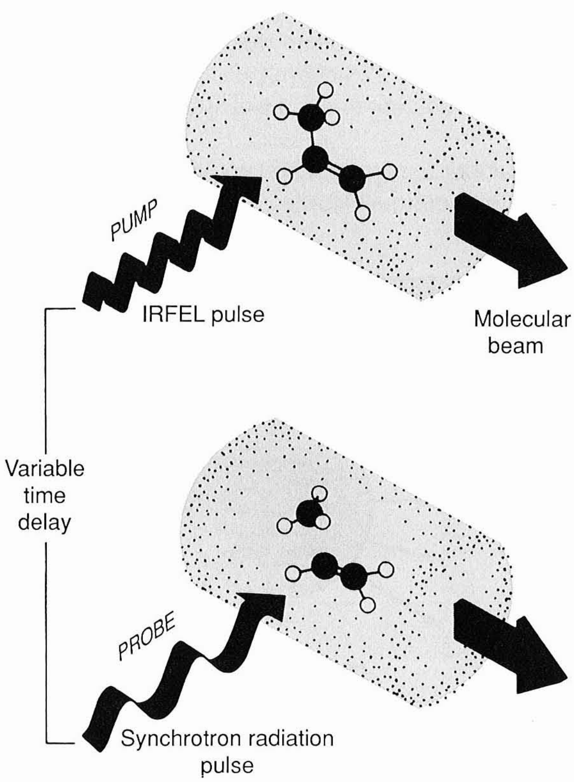
- An IRFEL optimized in the 3 to 50-μm wavelength for chemical reaction research;
- Advanced lasers, molecular-beam machines, universal mass spectrometric detectors, ALS chemical-physics beam lines, and computer-based modeling and control systems; and
- A laboratory facility to support and provide utilities, safety systems, and necessary space to conduct studies.



Research at the Combustion Dynamics Facility at LBL would utilize a new IRFEL and dedicated ALS chemical physics beam line in combination with molecular beam apparatus and spectrometers. Advanced lasers and powerful computation and control systems would also be employed.

The IRFEL will, for example, allow scientists to heat 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 multiphoton and unimolecular excitation. The powerful research facilities would be assembled by combining the various photon sources with molecular-beam 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 and with crossed molecular beams. The facility's scope also allows for the flexible management and arrangement of experimental apparatus, for safe transfer of chemicals and gases, and modular instrumentation and computer interface and systems.

These state-of-the-art national user facilities, together with complementary facilities at Sandia, will provide an unmatched capability for focused multi-investigator basic energy research programs. The CDF will be managed to host visiting scientists, and its user facilities will be made available to all qualified investigators. LBL's outstanding graduate student and science education programs will contribute to full utilization of the facility in support of national science education goals. Workshops and training seminars will be conducted to advance research progress and provide orientation to new users and graduate students. A steering committee of LBL, Sandia, and external advisors, necessary to achieve the national purposes of the facility, will be appointed to provide advice on



The Combustion Dynamics Facility 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.

policy issues and to ensure maximal scientific and technical productivity of the facilities. Collaborations of external users and in-house research personnel will be supported by a dedicated scientific and technical staff.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	2.2	3.5	5.8	9.8	9.1	9.5	39.9
Construction	0.0	0.0	4.4	19.1	26.6	5.6	55.5

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

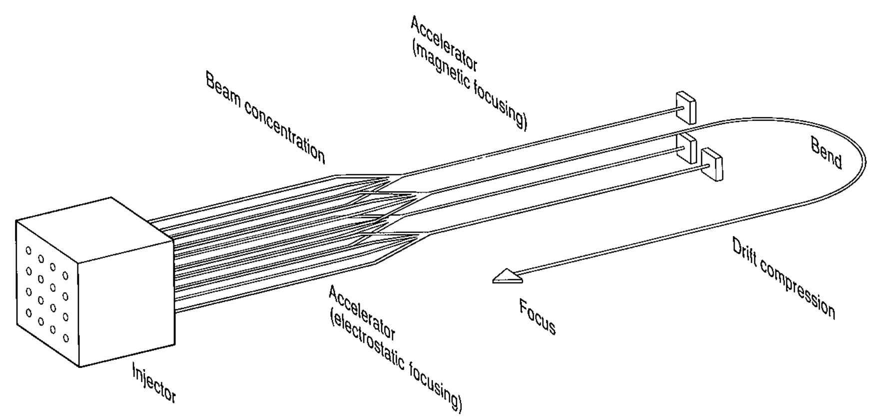
HEAVY-ION FUSION ACCELERATOR RESEARCH

Induction Linac System Experiment

The U.S. Heavy-Ion Fusion Accelerator Research 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 (MBE-4) 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, multicharged 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 and stability of the focal spot 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 (or 20 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 can



In ILSE, sixteen C^+ beams will be accelerated, current-amplified, and combined into four beams, which will then be accelerated further. Finally, one of the four beams will be bent, subjected to additional current amplification, and focused on a simulated target, carrying only one beam through the final stages. This approach will control costs while providing the desired data.

at best 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 PBFA-2 program in the next few years, ILSE could well complete the research data base that is the goal of the Heavy-Ion Fusion Accelerator Research program and, given success, could open the door in the 1990s for the planning of a fusion-power program based on inertial confinement. During 1989–90 the National Academy of Sciences review group on inertial fusion will consider the heavy-ion approach to controlled inertial fusion and may provide recommendations on the support of ILSE. Incremental costs of ILSE above the base Heavy-Ion Fusion Accelerator Research (HIFAR) program are indicated below.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	4.5	8.2	8.8	8.2	7.7	37.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

ALS USER PARTICIPATION PROGRAMS

With construction of the ALS underway, the Laboratory has begun to work with user groups to develop research proposals that will fully use the ALS capabilities that become available in 1993. Although funds for ALS construction and general operations are provided through BES–Materials Science, research proposals will be submitted by external users and LBL users to program sponsors in DOE and other agencies. Life sciences research opportunities are discussed in the subsequent section on Health and Environmental Research.

Interface and Materials Research

The materials/interface experiments combining new microscopic and spectroscopic techniques greatly benefit from high brightness. LBL scientists working at the National Synchrotron Light Source (NSLS) recently focused soft x-rays to a spot 500 Å in diameter with sufficient flux for microscopy and holography. The ALS will have much higher flux for combining microscopy and spectroscopy with unprecedented spatial and energy resolution. Photoelectron, photoion, or soft x-ray fluorescence microscopy on microelectronic structures, small particles, and grain boundaries will be possible.

Opportunities in Surface Science

Research on semiconductors, superconductors, and epitaxial systems will greatly benefit from the high brightness of the ALS, including studies of defects and impurities at the spatial resolution of integrated circuits. Metals, thin films, and clusters represent a second important category, with the ALS enabling the determination of geometry, bond lengths, and densities of electronic states. The ALS will also be a superior source of radiation for the study of chemical reactions on surfaces, including the identification of chemical species and their bonding characteristics in the chemisorbed state.

Chemical Applications of Undulator Radiation

Undulator radiation from the ALS will have a number of unique properties for chemistry, including short pulse duration, high brightness, and polarization. Two-color studies will involve synchrotron radiation in conjunction with a laser. Possible new pump-probe experiments are the high-resolution infrared spectroscopy of intermediates in molecular beams and the probing of reaction-product state distributions.

The ability to vary polarization will increase the quality of information about excited states, and circularly polarized undulator radiation will enhance the structural information about biological molecules. The short pulse duration will make possible fast-timing experiments, such as the direct measurement of autoionization lifetimes or threshold photoelectron spectroscopy. In addition, the ability to produce tunable VUV and soft x-ray radiation and the high repetition rate will minimize or eliminate detector saturation and space-charge effects, resulting in a very useful signal.

Soft X-Ray Near-Threshold Phenomena—Atomic and Molecular Physics

A number of basic problems in atomic and molecular physics still await solutions for lack of intense and tunable probes. New results in atomic and molecular physics will come with the significant flux and high resolution of the ALS. One problem that may soon be addressable is the three-body continuum problem. Experiments can be carried out in which the product particles are analyzed for energy, direction, and, especially, angular correlation.

The study of autoionizing states, multiple-excitation states, and scattering states generally requires both high resolution and great sensitivity to separate the various decay components. Other techniques and studies that will benefit are time-resolved spectroscopies (these will often translate into real-time studies); the detection and study of extremely dilute species; and delineation of the properties of excited states and intermediate atomic and molecular species. Resource estimates below represent programmatic support from BES-materials sciences.

ALS User Participation Programs
Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	2.0	3.5	5.0	7.2	7.6	25.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

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 resolution performance, where the Atomic Resolution Microscope (ARM) has been in the vanguard of the world effort. Three new forefront instruments are proposed to strengthen and complement existing capabilities:

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

NCEM's existing comprehensive computational capability will be expanded and integrated with the new microscope, allowing on-line image analysis, processing, and simulation. This initiative complements related materials science programs at LBL and support a range of programs funded by the Office of Basic Energy Sciences, such as those in metallurgy, ceramics, and 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.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	6.9	12.1	1.8	1.8	1.8	24.4
Construction	0.0	0.0	3.6	0.0	0.0	0.0	3.6

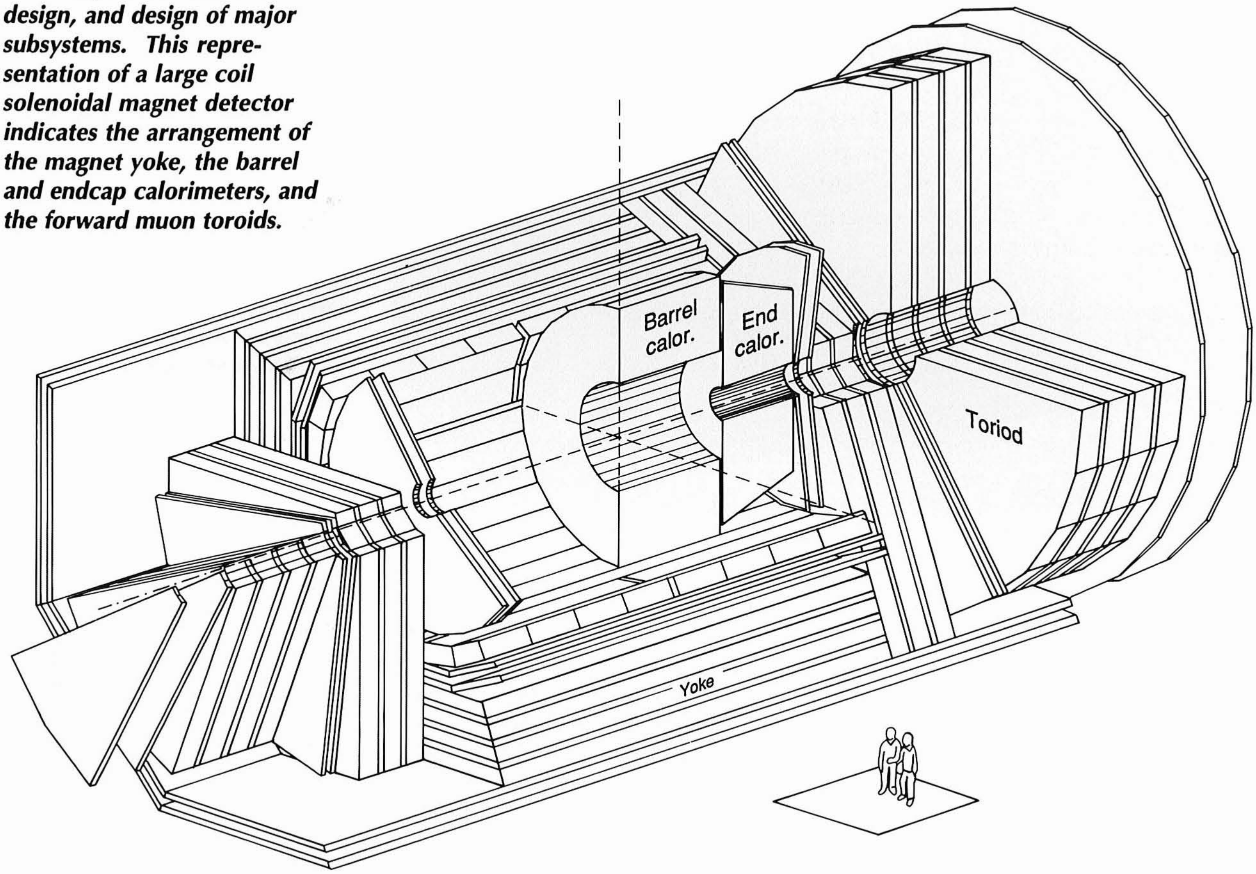
[a]Preliminary estimate of actual-year LBL Budgetary Authority.

HIGH ENERGY AND NUCLEAR PHYSICS

SSC DETECTOR PROGRAM

New high-energy and high-luminosity accelerator facilities such as the Superconducting Super Collider (SSC) and the Relativistic Heavy-Ion Collider (RHIC) for nuclear physics will require major developments in particle detectors and data acquisition. Major challenges include the

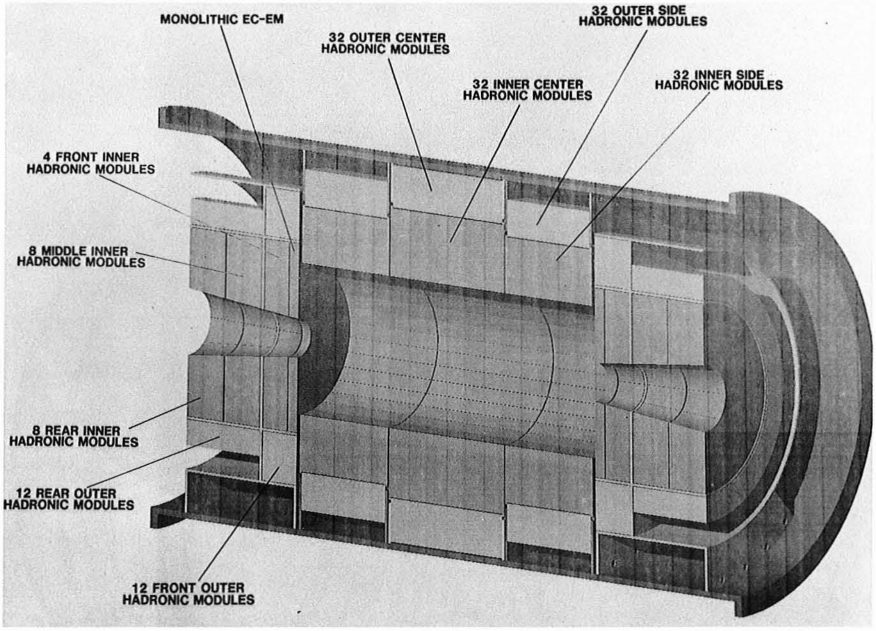
LBL's initial SSC Detector Program includes studies on generic R&D at high-luminosity colliders, overall detector design, and design of major subsystems. This representation of a large coil solenoidal magnet detector indicates the arrangement of the magnet yoke, the barrel and endcap calorimeters, and the forward muon toroids.



development of radiation-hard, high-resolution detectors with integrated electronics and software; tracking devices capable of handling high rates with good track separation and efficient pattern recognition; and calorimeters with good energy resolution, good segmentation, and stable calibration response. A coordinated R&D effort may be needed to achieve detector performance appropriate to the new domain of energy and luminosity.

LBL is developing an integrated plan for an SSC detector facility in addition to its advanced detector technology program. This planning activity builds on LBL strengths in engineering, hardware and software development, physics analysis, and management of large projects that will be invaluable in the construction and operation of the extraordinarily complex SSC detectors.

With construction of the SSC starting in 1990, LBL estimates that selection of the initial complement of detectors would take place by 1991 or 1992. Construction of the detector facility would take place by about 1997. In collaboration with other laboratories and universities, LBL plans to play an important major role in such detector fabrication. LBL would be a major hub, taking responsibility for either the entire detector system or major portions of it. The total project cost would be about $200 M.



LBL plays a major role in several international collaborations on the design and development of calorimetric detectors for the SSC. The multiple hadronic modules and overall calorimeter design of this proposed warm-liquid calorimeter provide for high segmentation and excellent 4π solid-angle coverage. Warm liquid calorimetry offers the high segmentation resistance the good energy reduction, and the fast signal response necessary for successful detector operation at the SSC.

The initial component of LBL's portion of the resource requirements, including equipment costs, is identified below.

SSC Detector Program
Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total[b]
Operating	1.5	3.0	5.0	5.0	5.0	5.0	24.5
Construction	0.0	0.0	5.0	15.0	20.0	20.0	60.0

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

[b]FY 1996 cost are an additional $5.0 M (operating) and $15.0 M construction.

PARTICLE ASTROPHYSICS

Particle physics and astrophysics have become increasingly complementary and interdependent sciences. As an example, the distribution of cosmic microwaves strongly supports an inflationary-universe model that is an outgrowth of elementary-particle theories. The early (distant) universe provides a range of high energies and densities that are unavailable in terrestrial particle accelerators.

Complementing the recently established Center for Particle Astrophysics at UC Berkeley, LBL is proposing a coordinated program of research, facilities development, and graduate education complementary to DOE's High Energy and Nuclear Physics program. LBL's program has four main purposes:

- **Basic cosmological parameters of the universe, such as gravitational mass density, age, and patterns of primordial nucleosynthesis, will be explored.** The development of key techniques will be emphasized, such as the use of supernovae and the application of accelerators to study specific nuclear process;

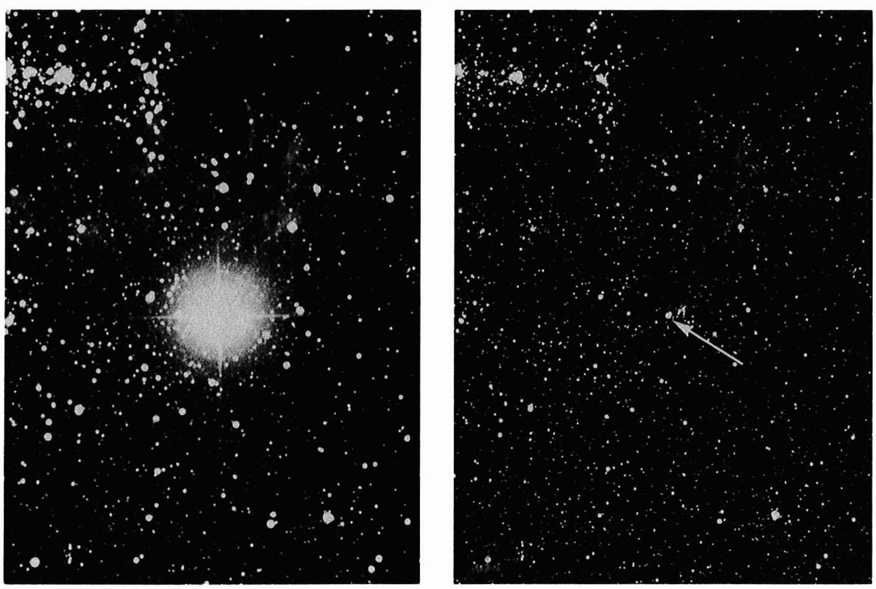
- **Signatures of nonbaryonic dark-matter particles will be explored to examine hypotheses related to the missing matter of the universe.** The development of methods to detect interaction of dark-matter particles will be emphasized using cryogenic and more-conventional temperature detectors, including the study of annihilation products in cosmic rays;

- **Diffuse radiation from the early universe will be explored to examine potential gravity-wave background and the signatures of particle decay, including supersymmetric particles.** The development of methods will emphasize the use of novel bolometric detectors of microwave background, as well as x-ray and gamma-ray background detectors associated with particle decays; and

- **Large-scale structure of the universe will be studied to explore the formation or merging of galaxies and possible density differences in dark matter.** The development of adaptive optics to large telescopes and the use of long-wave infrared images will greatly facilitate this research.

Complementing these experimental programs will be vigorous theoretical programs to study the evolution of the universe in the framework of particle physics. These theoretical areas include inflationary cosmology, the primordial distribution of dark matter, and the baryon content of the universe.

The Particle Astrophysics program is being developed in conjunction with other national laboratories and universities. DOE support for a cooperative program offers an opportunity for further strengthening the multidisciplinary effort toward integrating theory, experiment, and development of improved instrumentation and training opportunities.



LBL scientists discovered a sub-millisecond optical pulsar in Supernova l987A in the Large Magellanic Cloud galaxy. The unprecedented frequency of rotation has led to the hypothesis that the pulsar is a strange quark star, a type of matter never before observed.

Particle Astrophysics Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	1.5	2.0	2.5	2.5	2.5	2.5	13.5
Construction[b]	0.0	0.0	3.0	3.0	3.0	3.0	12.0

[a]Preliminary estimate of LBL Budgetary Authority (FY 1990 dollars).
[b]Costs are for detector fabrication.

