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