B FACTORY AT PEP

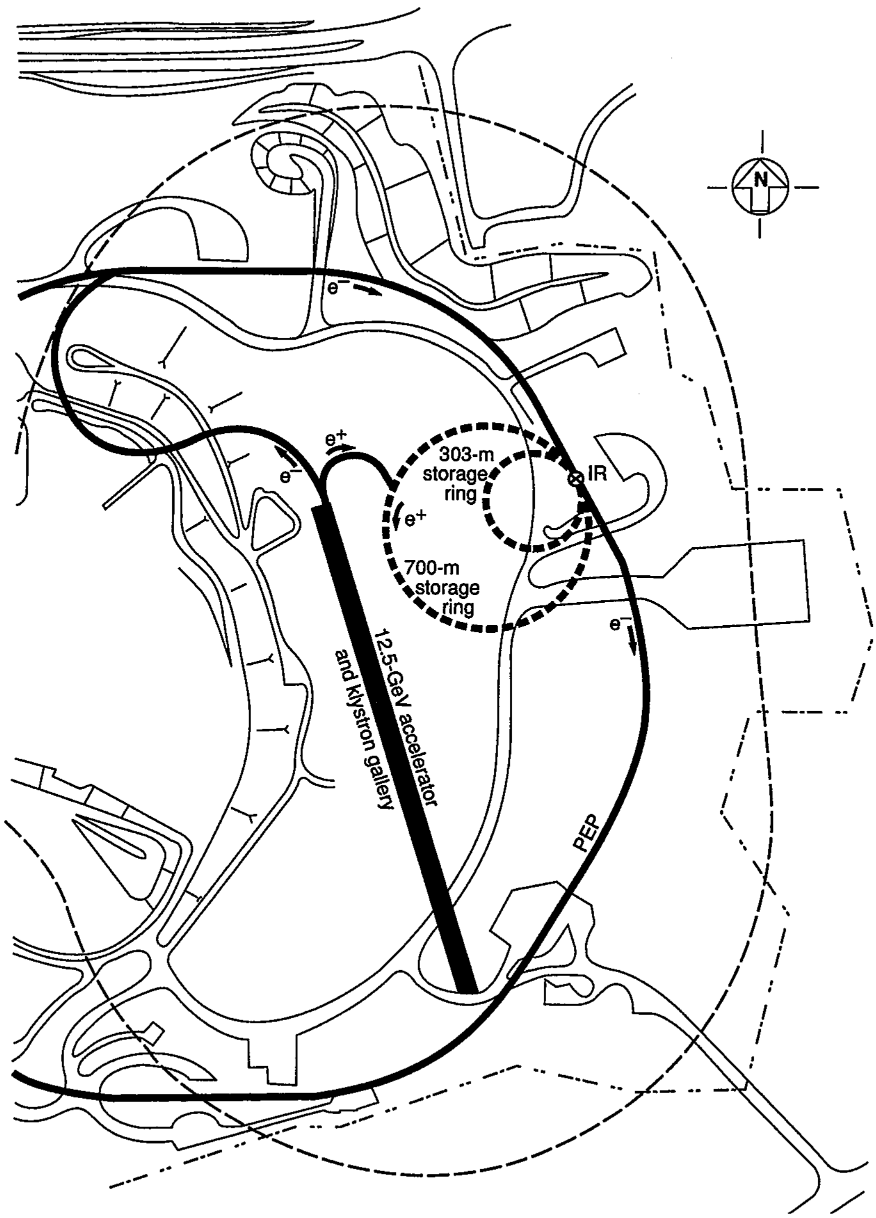
The study of B-meson decays will be one of the key elements of the worldwide high-energy physics program for many years to come. These studies are limited today by the relatively low rate of events produced at e^+e^- storage rings such as the Cornell Electron Storage Ring. An increase in the event rate by a factor of 20 or more is required for the study of the most interesting processes within the standard model, both rate 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) was originally proposed at LBL. It yields high luminosities by virtue of colliding beams from two different rings, allowing many more bunches in each ring than is possible with present single ring designs. Even more importantly, the Upsilon (4s) decays into two B mesons nearly at rest in the center of mass. Since the center of mass is moving because the energy of the two rings is substantially unbalanced, 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 in luminosity for the study of the most interesting channels CP violation.

LBL, in collaboration with Stanford Linear Accelerator Center (SLAC), has taken a serious technical look at using Positron Electron Project (PEP) in conjunction with a new low-energy storage ring. The high-energy ring (9–12 GeV) already exists at SLAC, namely the PEP collider. The technical feasibility of a viable B factory based on PEP, with the addition of a new low energy (2–3 GeV) ring, would be attractive both scientifically and fiscally. The initial exploratory 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, with LBL carrying responsibility for at least half the construction. Studies are presently being carried out to determine whether a modified Time Projection Chamber (TPC) or MkII detector could be used or a new detector fabricated. 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-GeV storage ring (in either of two physical sizes) near 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 space and time, making detection easier.



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

Category	1990	1991	1992	1993	1994	1995	Total[b]
Operating	0.0	10.0	25.0	20.0	20.0	20.0	95.0
Construction	0.0	0.0	0.0	50.0	75.0	75.0	200.0

[a]Includes SLAC/LBL costs. A preliminary estimate of Budgetary Authority.
[b]FY 1996 costs to complete the project are an additional $20.0 M (operating) and $50.0 M (construction).

RELATIVISTIC HEAVY-ION COLLIDER PARTICIPATION

LBL physicists were instrumental in initiating the ultrarelativistic heavy-ion program at CERN. The focus of this effort is the exploration of nuclear collisions at the highest available energies to produce and identify a baryon-rich quark-gluon plasma. During the past year solid new physics results have been obtained from the continuing analysis of heavy-ion data taken in the first round of running with 60 and 200 GeV/nucleon ^{16}O and ^{32}S beams in 1986–87. Several pieces of evidence seem to support the formation of a quark-gluon plasma even with these light projectiles. After a run with ^{32}S later in 1989, this ongoing program expects to provide high-energy Pb beams by the early 1990s.

LBL scientists also expect to extend this program by participation in the research program of the Brookhaven Alternating Gradient Synchrotron (AGS) and the planned Relativistic Heavy-Ion Collider (RHIC), playing a major role in the design, construction, and implementation of sophisticated detector systems. Major challenges include the development of tracking devices capable of handling high multiplicities (e.g., ~10^4 particles/event) with good track separation and efficient pattern recognition and calorimeters with the required energy resolution and segmentation. A detector R&D program is being proposed to address these future needs.

Relativistic Heavy-Ion Collider (and AGS) Participation Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.3	0.5	1.0	2.0	3.0	4.0	10.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

HEALTH AND ENVIRONMENTAL RESEARCH

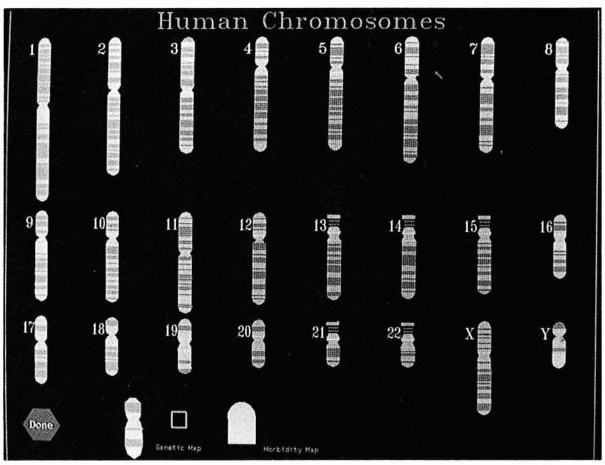
HUMAN GENOME CENTER

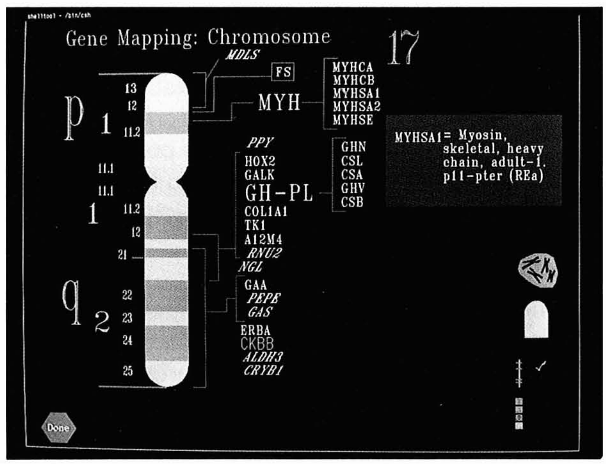
LBL was designated by the Secretary of Energy as a center for human genome studies as part of the Department of Energy's important role in the national effort to physically map and sequence the human genome. In response, LBL has established a Human Genome Center with a team of biologists, computer scientists, and engineers to begin the research and development needed to map and sequence the human genome and to analyze the resultant vast amounts of complex genomic data. This national program will contribute significantly to understanding, diagnosing, and preventing hereditary and environmental diseases. Programmatic elements of the Center 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. Application of these methods is for pilot studies on mapping human chromosome 21 and other selected 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;

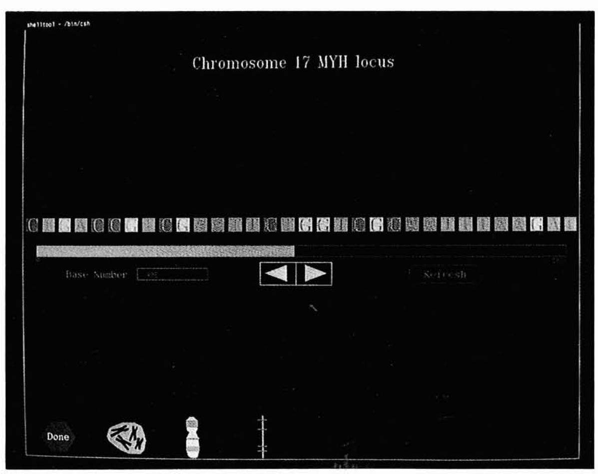
- Information systems—develop computational tools needed to analyze the mapping, cloning, and sequencing data generated from human genome research throughout the scientific community and to provide the computational foundation for the Human Genome Center. Develop the novel data-management techniques needed for map and sequence data. Investigate and implement methods for DNA fragment overlap detection, map assembly, and sequence and pattern matching;

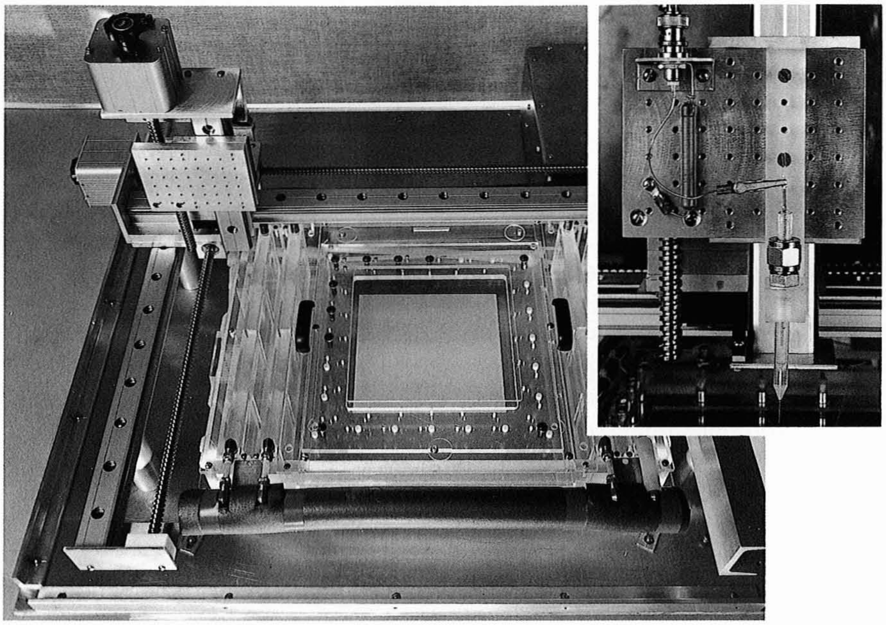
- Instrumentation—develop innovative techniques in instrumentation and automation to accommodate the size and complexity of the experimental procedures. In addition to improving existing laboratory methods, emphasis will be placed on developing advanced techniques for separating large DNA fragments, up to the size of intact human





The Human Genome Center will have sophisticated workstations, now under development, that would provide a uniform user interface with all mapping and sequencing data bases. The user examines data at increasing resolution by "enlarging" selected regions of successive displays showing the full complement of chromosomes, a single chromosome with mapped gene locations, and the sequence for a selected region.





In LBL's pulsed-field gel electrophoresis test bed, conditions at any point in the gel can be monitored by a probe mounted on a computer-controlled platform (see inset). The test bed also allows active computer control of electrode potentials, as well as the capability for programming complex pulse cycles. The results will increase resolution and shorten separation times, especially for DNA fragments of more than five million base pairs.

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 Human Genome Center 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 the UC Berkeley and other UC campuses. With the appointment of the Director of the Human Genome Center and the other scientific leadership, we expect the research and development efforts to accelerate rapidly during the next 2 years, reaching a level of about 50 FTEs. Operating funds needed at that time will be approximately $10 M/year. During the following 3 years, the program will double to 100 FTEs and a budget of about $15 M/year. The major experimental activities at that time will be conducted in a new facility, the Human Genome Laboratory, to be constructed in the Life Sciences Functional Area of the Laboratory. This new laboratory will consist of 32,200 gsf of light-laboratory space with functions dedicated to the conduct of mapping, cloning, and sequencing activities along with integrated instrumentation, computation, and related support facilities.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	6.0	9.0	11.0	13.0	14.0	15.0	68.0
Construction	0.0	1.1	8.3	2.2	0.0	0.0	11.6

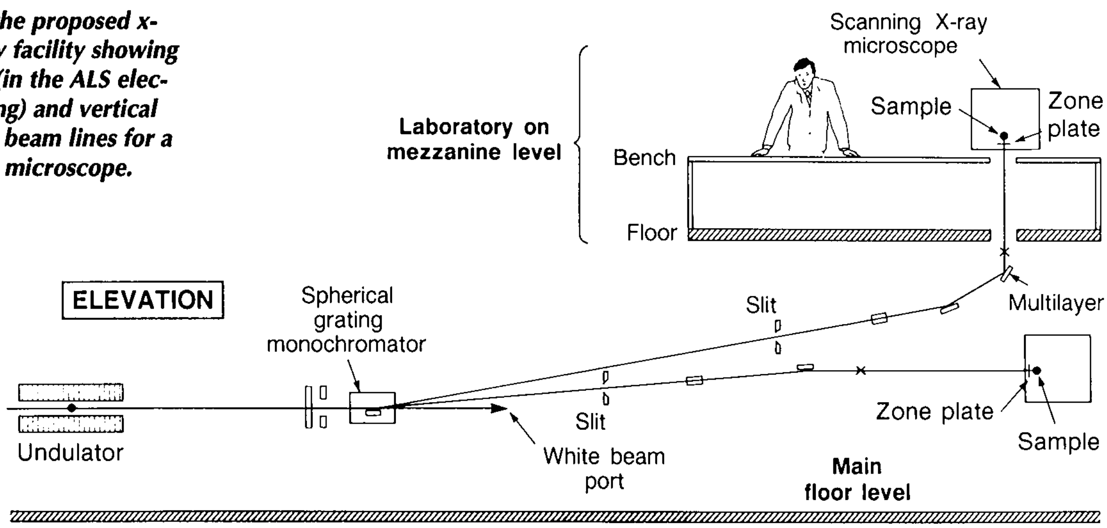
[a]Preliminary estimate of actual-year LBL Budgetary Authority.

ALS LIFE SCIENCES CENTER

In support of DOE's national structural biology program 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 excitations and reactions at high spatial and temporal resolution within cells and organelles; and**
- **Diffraction and scattering—static and dynamic analysis of higher-order macromolecular architecture with precise tuning and polarization.**

The layout of the proposed x-ray microscopy facility showing the undulator (in the ALS electron storage ring) and vertical and horizontal beam lines for a scanning x-ray microscope.



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 renovation 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 physical sciences. These communities include:

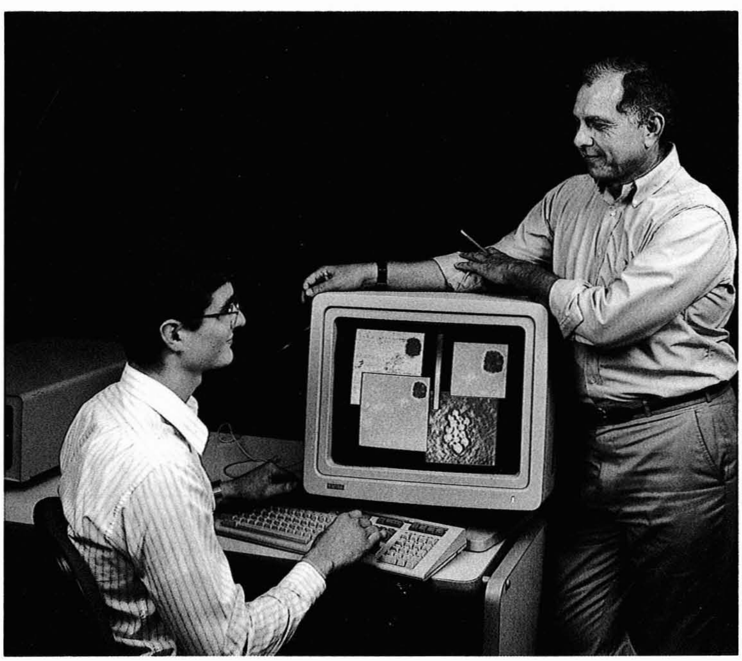
- General users in the biological science community, both external and internal to LBL, who have shorter-term interests in the application of synchrotron radiation with needs for specific analytical tasks and who may have a limited physics background;

- 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, that 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, laserlike 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, 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.

Supporting 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.



LBL scientists study the first images of an unaltered subcellular component of living tissue produced at LBL by holographic techniques and computer reconstruction.

Complementing this user facility, a collaborative structural biology research program is proposed, as described below.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.9	1.7	2.2	3.4	3.5	3.5	15.2
Construction	0.0	4.8	14.0	6.6	0.0	0.0	25.4

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

STRUCTURAL BIOLOGY RESEARCH PROGRAM

New applications of advanced imaging and diffraction techniques will greatly strengthen DOE's emerging national program in structural biology. The 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, 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. Support identified below includes an internal research program and an externally directed program to:

- Form consortia of university, industrial, and national laboratory scientists to provide training and to pursue nationally significant structural biology research. LBL's initial focus will be to further collaborations with regional biotechnology companies, the UC Berkeley Campus, UC San Francisco, Stanford, and other universities;

- Strengthen collaborations aimed at developing new detectors for biological applications of synchrotron light, to develop algorithms to analyze the three-dimensional structure of macromolecules and to improve structural data analysis and interpretation; and

- Support LBL's programmatic research at the ALS Life Sciences Center as well as complementary development of other tools, such as high-resolution electron crystallography, NMR, and scanning tunneling microscopy.

This initiative builds upon the ongoing research and student training activities in biophysical chemistry, molecular biology, research medicine, and x-ray optics. Recent examples of these strengths include the first ever elucidation of the three-dimensional and functional understanding of an oncogene protein, the microholography of subcellular structures, and direct imaging of the DNA helix. In each of these cases unique combinations of physical and biological sciences resulted in significant advances in technical capability and structural insight.

Structural Biology Research Program
Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	1.0	2.0	3.0	4.0	4.0	4.0	15.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

BIOMEDICAL ISOTOPE FACILITY

The Biomedical Isotope Facility will provide isotopes for use in the Research Medicine and Radiation Biophysics Division, the Chemical Biodynamics Division, and for other qualified users at LBL and other Federal and regional clinical research organizations. The capability for using the short-lived light-element tracers from a minicyclotron that is the heart of the facility will be especially appropriate to a range of metabolic studies. The primary isotopes produced would be ^{15}O, ^{11}C, ^{13}N, and ^{18}F for cerebral and cardiac positron-emission tomography studies. The two LBL positron tomographs, one with the highest spatial and temporal resolution in the world, are inadequately used due to the lack of positron-emitting tracers.

The facility will also provide isotopes for ^{13}C and ^{2}H biomedical compounds to be used for the 10-tesla NMR research program. The facility will be housed in a 3,800-gsf light-laboratory building with small supportive laboratories for safe incorporation of the radionuclides into useful pharmaceuticals and for preparation of precursor compounds.

Biomedical Isotope Facility
Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.2	4.3	0.0	0.0	0.0	5.5

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

GLOBAL CHANGE RESEARCH PROGRAM

The Office of Health and Environmental Research 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 theoretical, laboratory, and field 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 Assistant Secretary for Environmental Health and Safety. Areas of initial interdisciplinary research include:

- Laboratory and theoretical studies of the physics and chemistry of cloud processes, such as the effect on cloud optical properties of natural and anthropogenic nucleating particles;
- Atmospheric-ecosystem interactions, such as CO_2 buildup and temperature increases, that play a potential role in the modification of ecosystems, 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	1990	1991	1992	1993	1994	1995	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 1990 dollars).

CONSERVATION AND RENEWABLE ENERGY

ADVANCED COMPUTER-BASED BUILDING DESIGN

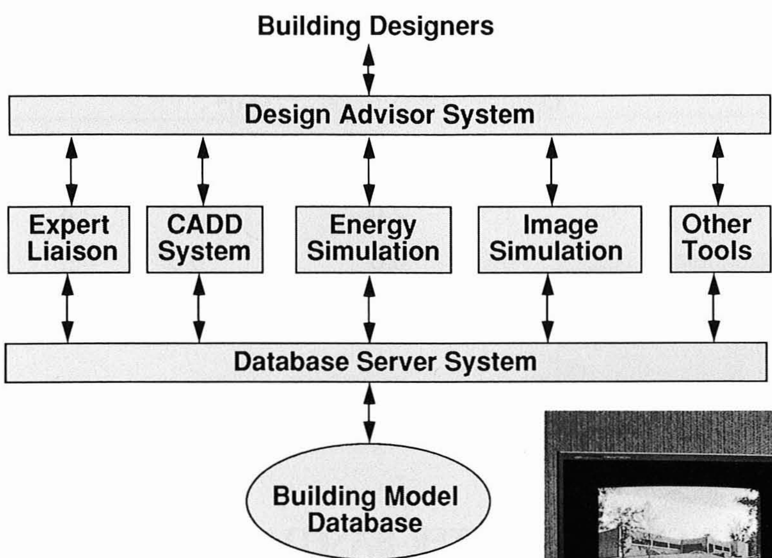
LBL and other DOE national laboratories are engaged in a continuing research effort to improve energy conservation in buildings. The LBL Advanced Computer-Based Building Design initiative would develop innovative methods to incorporate advanced conservation concepts directly into building design and 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.

The Advanced Computer-Based Building Design 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 conservation, 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 conservation is often being treated as separate from



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

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.

Advanced Computer-Based Building Design Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	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 1990 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: (1) fundamental research relevant to the development of practical, high-current conductors based on high-T_C superconducting materials; (2) the design, engineering, and fabrication of the conductors; and (3) the design, 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 effect 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
Resource Requirements($M)[a]

Category	1990	1991	1992	1993	1994	1995	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 1990 dollars).

FUSION ENERGY

1.3-MEV NEUTRAL-BEAM INJECTOR

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

The International Thermonuclear Experimental Reactor (ITER), a proposed next-generation tokamak to be built by a multinational collaboration, would need neutral-beam systems of higher power and energy (approximately 80 MW of D° at 1.3 MeV) 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 the production of a conceptual design for a neutral-beam system agreeable to all four participants (the U.S., Europe, Japan, and the U.S.S.R.) and to conduct supporting research and development in the areas of D^- ion sources and high-voltage dc accelerators. LBL is now investigating the possibility of a major ITER neutral-beam development project, including a new test facility for conducting a proof-of-principle accelerator demonstration.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	0.0	0.0	0.2	1.4	1.2	2.8
Construction	0.0	2.0	9.0	9.0	0.0	0.0	20.0

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

MULTILABORATORY COLLABORATION

ENVIRONMENTAL RESTORATION RESEARCH

In 1989, DOE established plans to assess and better manage waste disposal problems and to speed environmental cleanup at sites across the country, including the development of applied and basic research programs for new cost-effective cleanup methods and technologies. As a part of this activity, the Office of Energy Research has developed a mid- to long-term research plan, prepared with participation by the national laboratories. In support of national efforts LBL has established a multidisciplinary Environmental Restoration Research Program to focus our capabilities and resources on this critical DOE initiative. LBL strengths in the earth sciences, engineering, and biology will be important resources contributing to this research program.

LBL efforts are being planned consistent with programmatic guidance from the Office of the DOE Secretary and the Office of Energy Research. Our efforts are in concert with Pacific Northwest Laboratory (PNL) and other multiprogram laboratories to advance the fundamental knowledge of waste in environmental systems, including the development of new sampling, characterization, and monitoring methods. The program will be directed to develop innovative biological, chemical, and physical remediation technologies and the tools for assessing environmental restoration remediation design, optimization, and risk assessment, including environmental effects research.

The overall program will encompass basic research, up to and including proof of principle tests (intermediate and field scale) at appropriate sites and facilities. The LBL/PNL collaboration will focus on solutions to priority problems at identified sites on the Hanford Reservation. The program will be developed in conjunction with LBL's graduate training and education programs to develop manpower for national cleanup efforts and build on established links with industry to promote the transfer of technology. Resource estimates are in an early stage and represent LBL's support in the DOE-wide effort.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	2.0	4.0	5.0	6.0	7.5	7.5	32.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

LARGE EINSTEINIUM ACTIVATION PROGRAM (LEAP)

The Large Einsteinium Activation Program 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; and

- 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]

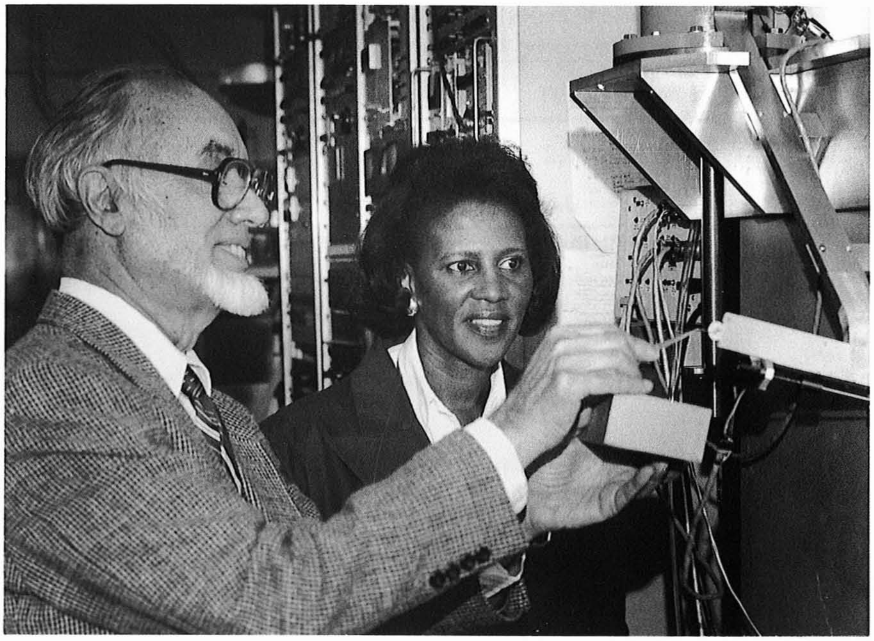
Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	0.5	0.8	1.1	0.9	0.8	4.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

EDUCATION/TECHNOLOGY TRANSFER INITIATIVES

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



A principal investigator in LBL's forefront studies at iridium anomalies and mass extinctions works with a Berkeley high school mathematics teacher. The FSETL would provide a basis for supporting her high school district's science education program and reach other precollege teachers in the East Bay.

economically disadvantaged students in northern California schools who are being lost to science and engineering due to lack of resources, motivation, or quality of experience. The 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 the FSETL are to improve quality of initial science experience, to increase retention of students in the science pipeline, and to provide equity in access to scientific careers. The FSETL would provide a support system for inner city science educators, including those from Oakland, Richmond, Berkeley, and other East Bay communities.

The 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.

The FSETL will require a one time 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 the FSETL, administrative support in CSEE, and program expenses.

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

Category	1990	1991	1992	1993	1994	1995	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 1990 dollars).

CALIFORNIA INSTITUTE FOR ENERGY EFFICIENCY

The California Institute for Energy Efficiency (CIEE) is a unique effort to make available to U.S. industry the research capability in energy efficiency developed at LBL and the UC campuses. CIEE was initiated in FY 1988 by the University as a statewide institution in conjunction with requests by the California Public Utilities Commission and the California Energy Commission. The financial sponsorship for CIEE to the University will come primarily from the California energy utilities, and CIEE will sponsor research and technology transfer activities at LBL, University campuses, and other California institutions.

The elements of CIEE research and technology transfer projects supported at LBL will be based on expertise developed under DOE sponsorship, primarily the Office of Buildings and Community Systems under the Office of Conservation and Renewable Energy. The CIEE-sponsored research at LBL in turn will enhance DOE's research program through cost sharing, by enhancing communications to make LBL basic research programs more responsive to long-term industry needs, and by moving results from DOE-supported research closer to private-sector commercialization.

California Institute for Energy Efficiency Advancement Resource Requirements ($M)[a,b]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	1.0	2.0	2.5	3.0	3.0	3.0	14.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Resource requirements supported through joint participation agreement with the University of California.

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

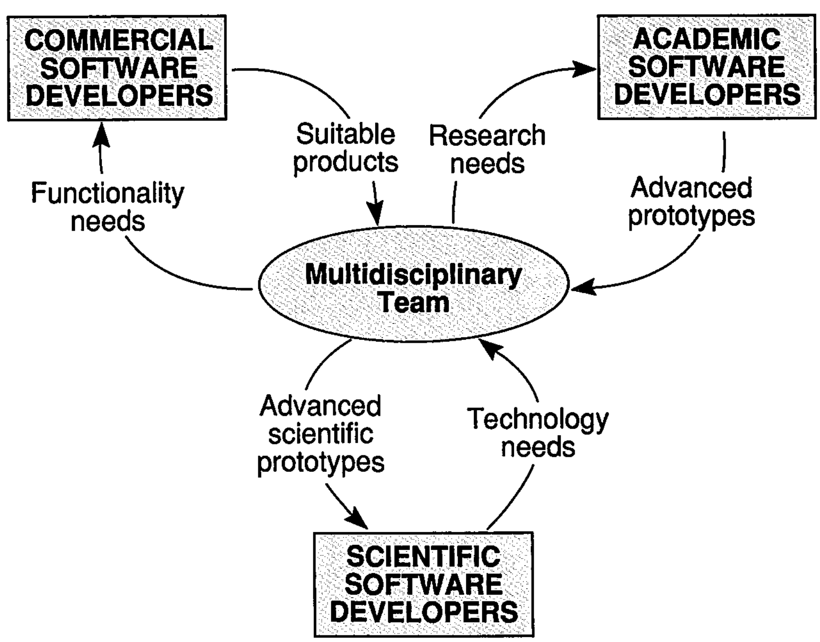
COOPERATIVE APPROACH TO SOFTWARE ADVANCEMENT

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 between 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 during FY 1990–1993. One or two additional CASA projects would be initiated during FY 1990 and each of the following fiscal years. Each CASA project is expected to last about 4 years. The CASA program would be managed at LBL.



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.

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

Category	1990	1991	1992	1993	1994	1995	Total
Operating	1.1	2.1	2.3	2.5	2.6	2.7	13.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

BIOMEDICAL RESEARCH ACCELERATORS

The Lawrence Berkeley Laboratory and the Fermi National Accelerator Laboratory, along with the industrial firms of SAIC and the commercial accelerator manufacturer, ACCSYS, are participating in a technology transfer program to build a Proton Therapy Facility at Loma Linda University Medical Center, Loma Linda, California. The Laboratory is directly involved in transferring accelerator technology, patient positioning and treatment facilities, and the clinical radiotherapy program.

The Merritt Peralta Medical Center, Oakland, California, has also proposed the utilization of LBL technology through the construction of a Light-Ion Biomedical Research Accelerator (LIBRA) to meet anticipated treatment and clinical research needs. LIBRA would provide intense 500-MeV/amu proton, helium, and carbon beams and beams of heavier ions at a reduced intensity. Initial conceptual design support for the transfer of DOE accelerator-engineering capabilities is planned. Following this conceptual design stage, detailed accelerator engineering would be conducted through the collaboration as a Work-for-Others project, with a total design cost of about $5.5 M.

LBL's primary role in LIBRA will be to design research-related facilities and to transfer technology for conceptual and engineering design of the accelerator facilities. After LIBRA is built, LBL studies using light ions will be conducted at the new accelerator, and those programs using neon or heavier ions will be conducted at the Bevalac. Both programs will have a basic research component and a clinical component, and both will be open to outside users.

Light-Ion Biomedical Research Accelerator Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	2.5	2.0	1.0	0.0	0.0	5.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Resource requirements supported through Work for Others.

GENERAL-PURPOSE FACILITIES

To revitalize 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 design limitations, obsolescence, and overcrowding. A general-purpose building, the Safety and Support Services Facility, would mitigate many of the limitations caused by inadequate physical resources for safety services, reduce maintenance needs, and result in identified cost reductions. The LBL environmental health and safety functions, chemicals and materials management, and electronics engineering 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 business services, purchasing, inventory management, shipping, and transportation functions, which interact closely with the EH&S Department and 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	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.5	2.8	4.4	0.0	0.0	7.7

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

MECHANICAL ENGINEERING REPLACEMENT PROJECTS

Existing mechanical technology facilities are more than 40 years old and are of outdated design, with structural and utility systems that require continuing and comprehensive modification to meet LBL's environmental, safety, and health standards. The replacement facility will provide full safeguards that minimize fire, electrical, mechanical, and chemical risks and bring facilities to existing construction standards. The projects will provide for safe, economic, and efficient support for many DOE programs through replacement of shop, assembly, and staging facilities used in fabricating high-technology magnets, precision detector systems, and high-vacuum beam lines, for example. Incompatible fabrication processes would be isolated, clearances made sufficient, and waste-handling systems improved. Construction of facilities totaling 52,000 gsf would occur in two phases and in conjunction with the removal of substandard buildings, with no increase in Laboratory size. Phase II costs are shown in the long-range plan in Section 8.

Mechanical Engineering Replacement Project, Phase I
Resource Requirements ($M)[a]

Category	1990	1991	1992	1993	1994	1995	Total
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	1.4	2.7	7.6	11.7

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

5 SCIENTIFIC AND TECHNICAL PROGRAMS

Lawrence Berkeley Laboratory research programs 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. In addition, other DOE offices, including Environment, Safety, and Health and the Nuclear Regulatory Commission, will support LBL programs. Work for Others (WFO) provides less than one-fifth of the support programs. This section summarizes current LBL research programs, including anticipated program trends.

Laboratory Funding Summary

(Fiscal Year Budgetary Authority, $M)

Major Program/Office	1988	1989	1990	1991
Office of Energy Research	145.2	153.2	167.9	180.7
Conservation & Renewable Energy	13.8	13.4	14.8	15.5
Office of Fossil Energy	1.5	1.5	1.5	1.6
Other DOE	28.3	29.6	18.5	17.3
Work for Others	32.0	31.5	33.6	33.8
Total	**220.8**	**229.2**	**236.3**	**248.9**

OFFICE OF ENERGY RESEARCH

During the plan period, the OER will continue to be the focus of research activities at the Laboratory, i.e., implementation of the initiatives described in Section 4 and selected growth in the Basic Energy Sciences and Life Sciences.

- The Laboratory contribution to national efforts in the Basic Energy Sciences includes constructing the Advanced Light Source (ALS) and developing advanced user facilities to support scientists in chemistry, materials research, biology, 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 Bevalac and the 88-Inch Cyclotron. The Bevalac will continue its pioneering studies of nuclear matter and contribute to advances in atomic physics, biomedical research, and related fields.

- High-energy physics research will continue with sophisticated detectors at forefront facilities, including the Mark II at the Stanford Linear Collider (SLC), Collider Detector at Fermilab (CDF), and D-zero at the Tevatron Collider. 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, strong 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-films 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 the Office of Energy Research is summarized in the table below.

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

Budget Code	Major Program	1988	1989	1990	1991
AT	Magnetic Fusion	2.6	2.6	2.6	2.7
KA	High-Energy Physics	22.6	25.6	26.7	27.8
KB	Nuclear Physics	37.9	38.7	39.8	42.6
KC	Basic Energy Sciences	64.2	63.6	71.0	77.1
KE	Univ. Research Support	1.5	1.5	1.7	1.8
KG	General Purpose Facilities	6.2	7.9	7.2	9.1
KP	Biological & Environ. Res.	10.2	13.3	18.9	19.7
Total		**145.2**	**153.2**	**167.9**	**180.7**
Percent of LBL Total		**65.8**	**66.8**	**71.1**	**72.6**

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.

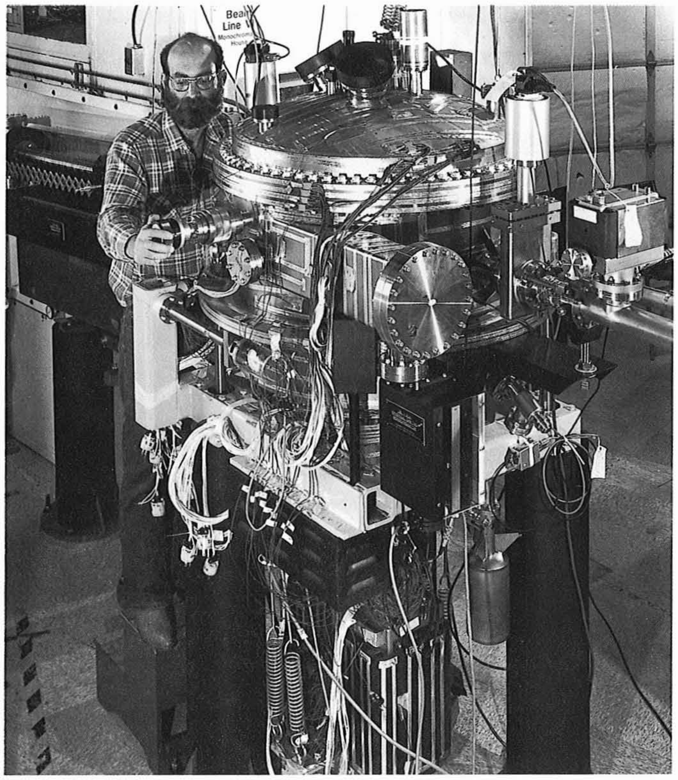
MATERIALS SCIENCE

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.

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, beam-line optical systems, and magnet systems. At the Center for X-Ray Optics, as described below, research is conducted on insertion devices and advanced optical-system components for the design of high-brilliance photon beams.

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:



A spherical grating monochrometer designed and developed at LBL's Center for X-Ray Optics can provide beam of monochromatic light from high brightness XUV synchrotron radiation sources such as the ALS.

- Diffractive x-ray optics for x-ray lenses to scan and image materials, microelectronic circuits, and biological systems in natural media and to improve resolution for spatially resolved spectroscopy;

- Reflective x-ray optics to develop high-reflectivity multilayer coatings for hard x-ray spectroscopy of materials and biological systems;

- Monochromator and spectrometer development for systems with high throughput and spectral resolution, including varied-line-space gratings;

- High-brightness x-ray source development of undulators, free-electron lasers and other laser systems, and high-temperature plasmas; and

- X-ray holography research to achieve true three-dimensional images of subcellular biological components.

The Center conducts research on the fundamental interactions of x-rays with matter and develops advanced beam lines at national synchrotron facilities. Efforts will include a VUV branchline at SSRL, 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 NSLS.

Center for Advanced Materials

The CAM will continue major research efforts that are vital to U.S. industrial strength. Five research programs are continuing, including the new research program on high-temperature superconductors.

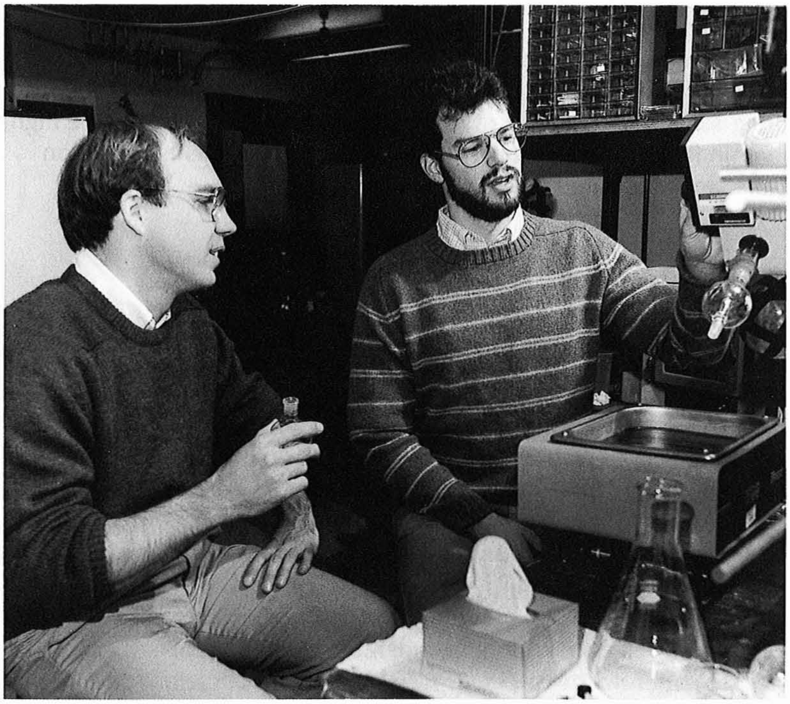
- The Surface Science and Catalysis Program focuses on the synthesis and molecular level understanding of heterogeneous catalysts, including zeolites and related compounds. The program includes depositions of surface compounds and development of instrumentation to characterize surfaces and interfaces.

- The Electronic Materials Program addresses technical obstacles to industrial development of very-large-scale gallium arsenide integrated circuits. The research elucidates mechanisms of defect formation, properties of semiconductor interfaces, thin-film defects, and advanced solders and interface adhesion.

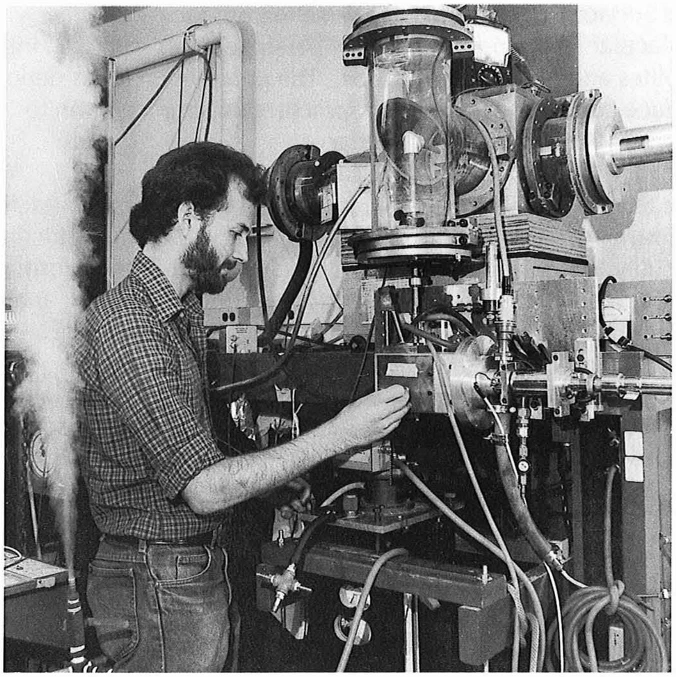
- The Polymers and Composites Program investigates relationships between processing and microstructure, focusing on anisotropic materials, surface interactions between polymer liquids and metals, and computational tools. It also includes a group studying materials synthesis through custom-designed enzymes.

- The Structural Materials Program advances the development of light alloys, including low-density aluminum alloys (primarily in aerospace systems) and new alloys for advanced energy needs. Advanced ceramic processing research is also pursued.

- 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.



A faculty scientist and graduate student prepare the first step in the production of catalytic antibodies, which may be used as artificial enzymes for novel synthesis of materials.



A graduate student measures reflectance in the infrared frequency range in a study of solid-state phenomena in high-temperature superconductors.

Superconductivity Research Center for Thin-Film Applications

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 and a conservation research program supported by DOE's Office of Conservation and Renewable Energy (see following sections). The goal of the thin-film program is to produce high-quality thin films that can be used in measuring instruments, radiation detectors, and electronic devices.

National Center for Electron Microscopy

The NCEM, 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 the NCEM consists of two microscopes: (1) the High-Voltage Electron Microscope (HVEM), the most powerful microscope of its kind in the U.S. and (2) the Atomic Resolution Microscope (ARM), 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).

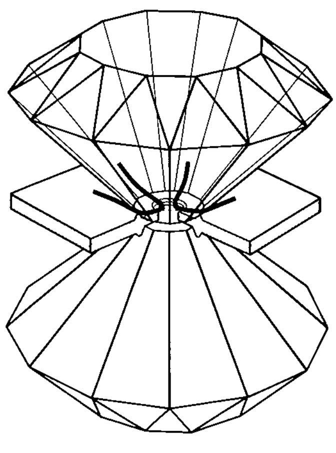
Research on high-temperature superconductor materials is coordinated with the Superconductivity Center for Thin-Film Applications and includes studies of the microstructure of new oxides, such as structural changes near grain boundaries and analysis of stacking sequences. Research on the structure and 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 (see 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.



A diamond anvil cell at LBL is used to investigate the properties of matter under pressures from hundreds of kilobars to megabars. Examples of materials investigated by the anvil technique are ultrahard solids and solids with unusual superconducting and magnetic properties.

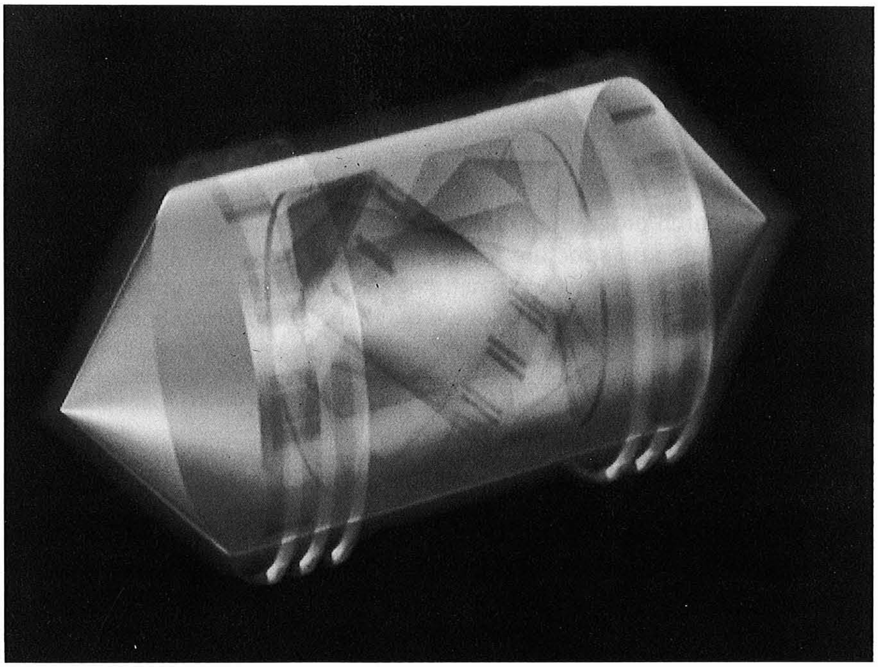
Solid-State Physics

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. Research on the use of high-temperature superconductors for dc superconducting quantum interference devices (SQUIDs) is a part of the Superconductivity Research Center for Thin-Film Applications. 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. Theoretical research furthers the basic understanding of the electronic and structural properties of broad classes of materials, ranging from the high-temperature superconductors to semiconductors.

An important new program on growth mechanisms at heterointerfaces would study 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 silicidefluoride 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.



Double rotation NMR is a new technique involving the rotation of a sample around two axes, overcoming the problem of broadening of spectral peaks of quadrupolar nuclei in solids. Double rotation NMR allows for much improved resolution of ^{17}O, ^{23}Na, and ^{27}Al.

CHEMICAL SCIENCES

DOE's Chemical Sciences Division supports focused research in several LBL Divisions. Programs in MCSD 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.

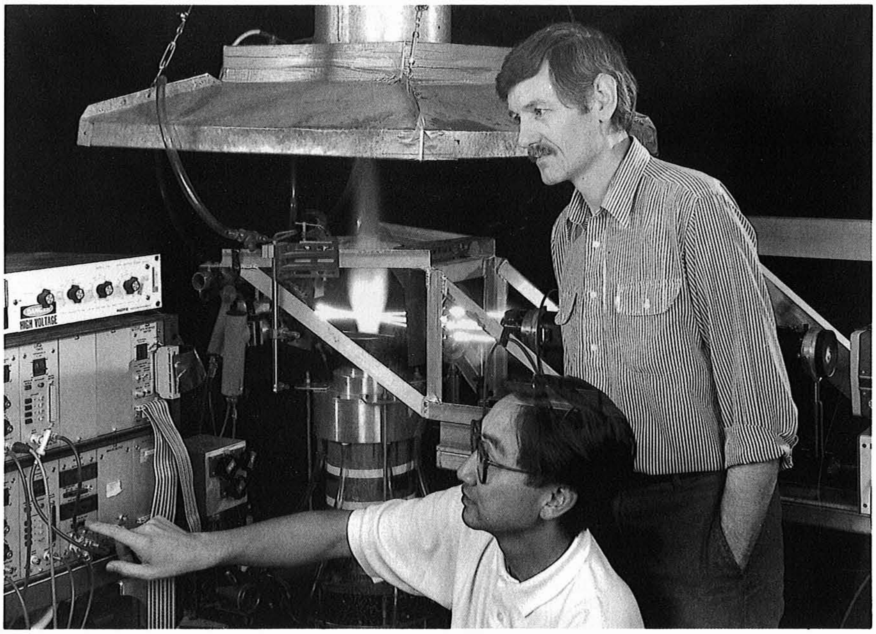
In MCSD, the extensive chemical-physics research includes several major programs. In one, a study of the spectroscopy and structures of reactive intermediates, laser magnetic resonance is used to study reactive molecules, such as molecular ions and free radicals, that may be important in combustion processes, 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 selective chemical reactions through 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. Physics studies of a free-electron laser could lay the groundwork for a photon source having enhanced photon flux at wavelengths as short as 100 nm for spectroscopy and pump/probe chemical-dynamics studies.

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

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

Research in the 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.

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 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.



Premixed turbulent combustion studies at LBL uses a range of diagnostic systems, including an apparatus for tracing the gas flow streamline through the flame zone using laser doppler anemometry.

Research in nuclear chemistry in MCSD focuses on the synthesis and safe handling of actinide materials. The program will continue its two thrusts: (1) design and synthesis of sequestering agents for treatment of actinide poisoning and for possible application to spent reactor fuels and (2) the preparation of new compounds incorporating actinides.

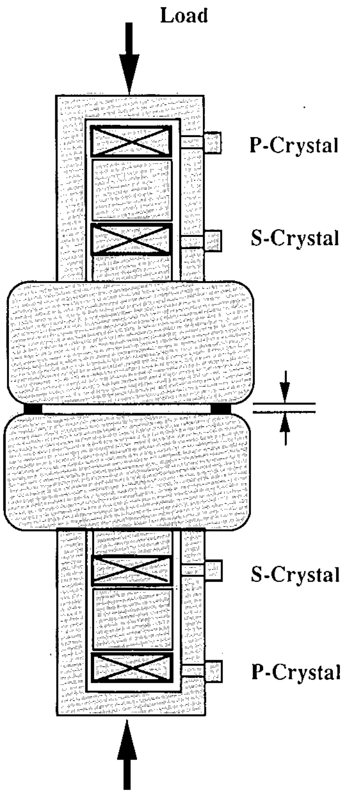
ENGINEERING AND GEOSCIENCES

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.

The 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

Diagrams of an experiment for measuring transmitted S and P wave seismic pulses across liquid layers, using piezoelectric crystals for transmitting and receiving these pulses under variable loads. Data are used to calibrate accurately seismic imaging of fluid-filled fractures.



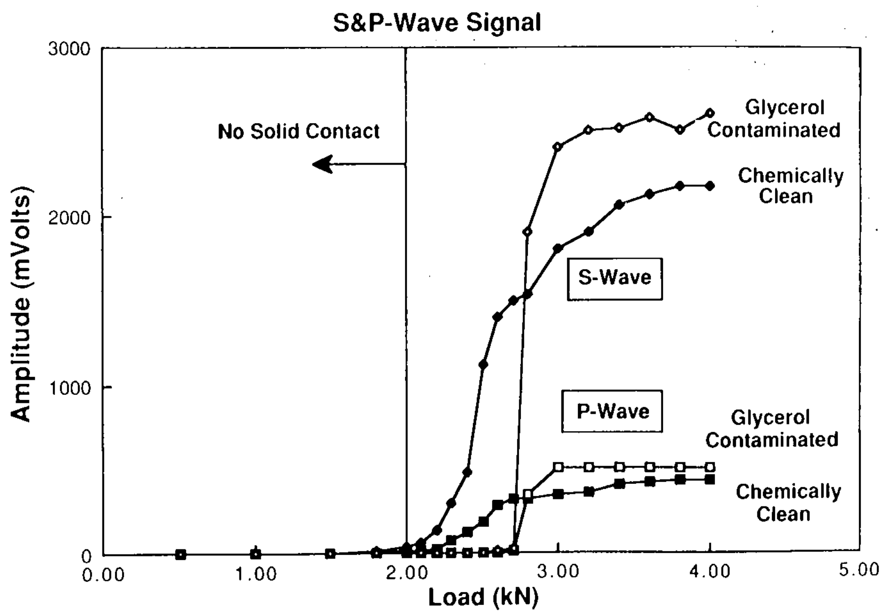
through the use of numerical models as well as novel laboratory techniques such as Positron Electron Tomography.

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.

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.

Evidence for the asteroid-impact hypothesis for biological extinctions through definition of trace-element time markers has been accumulating, and an enhanced LBL program has been implemented. The possibility that there have been several widespread extinctions with a periodicity of about 27 million years continues to be investigated, as is a related hypothesis that there is a dim companion star to the sun. These projects and a sky search to



Variation in S and P wave pulse transmission as a function of clear and contaminated experimental media conditions.

determine whether such a companion star can be observed are being conducted under collaborative BES support.

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.

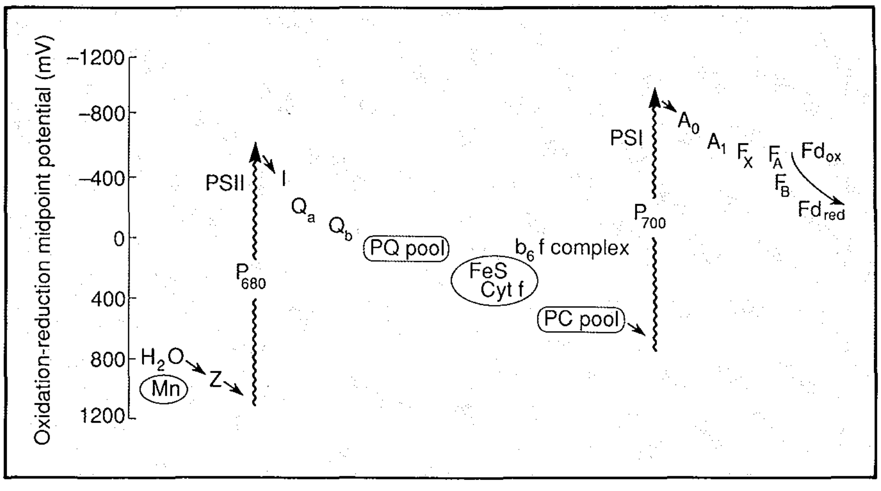
ENERGY BIOSCIENCES

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.

LBL is investigating the light-conversion properties of bacteriorhodopsin, a protein found in the purple membrane of salt-tolerant bacteria. The relatively simple structure of bacteriorhodopsin lends itself to study under laboratory conditions and shows promise for eventual technological applications such as photoelectric generators. The DOE Division of Energy Biosciences is also supporting research in LBL's Center for Advanced Materials on the enzymatic synthesis of materials.

ADVANCED ENERGY PROJECTS

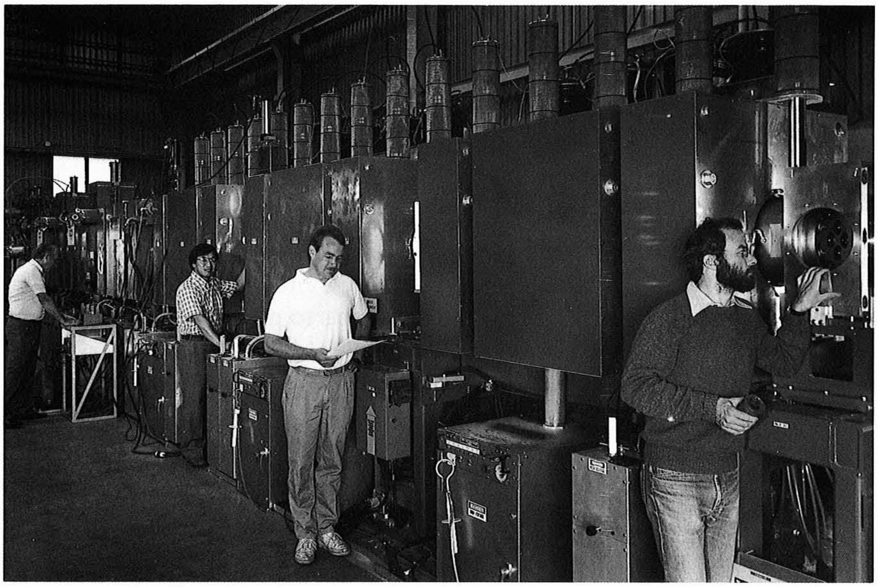
Research projects supported at LBL by DOE's Advanced Energy Projects provide for generic, long-term support of the heavy-ion fusion-accelerator research program. The LBL Heavy-Ion Fusion Accelerator Research Group



A diagram of the photosynthetic "Z-scheme," representing noncyclic electron flow in higher plants. Electrons flow from the water oxidation side of photosystem I. The two vertical lines represent the two light reactions of photosynthesis.

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 (most notably 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 NAS review of inertial fusion in 1989–90 is expected to make program and management recommendations, with the potential for enhanced LBL activity. This may lead to an Induction Linac System Experiment (ILSE), as described in Section 4.



The four-channel Multiple-Beam Experiment for studying the behavior of space-charge-dominated heavy-ion beams undergoing current amplification. The information gained will be useful in the design of any induction-linac heavy-ion fusion driver.

APPLIED MATHEMATICS AND COMPUTER SCIENCE

The Analytical and Numerical Methods Program at LBL will continue to focus on the development of new techniques for use in mathematics, physics, and engineering. Common to the various projects is the design of new methods that use computer resources to provide fast and efficient algorithms, with the goal of illuminating increasingly complex and realistic scientific and engineering phenomena.

The Scientific Data-Base Management Research Program will continue to investigate new data-management techniques suited to scientific and statistical applications. Because these applications have different requirements from conventional commercial Data-Base Management System applications, new techniques are needed. Such requirements arise from the structure of the 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.

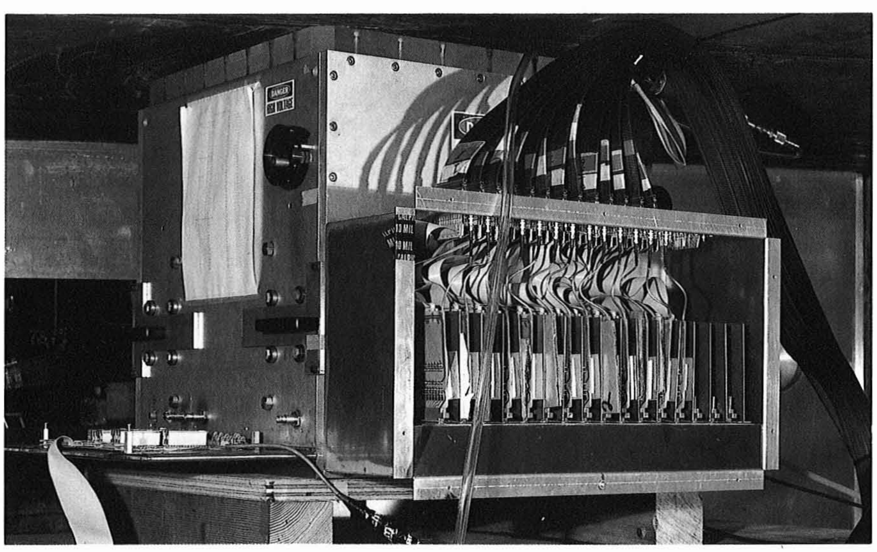
NUCLEAR PHYSICS

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. Upgrades and additional detectors are planned for the Dilepton Spectrometer (DLS) and the Heavy-Ion Spectrometer System (HISS) to exploit fully these scientific opportunities. A new Time Projection Chamber (TPC) is being built at the



The prototype Time Projection Chamber (TPC) shown here was recently tested in the HISS dipole magnet. As a charged particle passes through this gas-filled chamber, a cube about 20 cm on a side, it creates ions that can be collected by sensor pads beneath a charge-multiplying wire grid. The particle's path through the chamber is deduced from the pattern and time distribution of charge collected on the pads.

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 pursue aggressively 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 will also pursue the study of heavy-ion collisions at ultrarelativistic energies using the high-energy ^{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 Pb can be accelerated by 1993. Nuclear Science Division scientists recently submitted a letter of intent for a lead beam experiment.

LBL researchers will also participate in the use of beams of unique characteristics at Brookhaven's Alternating Gradient Synchrotron (AGS) and expect to be major participants in the Relativistic Heavy-Ion Collider (RHIC) research program. LBL also proposes to initiate the detector R&D effort required to support future ultrarelativistic heavy-ion experiments (see Section 4).

An LBL engineer tests the individual photomultiplier tubes of the new higher-resolution time-of-flight wall in the HISS cave at the Bevalac.

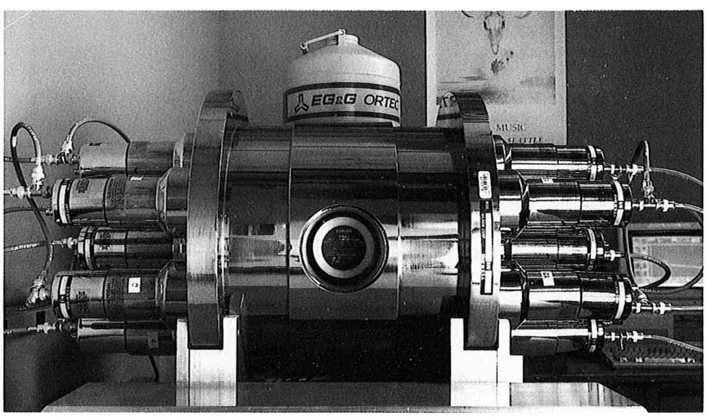
Nonrelativistic Physics

The broad and diversified nonrelativistic 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 the Electron Cyclotron Resonance (ECR) ion source; both heavy-ion and light-ion beams are used to study nuclear structure, nuclear reaction mechanisms, exotic nuclei, and nuclear astrophysics.

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 ECR source, and by exploitation of the Bevalac's unique capability to provide the heaviest ions in this intermediate-energy range. Since the complexity of reactions in this range for projectile-target combinations greater than mass 100 exceeds the ability of present Bevalac detection systems, a workshop was held in March 1989 to initiate a conceptual design process for a next-generation detector. Construction of this new detector is expected to begin in FY 1991. In the study of exotic nuclei at the Bevalac, a pioneering research program with radioactive beams is rapidly developing, highlighted by the discovery of a thick neutron skin or "halo" around the neutron-rich isotope ^{11}Li.

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 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 is extending these studies. Future experiments utilizing the proposed GAMMASPHERE, a national gamma-ray facility, would lead to further research opportunities in this field.

The nuclear astrophysics program is developing rapidly; activities 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. The nuclear astrophysics group plans to join the Sudbury (Ontario, Canada) Neutrino Observatory (SNO) collaboration to detect solar and supernova neutrinos using a large D_2O detector.



Offline counting facility for rare-decay experiments at the 88-Inch Cyclotron. The major components of this laboratory are a 12- by 12-inch split annular NaI detector, two Ge detectors, and multi-channel analyzers. Searches are made for decays that produce coincidences between the various detectors.

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, the 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. On-line access to the data bases is also provided to the scientific community.

Accelerator Improvements

Aimed at maximizing the Bevalac's scientific productivity, a modernization program has as its long-range goals achieving improvements in beam spill quality, increases in duty factor, better flexibility and reproducibility of operation, and increased intensity. Recently completed Accelerator Improvement Projects (AIP) include installation of a new high-current ion source and many enhancements of the SuperHILAC, and intensity improvements are being observed during almost every run. High intensity is a key to achieving improvements in beam quality and duty factor, especially for experiments not requiring all the available beam. In these cases, the extra intensity can ensure adequate beam current after collimation and stretching to improve beam quality and duty factor at the target. To achieve these goals, new controls will help assure the desired emittance and cleanliness and new main guide-field power supplies will provide for quieter spills and extended flattop and duty factor. Ongoing installation of new control systems is 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. Beam time on target, beam stability, and user satisfaction have all improved dramatically, and operation time has expanded from five to six days/week. Ongoing improvements in the ECR source have resulted in better source stability, simplified operation, and significant increases in the high-charge-state operation. 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 and design efforts for a next-generation ECR source are both underway.

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, and has been the host of the Superconducting Super Collider (SSC) Central Design Group. It further contributes to the SSC effort through R&D on superconducting magnets and through the SSC Detector Program initiative (see Section 4).

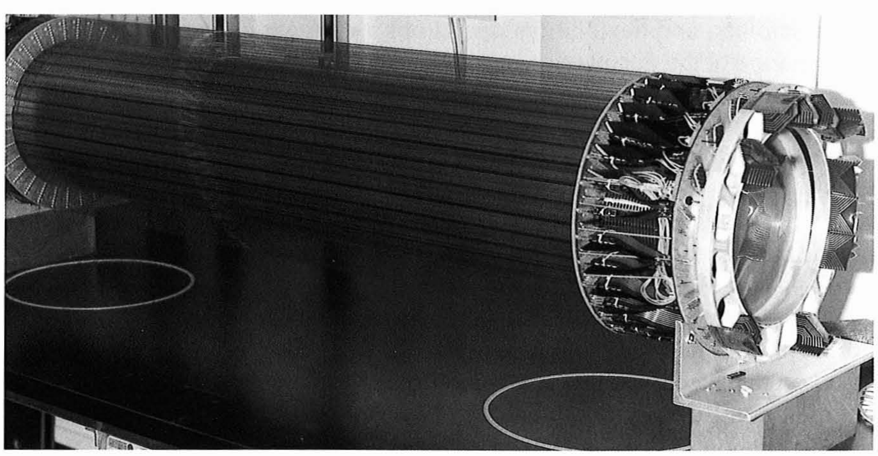
Experimental Programs

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 various colliding-beam facilities, where the highest-possible energies are available. Major experiments are in progress or in active preparation at SLAC and Fermilab.

The MARK II Detector has been upgraded for the first high-energy electron-positron collision experiments at the SLC. The endcap calorimeter, constructed at LBL, is now successfully taking data at SLAC. An ultrahigh-resolution drift chamber is also being developed in a collaborative effort with SLAC.

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, also at the Tevatron I. These include coordination of the design and fabrication of the central part of the detector and fabrication of a microvertex tracking



The three-layered vertex chamber for the D-zero detector at the Tevatron. The outer layer of wires in this precision drift chamber is visible. Tests show that two tracks separated by 700 microns can be resolved with 90% efficiency.

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.

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.

The D-zero endcap electromagnetic calorimeter printed circuit signal boards are interspersed with uranium plates. Multichannel readout enables precise determination of localized energy deposition to study jets and other high transverse momentum phenomena.

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 SLC and D-zero at 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 have played a leading role in solving major SSC physics issues. An effort that would build on both LBL's accelerator-physics expertise and its experience with beam-cooling systems (see below) is a proposed program to develop beam-control electronics for hadron colliders. 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.

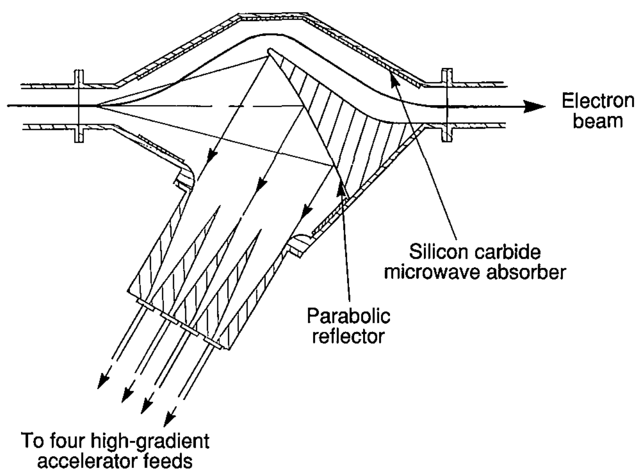
LBL's magnet-research efforts will emphasize continued development of high current densities for superconducting wire, improved cable design, and high-field magnets. LBL will pursue research on superconducting cables with very small filaments (2–3 μm diameter). If successful, this project will eliminate problems of field distortion at low fields and will eliminate 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 of a 6.6-T dipole magnet with a Nb-Ti superconductor continue to be refined at LBL. In addition, the Laboratory is contributing to the design and testing of special magnets and quadrupoles.

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 monochromatic beams of B mesons in the well-defined quantum state. This technique could be implemented by colliding the beam from the PEP storage ring with the beam from a new, small 2.5-GeV storage ring.

Another of LBL's contributions to high-energy physics has been the development of beam-cooling systems for Fermilab's Tevatron I. These systems are operating successfully, and the two laboratories continue to collaborate. LBL will continue to develop electrodes and signal-handling techniques for beam cooling and suppression of beam-induced instabilities.

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

This promising concept for extracting multi-GW microwave power from an Free-Electron Laser is now being studied. Small permanent-magnet dipoles (not shown) would "jog" the electron beam away from the centerline, permitting the microwaves to be reflected from the central region.



pioneered at LBL, would use either an FEL or relativistic klystrons to generate the needed microwaves. Studies are underway on a 35-GHz high-gradient accelerating structure, on the coupling of energy with such a structure, and on the power-generation sources.

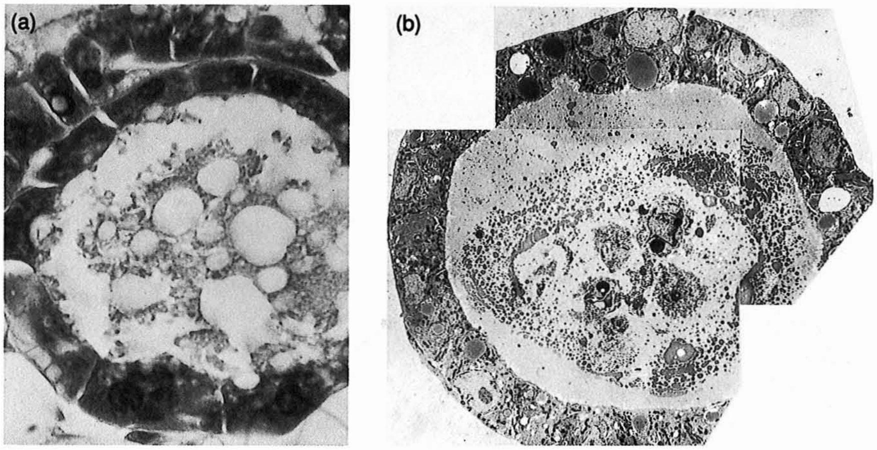
OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH

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 and 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 Center, is 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'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.



LBL scientists have determined that the extracellular matrix allows cells to recapitulate both form and functional differentiation. Photomicrographs of (a) an alveolus from a lactating murine mammary gland and (b) the structure formed by disaggregated cells grown on a reconstituted extracellular matrix from a murine tumor. The reaggregated cells can function to secrete milk proteins into the central lumin.

Structural Biology

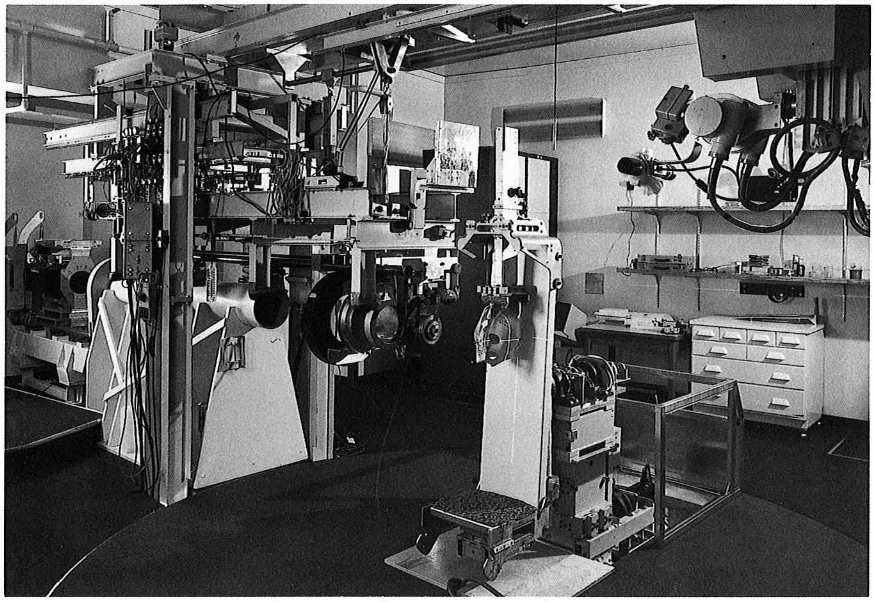
The central thrust of LBL's structural biology program is directed toward x-ray-based research at the proposed ALS Life Sciences Center, as described in Section 4. Supporting this research are activities in several divisions, including Research Medicine and Radiation Biophysics, Chemical Biodynamics, and Cell and Molecular Biology. Research on advanced techniques in x-ray microholography of subcellular structures is coordinated with the Center for X-Ray Optics. This research is expected to expand significantly. The Chemical Biodynamics Division will also expand its research on the relationship between nucleic-acid structure and gene functions, including elucidation of the structure of protein-DNA complexes by x-ray crystallography, NMR (including tritium NMR), and fluorescence-correlation spectroscopy. Several of these studies are aimed at determining the basic structure of how secondary structures within the molecules regulate function of genes, using the advanced imaging techniques, including x-ray diffraction and scanning tunneling microscopy.

The Cell & Molecular Biology Division will expand its structural biology studies in high-resolution crystallographic-structure analysis 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 receptor for extracellular matrix. This 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 new multilayer, high-resolution tomograph design is planned for use in medical studies of the human brain and heart, as well as 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

The new biomedical beam line at the Bevalac includes a newly developed computer-controlled scatterer that comprises a variable-thickness water absorber and metal scattering plates for improved control of dose delivery to patients.



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, 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 genetic recombination, DNA-binding proteins, DNA damage and repair, and the role of oncogenes in cancer induction and embryogenesis. In addition, research programs in cell and molecular biology of environmental damage and cancer initiation, promotion, and growth are expected to continue to develop during the period of the plan. 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 transformation.

An understanding of the molecular and cellular effects of accelerated ions is necessary to continued progress in radiation medicine and radiation-protection standards. 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 has been 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.

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 initiatives in the subsurface environment. The Laboratory's proposed program is in response to national needs for environmental restoration and encompasses the geochemical, biological, and hydrogeological 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 ecosystem changes (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.

The Population at Risk to Environmental Pollution (PAREP) 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.

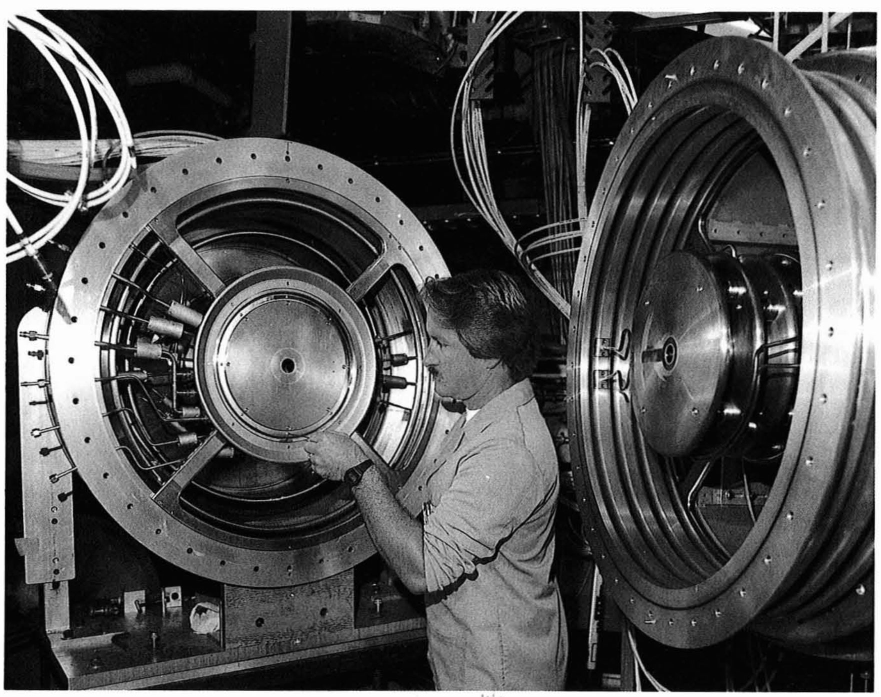
Measurement Technology

Key to the success of OHER programs is measurement technology. Better sensors and analytical techniques using these sensors have been developed out for a number of years at LBL with OHER support. At present, this work focuses on improvements in radiation detectors and materials for detectors and on the development of more-sensitive and -specific x-ray and atomic-absorption analytical methods. 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 both positive- and negative-ion-based neutral beams has been coupled with the research efforts at the Tokamak Fusion Test Reactor (TFTR) at Princeton and the Doublet III at GA Technologies in San Diego.

Studies for an Engineering Test Reactor (ETR), specifically the Toroidal Ignition and Burn Reactor (TIBER) study conducted at LLNL, have identified neutral beams as the leading candidate for driving current in a long-pulse



The Constant-Current, Variable-Voltage (CCVV) accelerator concept being developed and tested at LBL might be incorporated in neutral-beam injection systems for ITER. With such an accelerator, appropriate beam energies could be supplied at different stages of plasma heating without loss of current. Each modular acceleration stage can increase beam energy by as much as 100 keV.

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 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 is MCSD 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.

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 national needs, are described in Section 6. Science education and technology-transfer initiatives are 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 provides research support and technology development for energy conservation and renewable energy use, principally in building, transportation, and geothermal systems. The emphasis is on long-term laboratory-based research in the physical, chemical, and geological sciences.

Conservation and Renewable Energy Funding Summary

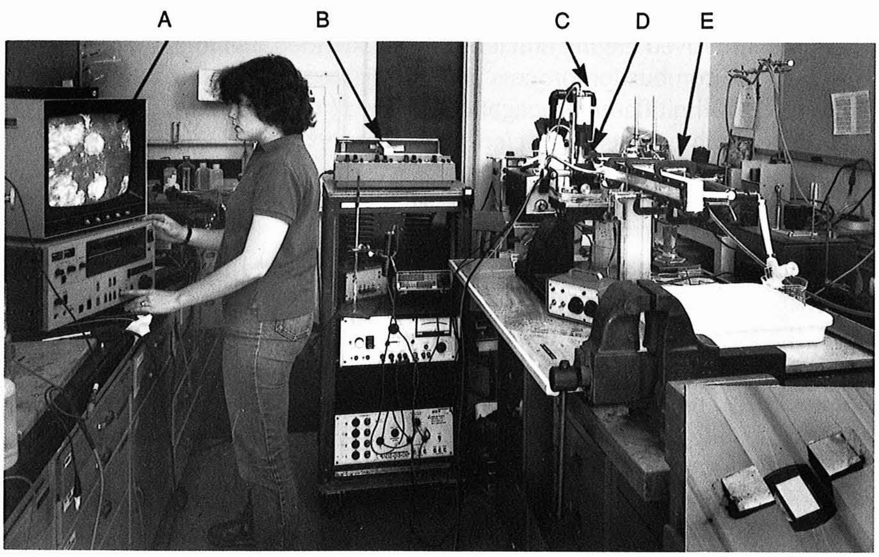
(Fiscal Year Operating and Capital Budgetary Authority, $M)

Budget Code	Major Program	1988	1989	1990	1991
AK	Electric Energy	0.5	0.9	1.0	1.0
AL	Energy Storage	3.0	2.8	3.8	4.0
AM	Geothermal	1.0	0.8	0.7	0.7
EB	Solar Energy	0.8	0.8	0.7	0.7
EC	Buildings & Community Systems	7.9	7.6	8.1	8.4
EF	State & Local Assistance	0.0	0.1	0.1	0.1
EG	Multisector	0.6	0.4	0.4	0.5
Total		**13.8**	**13.4**	**14.8**	**15.5**
Percent of LBL Total		**6.3**	**5.8**	**6.3**	**6.2**

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 recently initiated 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, laser ablation, and sol-gel processing. 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.



Video microscope for studies of electrodeposition in a flow cell. A: video screen showing image of developing deposit; B: electrical instrumentation; C: video camera and microscope; D: fiber-optic illumination; E: flow channel for deposition of zinc from acid chloride solution. Inset shows electrode arrangement in the channel allowing observation of the cathode surface.

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.

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.

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 sol-gel process for the production of high-temperature ceramics.

BUILDINGS AND COMMUNITY SYSTEMS

In the area of buildings and community systems, LBL will continue activities related to residential and commercial buildings, in a program of laboratory and field research. 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 Computer-Based Building Design (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.

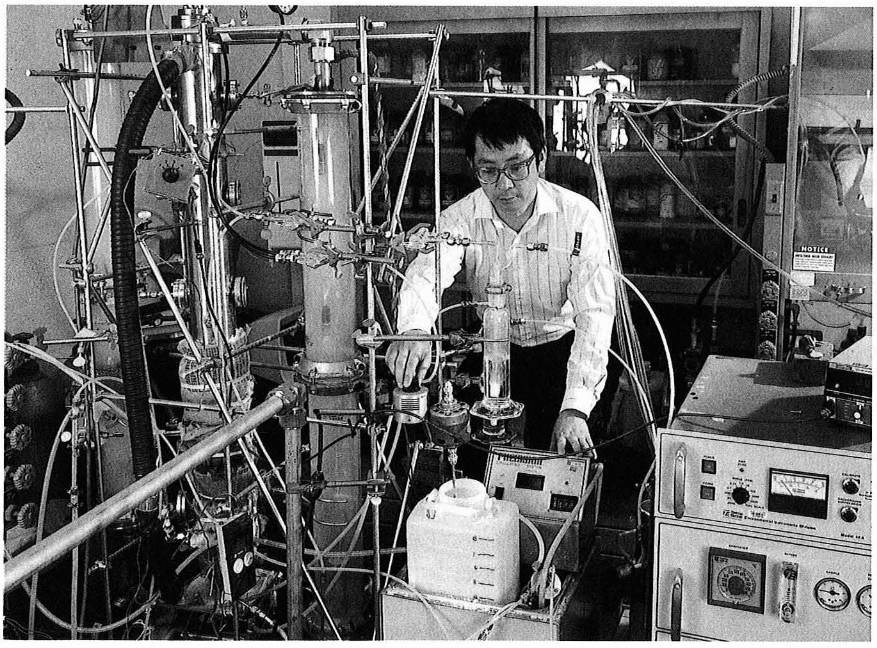
Both domestic and international studies of economic impacts of alternative conservation policies are expected to grow. The purpose of surveying the conservation policies of other developed countries is to enable the U.S. to compare progress in this area and perhaps adopt effective conservation measures. Considerable effort is devoted to analyzing the effects of conservation on electric utilities, including least-cost utility planning studies.

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



An innovative bench scale flue gas scrubber that makes possible the combined removal of nitrogen oxides and sulfur dioxide. The system uses inexpensive limestone, and its requirements for phosphorous are offset by phosphoric acid production.

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

Budget Code	Major Program	1988	1989	1990	1991
AA	Coal	1.1	1.2	1.2	1.3
AC	Petroleum	0.4	0.3	0.3	0.3
Total		**1.5**	**1.5**	**1.5**	**1.6**
Percent of LBL Total		**0.7**	**0.7**	**0.6**	**0.6**

studying the erosion and corrosion of materials used in systems developed for coal conversion and use.

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

OTHER DOE PROGRAMS

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

Budget Code	Major Program	1988	1989	1990	1991
DB	Civilian Radioactive Waste Management	3.8	4.0	4.9	5.1
HA	Environmental, Safety, Health	0.1	0.6	0.5	0.5
PE	Policy, Planning, & Analysis	0.5	0.3	0.5	0.5
WB	Management & Administration	2.3	0.3	2.6	1.1
—	Other DOE Contractors	21.6	24.4	10.0	10.0
Total		**28.3**	**29.6**	**18.5**	**17.3**
Percent of LBL Total		**12.8**	**12.9**	**7.8**	**6.9**

OFFICE OF 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.

ENVIRONMENT, SAFETY, AND HEALTH

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

OFFICE OF POLICY, PLANNING, AND ANALYSIS

LBL continues a long-term project to collect and analyze energy-consumption information from LDCs. Included in the study are twenty LDCs that account for most of the non-OECD oil imports and four large oil-exporting countries. This project includes a development of data base and complete analysis of the energy consumption of these countries, including, a review of important trends in structural change or composition, conservation, and fuel switching. 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 the potential for electric-utility least-cost planning programs.

MANAGEMENT AND ADMINISTRATION

LBL's In-House Energy Management program, supported by the Office of Management and Administration, pursues opportunities to reduce significantly 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 Superconducting Super Collider. This work, supported through the Universities Research Association (URA), has been the largest component of LBL's work for other DOE contractors and is phasing down with the CDG move to the SSC site in Texas. 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 (BPA).

WORK FOR OTHERS

LBL work (WFO) for others complements DOE research programs and provides unique research resources to other agencies and organizations. Reductions in support by Federal agencies other than DOE may be offset by collaborative research with the private sector consistent with technology transfer efforts.

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

Agency	1988	1989	1990	1991
Department of Defense	4.9	3.4	3.6	3.6
Department of the Interior	1.4	1.4	1.0	0.8
Environmental Protection Agency	0.6	1.0	1.2	1.2
National Aeronautics & Space Adm.	1.3	1.6	1.6	1.7
National Institutes of Health	13.7	13.0	13.9	14.1
Other Federal Agencies	1.6	1.5	1.9	1.9
State and Private	7.3	8.7	9.3	9.3
Capital Equipment	1.2	0.9	1.1	1.2
Total	**32.0**	**31.5**	**33.6**	**33.8**
Percent of LBL Total	**14.4**	**13.8**	**14.2**	**13.7**

OTHER FEDERAL AGENCIES

Agency for International Development

The Agency for International Development (AID) is supporting a multi-year 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's Construction Engineering Research Laboratory is using LBL's expertise in buildings to develop energy conservation requirements for new and retrofitted military buildings. 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 and training programs on x-ray microscopy and sources of high-brightness x-rays in addition to work in the magnetic fusion energy program. The Office of Naval Research (ONR) 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 as input to studies of the "nuclear winter" hypothesis.

Department of the Interior

Laboratory scientists, in collaboration with UC scientists and the Bureau of Reclamation, are investigating the ecological, geochemical, and hydrological aspects of selenium and other trace elements at Kesterson Reservoir, a terminus of agricultural drainage water in California's San Joaquin Valley. Continuing collaborative investigations are underway to evaluate remediation techniques for the area's soil. 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 will characterize the emissions of energy technologies, improve global energy projections, and gather information on the potential effect of global climate change on U.S. natural resources. In addition, LBL is developing advanced methods for the analysis of atmospheric aerosols.

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-LET radiation at LBL's Bevalac accelerator. LBL collaborates with NASA groups to develop gamma and x-ray detector systems for space applications. 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. In addition, EPRI supports research on the use of energy in buildings, including thermal storage to reduce air-conditioner loads.

The Gas Research Institute (GRI) supports data bases on heating and cooling loads in multifamily buildings to analyze advanced gas energy-use technology. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is sponsoring accurate determination of solar-heat gain through fenestration. The California Air Resources Board is sponsoring an analysis of indoor air concentrations of polycyclic aromatic hydrocarbons.

LBL's expertise in buildings is recognized by the California Energy Commission and the energy utilities. Support from these organizations is through the California Institute for Energy Efficiency (see Section 4). Pacific Gas and Electric Company supports LBL efforts to study indoor air quality to monitor the performance of daylighted buildings, to examine energy-management control systems, and, with Southern California Edison, to assess the energy savings of end-use technologies.

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

6 EDUCATION AND TECHNOLOGY TRANSFER PROGRAMS

In support of DOE's strengthening national role in energy-related science education and technology transfer, LBL is expanding its education, training, and technology-transfer activities as part of the Laboratory's mission to prepare the next generation of scientists and engineers and to foster productive relationships with industry. The following sections provide an overview and examples of the LBL efforts and plans in this area.

SCIENCE AND ENGINEERING EDUCATION

LBL's nationally oriented educational programs advance pre-university, undergraduate, graduate, and minority educational opportunities (Table 6-1). 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, a Center for Science and Engineering Education (CSEE) was established in 1987 in the Office for Planning and Development. By consolidating pre-university, undergraduate, and minority programs, CSEE provides a foundation for expanding and enhancing LBL's educational efforts.

Pre-university Programs

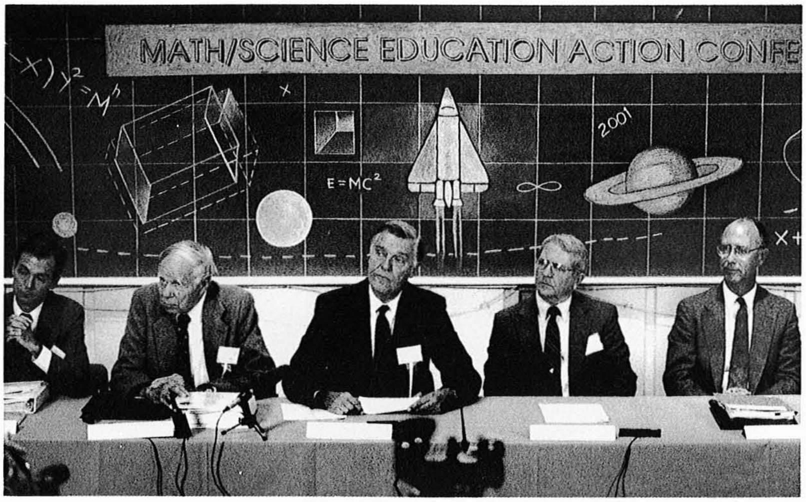
LBL is providing high school and community college teachers the opportunity to participate in frontier scientific research and technology development. Since 1983 LBL has provided over 100 community college, high school, and junior high school science and mathematics teachers with an opportunity to update their knowledge and revitalize their interests in science by spending a summer in research positions at LBL. Teachers of chemistry, physics, biology, and mathematics now spend eight weeks during the summer at LBL assigned to a research group along with scientists, graduate students, and technical support staff.

An outgrowth of the LBL teacher summer research participation program is the DOE TRAC program (Teacher Research Associates Program). This national program has placed over 130 high school teachers at eight national laboratories in FY 1989 and was piloted as the Residence in Science and Technology (REST) program in 1985 as a

Table 6-1. Educational Programs at LBL

Program Area	FY 1989 Participants
Pre-university Programs	
Teachers	
Residence in Science and Engineering (Teacher Research Associate-TRAC)	30
Students	
Horizon	250
High School Honors Program	61
LHS Partnership	
High School Science Symposium	275
Updating Science Knowledge for Instruction Colloquium	300
National Science & Technology Week	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	
Faculty/Student Research Team	3
Graduate	
Graduate Student Research Associates	493
Postgraduate	
Minority College Faculty	10
Postdoctoral Fellows	98
Faculty Visitors	350
Public Programs	
Tours and Seminars	~3,000

consortium of Lawrence Berkeley Laboratory, Argonne National Laboratory, and Brookhaven National Laboratory. The High School Honors Program in the Life Sciences, started in 1987, brings 61 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 lectures and laboratory experiences.



Math/Science Education Action Conference held at the LHS during October 1989. Participants included (from left) Charles Kolf, Deputy Under Secretary of the Department of Education; Glenn Seaborg Conference Co-Chairman , Chairman of LHS and LBL Associate Director at Large; DOE Secretary James Watkins, Co-Chairman; Admiral Richard Truly, Administrator, NASA; and UC President David Gardner.

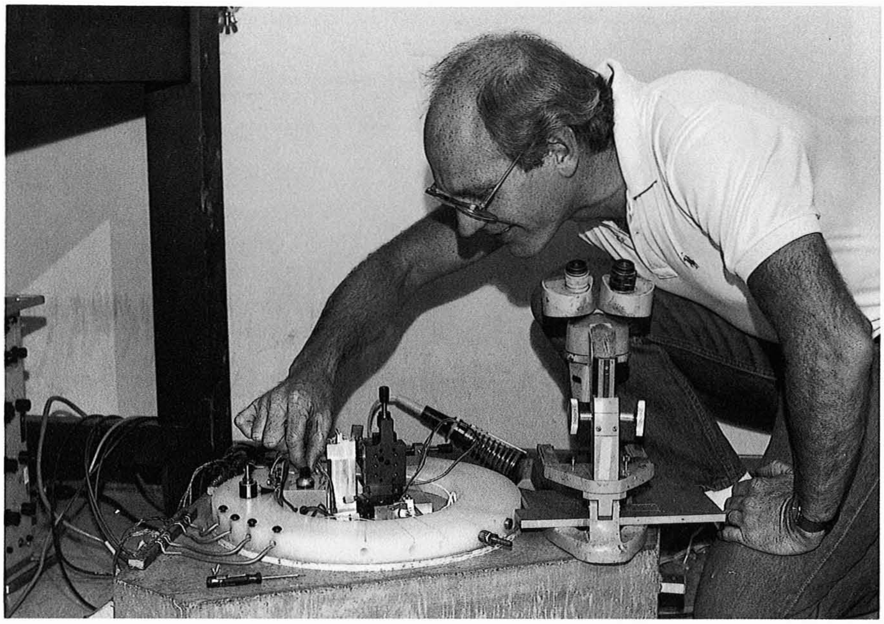
The program was one of seven DOE High School Honors Programs nationwide created to provide some of the country's best science students with the opportunity to gain firsthand experience in advanced scientific research at the DOE national laboratories.

A new program for inner city minority students (Horizon) was started this past year providing weekend academic activities in exciting scientific breakthrough areas for several hundred middle and high school students. In addition, LBL cosponsors activities with the LHS to promote public understanding of science and technology and to enrich teacher opportunities. An annual National Science and Technology Week program honoring teachers is planned with the 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.

Undergraduate Programs

Two undergraduate programs, the Laboratory Co-op Program and the Science and Engineering Research Semester, comprise the core of current activity in undergraduate student education. These programs provide advanced research participation for 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

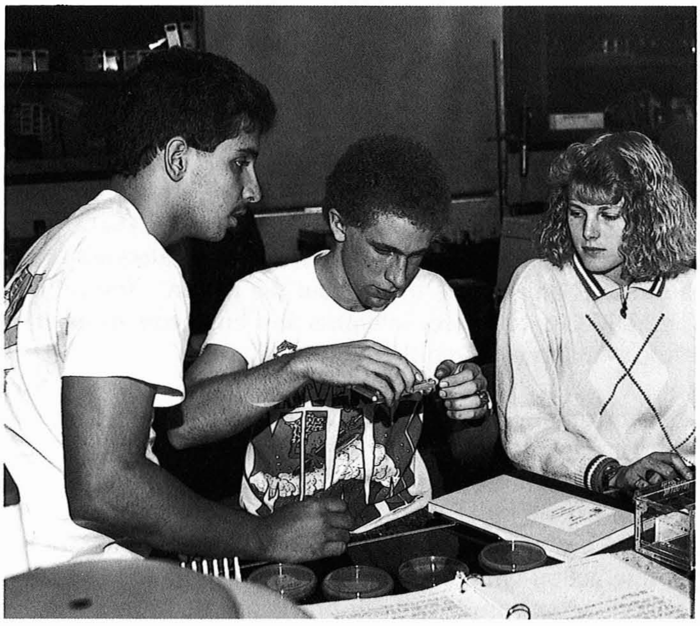


An East Bay teacher working with an atomic force microscope at LBL's Center for Advanced Materials.

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. This is the second year LBL has provided community college transfer students with an opportunity for research and mentorship at the Laboratory.

Graduate and Postgraduate Training and Research

LBL has a strong relationship with the UC at Berkeley, involving 211 faculty members who are LBL staff and about 500 graduate students. In



Several of the 61 students from the Life Sciences High School Honors Program conducting biotechnology experiments at LBL.

addition, the Laboratory provides more than 80 postdoctoral appointments for researchers. Each year, typically over a hundred 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 the 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

The LBL's primary programs to further minority education in science are operated under a consortium of LBL, Jackson State University (JSU), and the Ana G. Méndez Educational Foundation (AGMEF). Joint scientific research is conducted among the participating institutions, as well as a strengthening of academic and research capabilities of JSU and AGMEF. The goals of the consortium are 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.

During the summer of 1989, five AGMEF faculty worked on collaborative research projects at LBL and at a special environmental research campaign in Puerto Rico; four JSU faculty came to LBL in the summer of 1988. In the pre-university area, teachers and faculty and graduate students participated in the Puerto Rico program.

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 engineering. The Semester Cooperative Program is designed to be as complete an academic/research experience as possible.

Future Educational Program Plans

The 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 to provide new access and support for teachers and students from Oakland city schools and other urban communities (see Section 4). 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 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 1990. These activities will be expanded for research participation by community college, middle-school, and high-school teachers through DOE Teacher Research Associates appointments. The overall LBL teacher research participation will be called the Residence in Science and Engineering (RISE) program. Identifying and challenging students with high potential but low career horizons will remain important dimensions of pre-university programs.

Minority programs sponsored by the consortium of LBL, JSU, and AGMEF will continue with increased support given to research development and funded projects will further the goal of identifying specific areas of research excellence that can be conducted jointly by two, or all three, of the institutions.

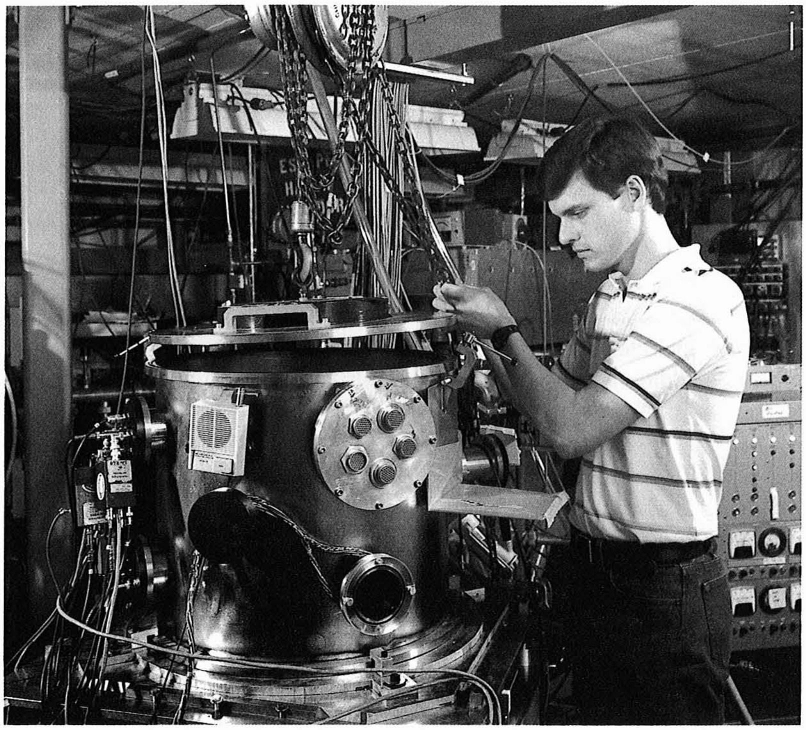
A partnership between the Lawrence Livermore National Laboratory (LLNL), Lawrence Hall of Science, and Stanford Linear Accelerator Center is being developed for retraining teachers in the Oakland school system. The LLNL and LBL are also developing a university/laboratory regional educators and research consortium for an Environmental Restoration and Waste Management education initiative.

COLLABORATIVE RESEARCH CENTERS

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 Complex—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 the highest 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;



Vacuum test chamber at the 88-Inch Cyclotron used by the aerospace and electronics industry for bombarding integrated circuit chips with accelerated heavy ions, simulating the space environment.

- 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 (highest resolution in the world), 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 1989, 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, the Sky Simulator, the Mobile Window Thermal Test Facility, the Low Background Counting Facility, and the Heavy Charged Particle Treatment Facility. Specific 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 1989)[a]

Facility	Laboratory	University	Industry	Total
Bevalac	154	98	28	280
88-Inch Cyclotron	86	39	62	187
National Center for Electron Microscopy	35	87	24	146
National Tritium Labeling Facility	39	14	9	62
TOTAL	**314**	**238**	**123**	**675**

[a] "Laboratory" includes University of California at Berkeley, and "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 specific collaborative research projects, through research centers and through industry involvement in advisory committees, panels, and review groups. 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 388 industrially sponsored research agreements in FY 1988, and is currently involved in negotiating nine collaborative research agreements (Table 6-3).

Table 6-3. Selected Technology Transfer Activities and Staffing

Category	FY 1988	FY 1989	FY 1990
Activity			
Industry Cooperative Agreements	0	4	9
Agreement value ($M)	0	0.2	2.9
Personnel Exchanges	6	8	9
Patent Applications	14	14	20
Patents Awarded	14	17	16
Staffing (Administrative)			
Technology Transfer Office	1.5	2.5	3.5
Patent Department	4	4	4
Office of Sponsored Research	1	2	2
TOTAL	**6.5**	**8.5**	**9.5**

The Center for Advanced Materials (CAM) 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). The Laboratory's initiatives, such as the Advanced Light Source, will provide a wide range of research opportunities and further extend these collaborations.

LBL recognizes the need to transform the Laboratory's research into economically practical technologies for U.S. industry and actively participates in the DOE's Laboratory Technology Exchange Program. Through this program, the DOE provides financial assistance needed to support extended visits by senior American industry scientists to the national laboratories. These visits were 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 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 scientists are actively involved in transferring technology to the private sector 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 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.

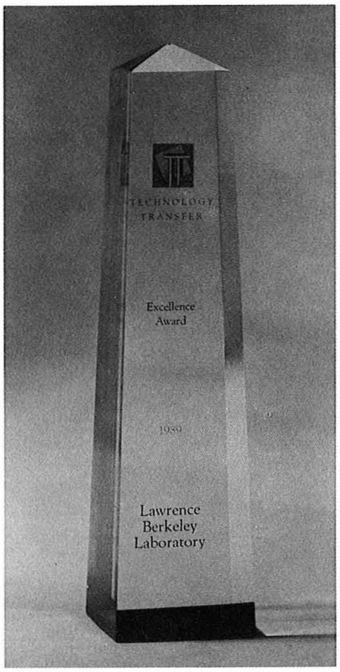
LBL's plans for further development and enhancement of technology transfer include expanding conventional mechanisms for DOE-developed technology transfer and initiating a new marketing program aimed at packaging intellectual property so that it is useful to U.S. companies. LBL-developed technology will 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
- Efficient fluorescent lighting technology
- Amorphous silicon detectors

New technologies will be handled in a manner that protects the potential proprietary interest for the U.S. market. An outreach program is planned to enable LBL scientists to contribute to industry.

For the marketing program, 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 through 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 target patent applications and licensing opportunities and further the effectiveness in negotiating licenses for LBL technology.



LBL initiated a Technology Transfer Recognition Program in FY 1989. Thirty scientists and engineers were honored with this Technology Transfer Excellence Award, and 100 investigators received Certificates of Merit.

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 1989, procurement was $104.5 M from all sources, including $5.8 from universities (Table 6-4). Increased expenditures over FY 1988 are 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 business (Table 6-5).

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

Recipient	FY 1987	FY 1988	FY 1989
Universities	6.4	5.9	8.0
All Other	68.8	71.3	93.9
Other DOE	0.9	.6	2.4
TOTAL	**76.1**	**77.8**	**104.3**

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

Business	FY 1988		FY 1989	
Category	Transactions	$M (%)[a]	Transactions	$M (%)[a]
Disadvantaged	3,016	5.6 (7.9)	3,160	8.0 (8.3)
Women owned	2,182	2.4 (3.4)	2,867	3.4 (3.6)
All Small	27,201	34.7 (48.7)	28,081	44.4 (46.4)

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

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 3336 employees, more than two-thirds with Baccalaureate or advanced degrees (Table 7-1). Part-time employees include 493 graduate and 178 undergraduate students, important components that contribute to LBL's education and training mission. In addition, 212 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.

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

Group	Doctoral	Masters	Bachelor	Other	**Total**
Staff Scientists	604	141	158	35	**938**
Students/Postdoctoral	104	129	396	160	**789**
Management	26	44	69	34	**173**
Administrative	3	22	104	281	**410**
Technical	7	58	196	765	**1026**
Total	**744**	**394**	**923**	**1275**	**3336**

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, 52 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.

Although LBL's population staff is relatively stable, the Laboratory has an active staff recruitment program, including divisional fellows and postdoctoral associates, directed toward ensuring a breadth of age and experience, a strong scientific and technical base, and a commitment to affirmative action and equal opportunity. Some programs in the life and physical sciences are projected to expand, but significant new additions to staff are not anticipated.

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.

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 Opportunity Officer at the Laboratory and the Equal Employment Opportunity Officer review 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 Director. The program goals include active recruitment outreach, training, and retention activities.

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.

In addition to formal training programs, special management institutes, are conducted to improve the management capabilities of staff and to advance LBL management goals and objectives.

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. These allocations are subject to the approval of the Laboratory's Overhead Budget Task Force, the Director, and DOE.

Table 7-2 Exploratory Research and Development Program

Category	FY 1988 Actual	FY 1989 Actual	FY 1990 Planned
Funding ($M)	3.20	3.29	3.64
Projects Approved	45	46	47

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.

One-third of the funds are reserved for proposals recommended through a peer review process, the objectives of which are primarily innovative and creative research, with funding levels being limited to $150 K per project. Two-thirds of the funds are allocated, following review by the Director's

Executive Committee, to projects with objectives primarily in forefront areas of science that enrich Laboratory research and development capabilities.

Recent achievements sponsored by the program include the first direct image of an unaltered DNA double helix, the first x-ray holograms of subcellular structure, definition of specific genetic alterations associated with atherosclerosis, and determination of optimal bond-lengths in high-temperature superconductors. Four projects have resulted in patent applications in areas of medical and biotechnology, microelectronics, and petroleum science.

An annual *Report on the LBL Exploratory Research and Development Fund* is available from the Office for Planning and Development.

8 SITE AND FACILITIES

The Laboratory prepares a long-range construction-project plans for meeting scientific and technical needs and for rehabilitation 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 replace obsolete facilities; to avert shutdowns, failures, and safety hazards; and to optimize use of the Laboratory's building resources. Recent department-wide planning efforts such as the Five-Year Environmental and Waste Management Plan are integrated with this planning process.

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), In-House Energy Management, Strategic Facilities Initiative, and General Purpose Equipment (GPE). Adequate funding in these areas will provide DOE with a strong multiprogram Laboratory capable of efficiently meeting the Laboratory's mission.

LBL's facilities planning is coordinated through specific Laboratory management activities and DOE initiatives. The *Long Range Site Development Plan*, revised for FY 1989–1994, will be reviewed and updated annually. 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 management processes.

SITE DESCRIPTION AND STATUS

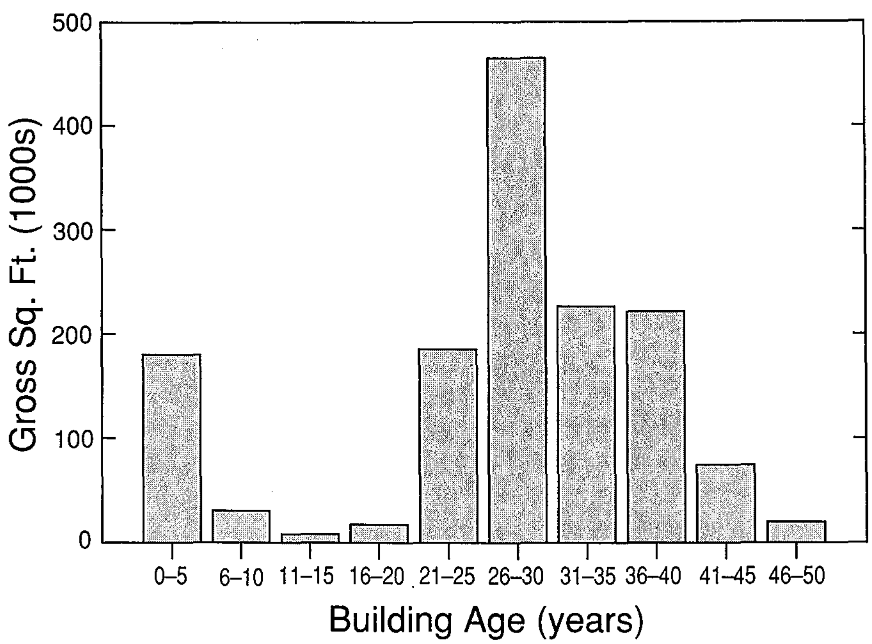
The first building on the LBL site was constructed in 1940. In FY 1990 over 70% of the gsf of permanent buildings is greater than 25 years old. As financial resources have become available, the basic structures, utilities, and interiors of many buildings have been rehabilitated or upgraded. During the 1980s the first major new laboratories since the mid-1960s have been completed for CAM. 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 facilities are planned, the total space associated with the proposed MEL-FS projects in the long-range plan remains relatively constant as construction projects are offset by demolition. The space distribution upon completion of current projects in FY 1989 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**

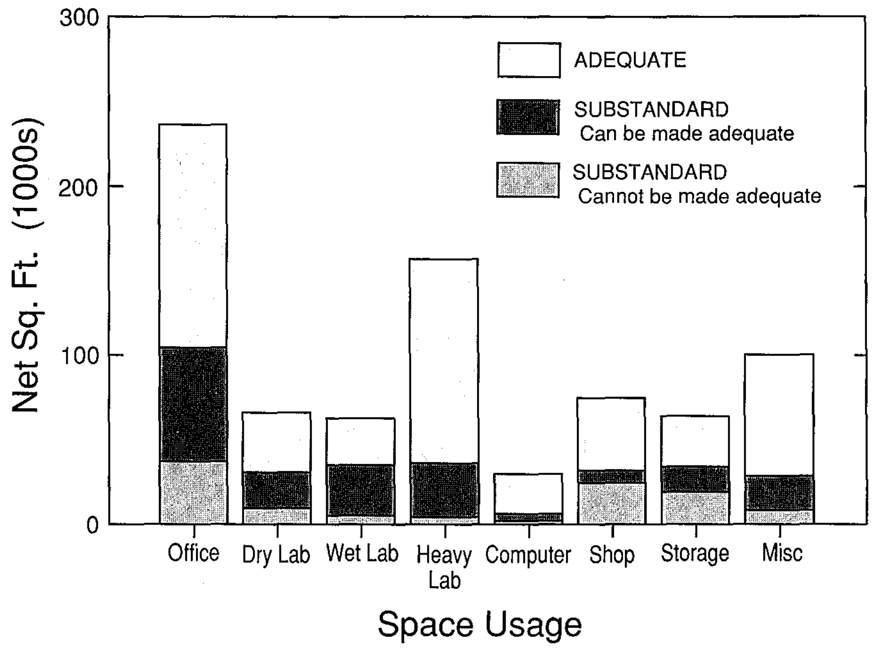
[a] Includes funded and budgeted projects.

LBL space in campus buildings is available to the 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 5% gsf are in trailers and other temporary structures. The 1989 replacement value of the buildings, utilities, and other improvements at the main site, as determined by DOE's Real Property



Age distribution of permanent main-site building.

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



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**

Significant modifications are required in laboratory buildings to provide improved systems for utilizing materials handling and to conform to current standards. 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.

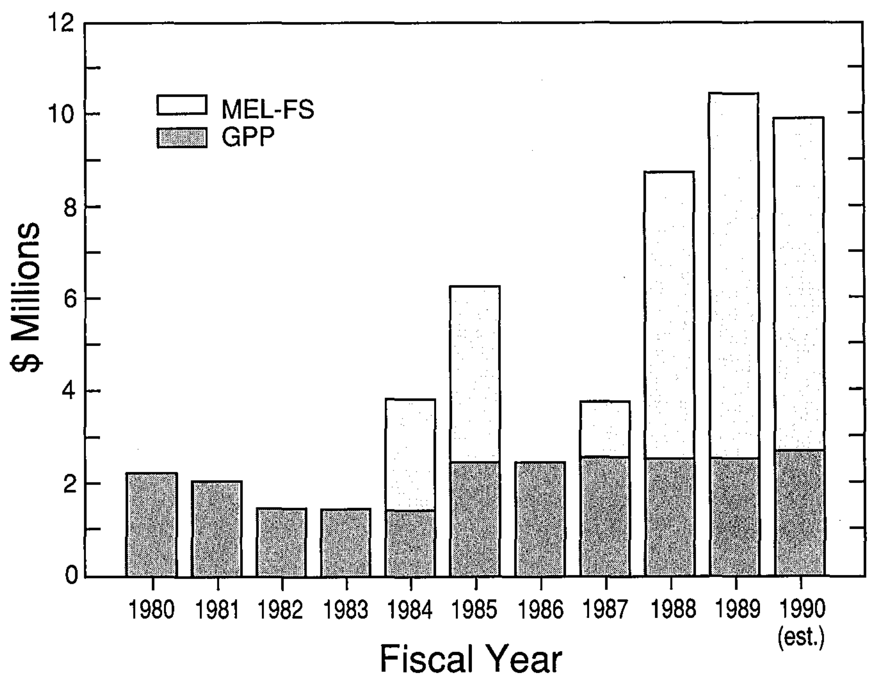
MULTIPROGRAM ENERGY LABORATORY FACILITIES SUPPORT

The 15-year MEL-FS plan calls for an overall increase from $7.2 M in FY 1990. Rehabilitation projects, which would improve and maintain laboratories and other facilities according to a realistic depreciation schedule, generally anticipate a depreciation cycle of 10–40 years, depending on building type and use. For general-purpose facilities and existing laboratories, plans include the removal of 230,000 gsf, the rehabilitation of 797,400 gsf, and the replacement of obsolete general-purpose facilities (through on-site construction) of 302,000 gsf. The total MEL-FS (FY 1990–2004) needs represent an investment of $207.0 M (Table 8-3). Laboratory buildings have the greatest need for rehabilitation. 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 1990–2004

Category	TEC ($M)	Period
Environment, safety, and roofs	34.7	1988–2004
Mechanical utilities[a]	35.7	1987–2004
Electrical utilities[a]	30.7	1987–2004
Building rehabilitation[a]	60.6	1990–2004
Building replacement[a]	45.3	1993–2001
TOTAL	**202.7**	

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



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.

SAFETY AND ENVIRONMENTAL IMPROVEMENTS

Environmental health and safety improvements are needed in safety services, medical services, building illumination, radiation protection, and water-pollution control and monitoring and in other safety systems. Many of these projects were initiated as MEL-FS in FY 1988. Slope and seismic stabilization, required in the Bevalac and Shops Areas, and the Safety and Supply Services Facility have been scheduled for FY 1990 and FY 1991. Environmental Monitoring and Restoration Facilities are proposed for subsurface remedial action for areas of contaminated soil. Facility improvements for chemical safety upgrades are also proposed. These projects are identified as proposed resource requirements and submitted as part of a five-year environmental plan to DOE as operating, equipment, and general plant projects supported through DOE's Environmental Restoration Program (Table 8-4).

Table 8-4. Environmental Restoration and Waste Management Proposed Resource Requirements ($M)[a]

Category	FY 1990	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995
Operating	1.93	6.62	1.17	0.61	0.64	0.67
Equipment	0.11	0.00	0.00	0.00	0.00	0.00
General plant	0.46	1.20	3.19	1.84	1.94	2.07
Line item	0.00	0.00	1.78	0.00	0.00	0.00
TOTAL	**2.50**	**7.82**	**6.14**	**2.45**	**2.58**	**2.74**

[a] Requirements are in addition to those tabulated in Table 8-3 and in Section 9.

Road safety improvements are required to facilitate the safe and efficient movement of staff and materials throughout the site. Roads need widening, base materials need to be replaced to conform to current standards, acute curves and blind spots need to be eliminated, and road beds and adjacent slopes on steep hillsides need to be stabilized. The plan calls for three phases of road rehabilitation as MEL FS projects: one each in FY 1992, FY 1999, and FY 2004.

MECHANICAL UTILITIES/EQUIPMENT

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 that programs can be disrupted by loss of essential utilities and equipment.

ELECTRICAL UTILITIES

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 Blackberry Canyon Substation and Feeders Project will provide increased reliability for the facilities in the Central Research and Administration Area and the Bevalac.

BUILDING REHABILITATION AND REPLACEMENT

The nonprogrammatic construction projects include 171,800 gsf of new on-site projects through FY 2004. The new construction responds to the needs for safety and supply services infrastructure and general-purpose mechanical- and electrical-engineering facilities. (Table 8-5 and accompanying figure). Included in the long-range plan is the removal of substandard facilities that cannot be made adequate. An important priority for FY 1991 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 of FY 1992 is the Seismic Rehabilitation of Building 90 Phase I. Ongoing seismic analysis of Laboratory facilities has identified structural limitations that are exacerbated by settling of the foundation. A second phase may be required for further structural reinforcement.

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). The ALS Facility improvements , Combustion Dynamics Facility, Human Genome Laboratory, and ALS Life Sciences Center are significant resources for programs supported by the DOE's Materials Sciences Division, Chemical Sciences Division, and Office of Health and Environmental Research.

GENERAL PLANT PROJECTS

LBL's GPP funds are provided by DOE's Nuclear Physics Division. The GPP program has the advantage of providing a mechanism 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 for other utilities and building maintenance, 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 rehabilitation program.

MAINTENANCE PLANS

Maintenance plans and budgets are developed annually within an overall five-year planning 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 section above, the long-range plan addresses many of the major maintenance issues. The reroofing, road projects, slope and seismic stabilization, environmental health and safety improvements, and general-purpose-facilities replacement projects are examples. However, 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 during periods of constrained operating budgets, 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.

GENERAL-PURPOSE EQUIPMENT

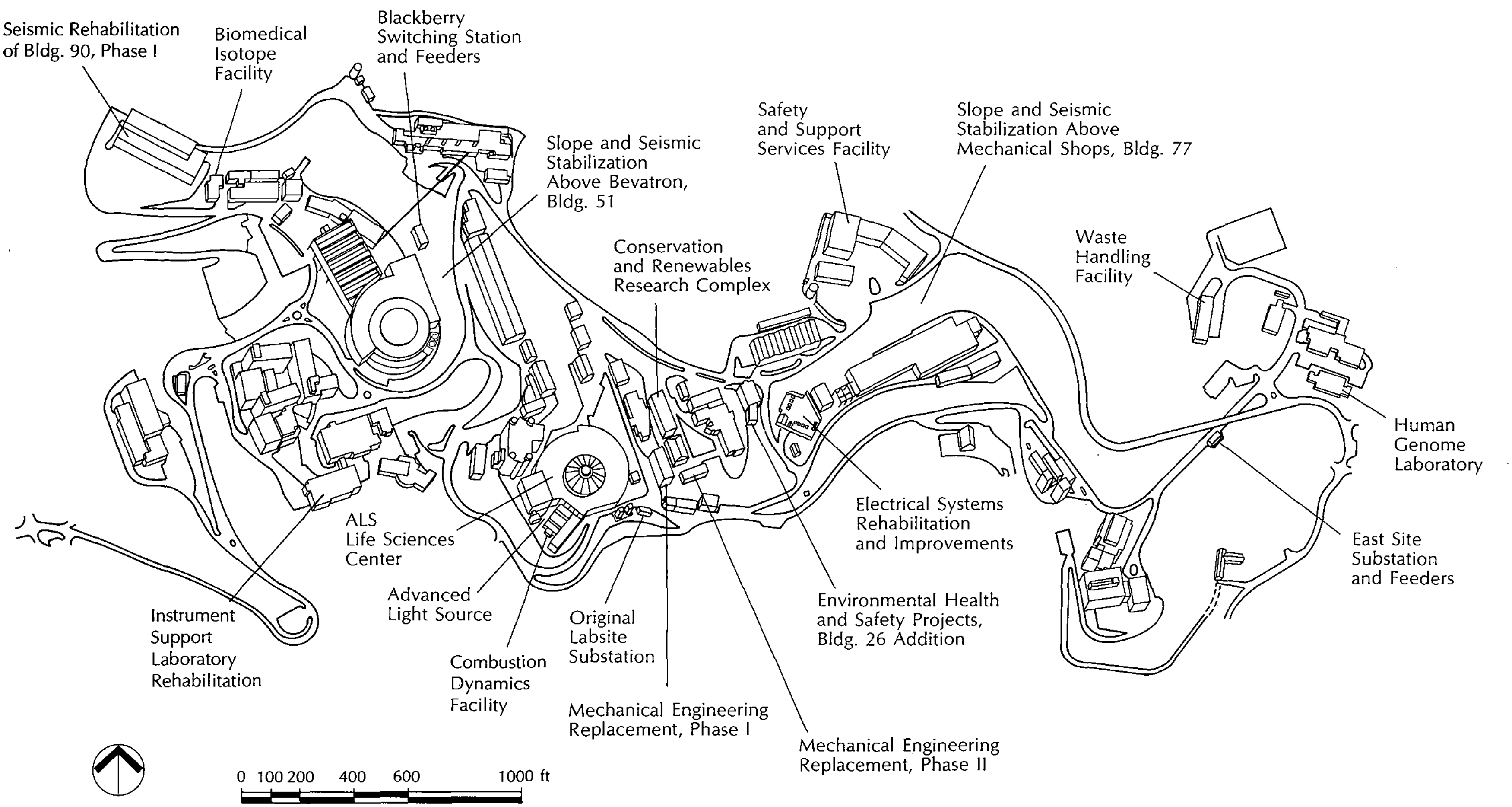
GPE funds are essential for the Laboratory to replace worn-out and obsolete plant-maintenance equipment, vehicles, administrative equipment, shop equipment, environmental monitoring and safety equipment, and information processing equipment. The Laboratory requires GPE funding to maintain its complement 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. GPE support at $3 M/year would provide a basis for reducing this backlog incrementally.

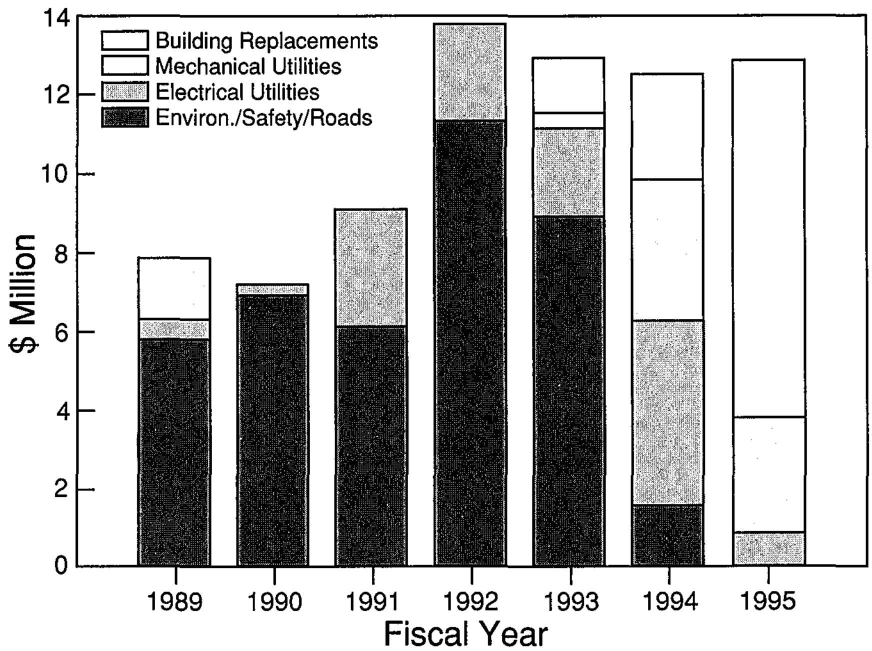
Table 8-5. Long-Range Plan for Programmatic and General Purpose Facilities, Including Funded, Budgeted and Proposed Construction (FY BA,$M)

Project	TEC	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
FUNDED PROGRAM RELATED PROJECTS:																		
Advanced Light Source	99.5	18.0	25.0	26.0	23.0	6.0												
FUNDED MEL-FS PROJECTS (KB):																		
Electrical Systems Rehabilitation & Improvements	2.6	1.8	0.5															
Mechanical Utilities Rehabilitation, Phase I	5.5	3.0	1.6															
Environmental Health & Safety Projects	10.3	0.9	3.0	4.8	1.6													
Waste Handling Facility	4.7	0.5	2.8	1.4														
Subtotal (MEL-FS Projects)	**23.1**	**6.2**	**7.9**	**6.2**	**1.6**													
TOTAL FUNDED	**122.6**	**24.2**	**32.9**	**32.2**	**24.6**	**6.0**												
BUDGETED MEL-FS PROJECTS (KB)																		
Original Labsite Substation	2.8			0.3	2.5													
Instrument Support Laboratory Rehabilitation	2.0			0.2	1.8													
Slope and Seismic Stabilization	3.7			0.5	2.2	1.0												
TOTAL BUDGETED	**8.5**			**1.0**	**6.5**	**1.0**												
TOTAL FUNDED and BUDGETED	**131.1**	**24.2**	**32.9**	**33.2**	**31.1**	**7.0**												
PROPOSED PROGRAM RELATED PROJECTS:																		
Human Genome Laboratory (HA)	11.6				1.1	8.3	2.2											
Life Sciences Center (HA)	25.4				4.8	14.0	6.6											
Biomedical Isotope Facility (HA)	5.8				1.3	4.5												
Advanced Light Source User Facilites (KC)	9.7				3.0	6.7												
Combustion Dynamics Facility	55.5					4.4	19.1	26.6	5.6									
Conservation & Renewables Energy Laboratory (EC)	24.9					1.7	22.1	1.1										
SUBTOTAL - PROPOSED PROGRAM RELATED	**133.1**				**10.2**	**39.6**	**50.0**	**27.7**	**5.6**									
PROPOSED MEL-FS PROJECTS:																		
Safety and Support Services Facility	7.7				0.5	2.8	4.4											
Blackberry Switching Station and Feeders	4.8				0.5	2.5	1.8											
Seismic Rehabilitation of Bldg. 90, Phase 1	5.5					2.5	3.0											
Roadway Safety and Stabilization	5.0					2.0	1.5	1.5										
Roof Replacements, Phase I	3.0					3.0												
East Site Substation and Feeders	5.1						0.4	4.7										
Mechanical Engineering Replacement, Phase I	11.7						1.4	2.7	7.6									
Sitewide Mechanical Equipment Replacement, Phase I	3.4						0.4	3.0										
Mechanical Utilities Rehabilitation, Phase II	3.5							0.6	2.9									
Replace Central Switch & Feeders	4.6								0.8	1.6	2.2							
Electrical Engineering Replacement, Phase I	11.0								1.5	9.1	0.4							
Upper Blackberry Switch Replacement	5.9									0.5	5.4							
Rehabilitation of Bldg. 46	3.2									0.3	1.9	1.0						
Mechanical Engineering Replacement, Phase II	8.0										1.0	2.0	5.0					
Cooling Towers & Chillers Replacement	4.3										0.5	3.8						
Sitewide Electrical Equipment Replacement, Phase I	4.0										0.5	3.5						
Roof Replacements, Phase II	4.4										0.6	2.3	1.5					
Road Rehabilitation, Phase II	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
Rehabilitation of Bldg. 62	7.0																0.8	2.7
Roof Replacements, Phase III	5.0																	0.5
Road Rehabilitation, Phase III	5.0																	0.5
SUBTOTAL - PROPOSED MEL-FS PROJECTS	**167.7**	**0.0**	**0.0**	**0.0**	**1.0**	**12.8**	**12.9**	**12.5**	**12.8**	**11.5**	**12.5**	**13.0**	**12.8**	**11.7**	**11.5**	**11.5**	**11.5**	**11.5**

Escalated at 4.2%, FY 1989; 4.8%, FY 1990; 5.0%, FY 1991; 5.2%, FY 1992; 5.7%, FY 1993; 6.0%, FY 1994; 6.2%, FY1995; 6.4%, FY 1996; and 6.5%, FY 1997. Beyond 1997 in constant dollars. 10/19/89

Current and proposed major construction project.





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

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 1988 Actual	FY 1989 Actual	FY 1990 (Estimated)
LBLnet (million packets/mo)	266	833	2,500
Workstations	1,850	2,395	2,600
Central processor (MIPS)	44	57	77
Central storage (Gbytes)	41	51	61

The Laboratory will promote the introduction of workstation-based "seamless" computing and communications environment 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.

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 1988 BA and estimated FY 1989 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 (Tables 9-8).

The FY 1990 estimate is based on FY 1990 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 1991 and beyond, operating cost projections are in constant-year dollars and construction costs are in actual-year dollars (as indicated in the DOE Institutional Plan Guidance). For FY 1991 to FY 1995, 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, construction and operational costs for the Advanced Light Source, and the initial increment of operating support for the Human Genome Center. 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 and proposed Environmental Restoration and Waste Management program resources are provided in Section 8.

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

Category	1988	1989	1990	1991	1992	1993	1994	1995
DOE Operating	133.0	142.5	146.2	157.2	165.6	173.1	180.6	182.5
WFO Operating	30.8	30.6	32.5	32.6	32.8	32.8	32.8	32.8
Total Operating	**163.8**	**173.1**	**178.7**	**189.8**	**198.4**	**205.9**	**213.4**	**215.3**
Capital Equipment	18.2	18.0	16.3	16.0	16.2	17.0	17.6	17.6
Program Construction	28.7	26.2	29.5	28.0	14.2	2.0	2.0	2.0
General Purpose Facilities	6.2	7.9	7.2	9.1	13.8	12.9	12.5	12.8
General Plant Projects	2.6	2.6	2.6	3.5	4.0	4.0	4.0	4.0
General Purpose Equipment	1.3	1.4	2.0	2.5	3.0	3.0	3.0	3.0
Total Lab Funding	**220.8**	**229.2**	**236.3**	**248.9**	**249.6**	**244.8**	**252.5**	**254.7**

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

Category	1988	1989	1990	1991	1992	1993	1994	1995
DOE Direct	1475	1553	1567	1588	1614	1618	1622	1639
WFO	296	295	299	285	287	287	287	287
Total Direct	**1771**	**1848**	**1866**	**1873**	**1901**	**1905**	**1909**	**1926**
Total Indirect	**712**	**724**	**724**	**727**	**730**	**732**	**733**	**733**
Total Lab Personnel	**2483**	**2572**	**2589**	**2600**	**2630**	**2637**	**2642**	**2658**

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
Office of Energy Research								
Operating	96.8	101.7	116.7	126.6	135.1	142.6	150.1	151.9
Capital Equipment	13.0	15.0	14.4	14.5	15.2	16.0	16.6	16.6
Construction	35.4	36.5	36.8	39.6	31.0	17.9	17.5	17.8
Total	**145.2**	**153.2**	**167.9**	**180.7**	**181.3**	**176.5**	**184.2**	**186.3**
Conservation & Renewable Energy								
Operating	13.4	12.6	14.1	14.8	14.8	14.8	14.8	14.8
Capital Equipment	0.4	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.8**	**13.4**	**14.8**	**15.5**	**15.5**	**15.5**	**15.5**	**15.5**
Fossil Energy								
Operating	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6
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	**1.5**	**1.5**	**1.5**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**
Office of Civilian Waste Management								
Operating	3.8	4.0	4.8	5.0	5.0	5.0	5.0	5.0
Capital Equipment	0.0	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	**3.8**	**4.0**	**4.9**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Environment, Safety and Health								
Operating	0.1	0.6	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	**0.1**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Management & Administration								
Operating	0.2	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	2.1	0.2	2.5	1.0	1.0	1.0	1.0	1.0
Total	**2.3**	**0.3**	**2.6**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Office of Policy, Planning & Analysis								
Operating	0.5	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	**0.5**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Work for Other DOE Contractors								
Operating	16.7	21.7	8.0	8.0	8.0	8.0	8.0	8.0
Capital Equipment	4.9	2.7	2.0	2.0	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**21.6**	**24.4**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Total DOE								
Operating	133.0	142.5	146.2	157.2	165.6	173.1	180.6	182.5
Capital Equip.(inc.GPE)	18.3	18.5	17.2	17.3	18.0	18.8	19.4	19.4
Construction (inc. GPF)	37.5	36.7	39.3	40.6	32.0	18.9	18.5	18.8
Total	**188.8**	**197.7**	**202.7**	**215.1**	**215.6**	**210.8**	**218.5**	**220.7**
Work for Others	32.0	31.5	33.6	33.8	34.0	34.0	34.0	34.0
Total Lab Funding	**220.8**	**229.2**	**236.3**	**248.9**	**249.6**	**244.8**	**252.5**	**254.7**

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
Office of Energy Research	1152	1216	1258	1284	1309	1314	1318	1335
Conservation & Renewable Energy	129	126	125	126	126	126	126	126
Fossil Energy	18	16	16	16	16	16	16	16
Office of Civilian Waste Management	41	45	50	50	50	50	50	50
Environment, Safety & Health	1	5	5	5	5	5	5	5
Management & Administration	6	4	6	6	6	6	6	6
Office of Policy, Planning & Analysis	3	1	2	2	2	2	2	2
Other DOE Contractors	125	140	105	100	100	100	100	100
Total DOE	**1475**	**1553**	**1567**	**1588**	**1614**	**1618**	**1622**	**1639**
Work for Others	296	295	299	285	287	287	287	287
Total Direct	**1771**	**1848**	**1866**	**1873**	**1901**	**1905**	**1909**	**1926**
Total Indirect	**712**	**724**	**724**	**727**	**730**	**732**	**733**	**733**
Total Personnel	**2483**	**2572**	**2589**	**2600**	**2630**	**2637**	**2642**	**2658**

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
AT Magnetic Fusion								
Operating	2.3	1.6	2.1	2.2	2.2	2.2	2.2	2.2
Capital Equipment	0.3	1.0	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**	**2.6**	**2.6**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Direct FTE	33	25	25	25	25	25	25	25
KA High Energy Physics								
Operating	19.9	22.1	24.0	25.1	25.5	25.8	26.2	26.6
Capital Equipment	2.7	3.5	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	**22.6**	**25.6**	**26.7**	**27.8**	**28.2**	**28.5**	**28.9**	**29.3**
Direct FTE	187	205	212	211	214	218	221	224
KB Nuclear Physics								
Operating	30.4	30.9	31.5	32.9	33.4	33.9	34.4	34.9
Capital Equipment	3.9	4.2	4.7	5.2	5.7	5.7	5.7	5.7
Construction	3.6	3.6	3.6	4.5	5.0	5.0	5.0	5.0
Total	**37.9**	**38.7**	**39.8**	**42.6**	**44.1**	**44.6**	**45.1**	**45.6**
Direct FTE	336	330	310	312	319	323	328	332
KC 02 Materials Sciences								
Operating	15.8	15.6	20.7	26.3	33.1	39.0	45.0	45.2
Capital Equipment	2.6	2.9	3.3	2.8	3.0	3.8	4.4	4.4
Construction	25.6	25.0	26.0	26.0	12.2	0.0	0.0	0.0
Total	**44.0**	**43.5**	**50.0**	**55.1**	**48.3**	**42.8**	**49.4**	**49.6**
Direct FTE	276	310	337	361	371	361	351	354
KC 03 Chemical Sciences								
Operating	7.4	7.4	7.6	7.9	8.1	8.2	8.3	8.5
Capital Equipment	1.1	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	**8.5**	**8.3**	**8.5**	**8.9**	**9.1**	**9.2**	**9.3**	**9.5**
Direct FTE	91	90	88	87	89	90	91	93
KC 04 Engineering, Math and Geosciences								
Operating	2.4	2.6	2.6	2.7	2.8	2.8	2.8	2.9
Capital Equipment	0.6	0.3	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**	**3.1**	**3.2**
Direct FTE	26	24	23	23	23	23	24	24
KC 05 Advanced Energy Projects								
Operating	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.7
Capital Equipment	0.8	0.6	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	**5.7**	**5.6**	**5.7**	**5.9**	**6.0**	**6.1**	**6.2**	**6.3**
Direct FTE	45	43	42	42	42	43	43	44

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
KC 06 Energy Biosciences								
Operating	1.1	1.3	1.5	1.6	1.6	1.6	1.6	1.7
Capital Equipment	0.2	0.2	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	**1.3**	**1.5**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.8**
Direct FTE	14	16	18	18	18	18	18	19
KC 07 Applied Math Sciences								
Operating	1.6	1.7	2.2	2.3	2.3	2.4	2.4	2.5
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	**1.7**	**1.8**	**2.3**	**2.4**	**2.4**	**2.5**	**2.5**	**2.6**
Direct FTE	17	18	22	22	23	23	23	24
KC Basic Energy Science (Total)								
Operating	33.2	33.6	39.7	46.2	53.4	59.6	65.8	66.4
Capital Equipment	5.4	5.0	5.3	4.9	5.1	5.9	6.5	6.5
Construction	25.6	25.0	26.0	26.0	12.2	0.0	0.0	0.0
Total	**64.2**	**63.6**	**71.0**	**77.1**	**70.7**	**65.5**	**72.3**	**72.9**
Direct FTE	469	501	529	552	565	559	552	557
KE University Research Support								
Operating	1.5	1.5	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.5**	**1.5**	**1.7**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
Direct FTE	15	15	16	16	16	16	16	16
KG Multiprogram Energy Laboratories 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	6.2	7.9	7.2	9.1	13.8	12.9	12.5	12.8
Total	**6.2**	**7.9**	**7.2**	**9.1**	**13.8**	**12.9**	**12.5**	**12.8**
Direct FTE	8	10	10	12	12	12	12	12
KP Biological and Environmental Research								
Operating	9.5	12.0	17.7	18.5	18.9	19.2	19.6	20.0
Capital Equipment	0.7	1.3	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	**10.2**	**13.3**	**18.9**	**20.1**	**20.4**	**20.4**	**20.8**	**21.2**
Direct FTE	104	130	156	155	161	161	164	168
Total OER								
Operating	96.8	101.7	116.7	126.6	135.1	142.6	150.1	151.9
Capital Equipment	13.0	15.0	14.4	14.5	15.2	16.0	16.6	16.6
Construction	35.4	36.5	36.8	39.6	31.0	17.9	17.5	17.8
Total	**145.2**	**153.2**	**167.9**	**180.7**	**181.3**	**176.5**	**184.2**	**186.3**
Total Direct FTE	**1152**	**1216**	**1258**	**1284**	**1309**	**1314**	**1318**	**1335**

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
AK Electric Energy Systems								
Operating	0.5	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.5**	**0.9**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Direct FTE	4	10	10	9	9	9	9	9
AL Energy Storage								
Operating	3.0	2.8	3.7	3.9	3.9	3.9	3.9	3.9
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	**3.0**	**2.8**	**3.8**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
Direct FTE	25	25	27	27	27	27	27	27
AM Geothermal								
Operating	1.0	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.2	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	**1.0**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Direct FTE	8	6	6	6	6	6	6	6
EB Solar Energy								
Operating	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7
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**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Direct FTE	7	6	5	5	5	5	5	5
EC Building & Community Systems								
Operating	7.5	7.0	7.5	7.8	7.8	7.8	7.8	7.8
Capital Equipment	0.4	0.6	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	**7.9**	**7.6**	**8.1**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**
Direct FTE	76	72	71	71	71	71	71	71
EF State/Local								
Operating	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Direct FTE	0	1	1	1	1	1	1	1
EG Energy Conversion Technology								
Operating	0.6	0.4	0.4	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	**0.6**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	9	6	6	7	7	7	7	7
Total Conservation & Renewable Energy								
Operating	13.4	12.6	14.1	14.8	14.8	14.8	14.8	14.8
Capital Equipment	0.4	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.8**	**13.4**	**14.8**	**15.5**	**15.5**	**15.5**	**15.5**	**15.5**
Total Direct FTE	**129**	**126**	**125**	**126**	**126**	**126**	**126**	**126**

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
AA Coal								
Operating	1.1	1.2	1.1	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.1**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
Direct FTE	11	10	10	10	10	10	10	10
AC Petroleum								
Operating	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Direct FTE	7	6	6	6	6	6	6	6
Total Fossil								
Operating	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6
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	**1.5**	**1.5**	**1.5**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**
Direct FTE	18	16	16	16	16	16	16	16
HA Environment, Safety & Health								
Operating	0.1	0.6	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	**0.1**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	1	5	5	5	5	5	5	5
DB Total Office of Civilian Waste Management								
Operating	3.8	4.0	4.8	5.0	5.0	5.0	5.0	5.0
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	**3.8**	**4.0**	**4.9**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Direct FTE	41	45	50	50	50	50	50	50
WB Management & Administration								
Operating	0.2	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	2.1	0.2	2.5	1.0	1.0	1.0	1.0	1.0
Total	**2.3**	**0.3**	**2.6**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Direct FTE	6	4	6	6	6	6	6	6
PE Policy, Planning and Analysis								
Operating	0.5	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	**0.5**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct FTE	3	1	2	2	2	2	2	2
Work for Other DOE Contractors								
Operating	16.7	21.7	8.0	8.0	8.0	8.0	8.0	8.0
Capital Equipment	4.9	2.7	2.0	2.0	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**21.6**	**24.4**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Direct FTE	125	140	105	100	100	100	100	100

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

Office/Program	1988	1989	1990	1991	1992	1993	1994	1995
Federal Agencies								
AID	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Direct FTE	2	2	2	2	2	2	2	2
Defense	4.9	3.4	3.6	3.6	3.6	3.6	3.6	3.6
Direct FTE	41	33	33	32	32	32	32	32
EPA	0.6	1.0	1.2	1.2	1.2	1.2	1.2	1.2
Direct FTE	7	10	12	11	11	11	11	11
NASA	1.3	1.6	1.6	1.7	1.7	1.7	1.7	1.7
Direct FTE	14	12	8	6	6	6	6	6
NIH	13.7	13.0	13.9	14.1	14.3	14.3	14.3	14.3
Direct FTE	136	125	127	123	125	125	125	125
NRC	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct FTE	3	3	3	3	3	3	3	3
Reclamation	1.4	1.4	1.0	0.8	0.8	0.8	0.8	0.8
Direct FTE	14	12	8	6	6	6	6	6
Other Federal Agencies	0.7	0.6	1.1	1.1	1.1	1.1	1.1	1.1
Direct FTE	4	4	7	7	7	7	7	7
Total Federal Agencies								
Operating	23.5	21.9	23.2	23.3	23.5	23.5	23.5	23.5
Capital Equipment	0.8	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Total	**24.3**	**22.5**	**23.9**	**24.1**	**24.3**	**24.3**	**24.3**	**24.3**
Total Direct FTE	**221**	**205**	**207**	**198**	**200**	**200**	**200**	**200**
State/Private								
Operating	7.3	8.7	9.3	9.3	9.3	9.3	9.3	9.3
Capital Equipment	0.4	0.3	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	**7.7**	**9.0**	**9.7**	**0.7**	**9.7**	**9.7**	**9.7**	**9.7**
Direct FTE	**75**	**90**	**92**	**87**	**87**	**87**	**87**	**87**
Total Work for Others								
Operating	30.8	30.6	32.5	32.6	32.8	32.8	32.8	32.8
Capital Equipment	1.2	0.9	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	**32.0**	**31.5**	**33.6**	**33.8**	**34.0**	**34.0**	**34.0**	**34.0**
Total Direct FTE	**296**	**295**	**299**	**285**	**287**	**287**	**287**	**287**

ACRONYMS AND ABBREVIATIONS

AARM	Advanced Atomic Resolution Microscope
AGMEF	Ana G. Méndez Educational Foundation
AGS	Alternate Gradient Synchrotron
AID	Agency for International Development
AIP	Accelerator Improvement Projects
ALS	Advanced Light Source
ANL	Argonne National Laboratory
ARM	Atomic Resolution Microscope
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
AVMs	arteriovenous malformations
BA	budgetary authority
BES	Basic Energy Sciences
BGO	bismuth germanate
BNL	Brookhaven National Laboratory
BPA	Bonneville Power Administration
CAD	Computer-aided design
CAM	Center for Advanced Materials
CASA	Cooperative Approach to Software Advancement
CDC	Centers for Disease Control
CDF	Collider Detector at Fermilab
CDF	Combustion Dynamics Facility
CDG	Central Design Group
CDRL	Chemical Dynamics Research Laboratory
CEBAF	Continuous Electron Beam Accelerator Facility
CERN	European Laboratory for Particle Physics
CEVV	Constant-Current, Variable-Voltage (accelerator)
CFCs	chlorinated fluorocarbons
CIEE	California Institute for Energy Efficiency
CP	charge parity
CRE	Conservation and Renewable Energy
CSEE	Center for Science and Engineering Education
CSDP	Continental Scientific Drilling Program
DHHS	Department of Health and Human Services
DLS	DiLepton Spectrometer
DOE	U.S. Department of Energy
ECR	Electron Cyclotron Resonance
EH&S	Environmental Health and Safety Department
EKS	energy kernal system
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ETR	Engineering Test Reactor
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
HGIS	Human Genome Information System
HIFAR	Heavy-Ion Fusion Accelerator Research
HIREFS	high-resolution erect-field spectrometer
HISS	Heavy-Ion Spectrometer System

HVEM	High-Voltage Electron Microscope
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
LIBRA	Light-Ion Biomedical Research Accelerator
LLNL	Lawrence Livermore National Laboratory
MBE	Multiple-Beam Experiment
MCSD	Materials and Chemical Sciences Division
MEL-FS	Multiprogram Energy Laboratory Facilities Support
MEVVA	metal vapor vacuum arc
Mgsf	million gross square feet
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCEM	National Center for Electron Microscopy
NIH	National Institutes of Health
NMR	nuclear magnetic resonance
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NSLS	National Synchrotron Light Source
OECD	Organization for Economic Cooperation and Development
OER	Office of Energy Research
OFA	Other Federal Agencies
OHER	Office of Health and Environmental Research
ONR	Office of Naval Research
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PAREP	population at risk to environmental pollution
PEP	Positron Electron Project
PNL	Pacific Northwest Laboratories
R&D	research and development
REST	Residence in Science and Technology
RHIC	Relativistic Heavy-Ion Collider
RISE	Residence in Science and Engineering
SNL	Sandia National Laboratories
SERS	Science and Engineering Research Semester
SLAC	Stanford Linear Accelerator Center
SLC	Stanford Linear Collider
SNO	Sudbury Neutrino Observatory (Ontario, Canada)
SQUID	superconducting quantum interference device
SPS	Super Protron Synchrotron
SSC	Superconducting Super Collider
SSRL	Stanford Synchrotron Radiation Laboratory
TBA	Two-Beam Accelerator
TEC	total estimated cost
TFTR	Tokamak Fusion Test Reactor
TIBER	Toroidal Ignition and Burn Reactor
TPC	Time Projection Chamber
TRAC	DOE Teacher Research Associates Program
UC	University of California
URA	Universities Research Association
USGS	U.S. Geological Survey
VUV	vacuum ultraviolet
WFO	Work for Others

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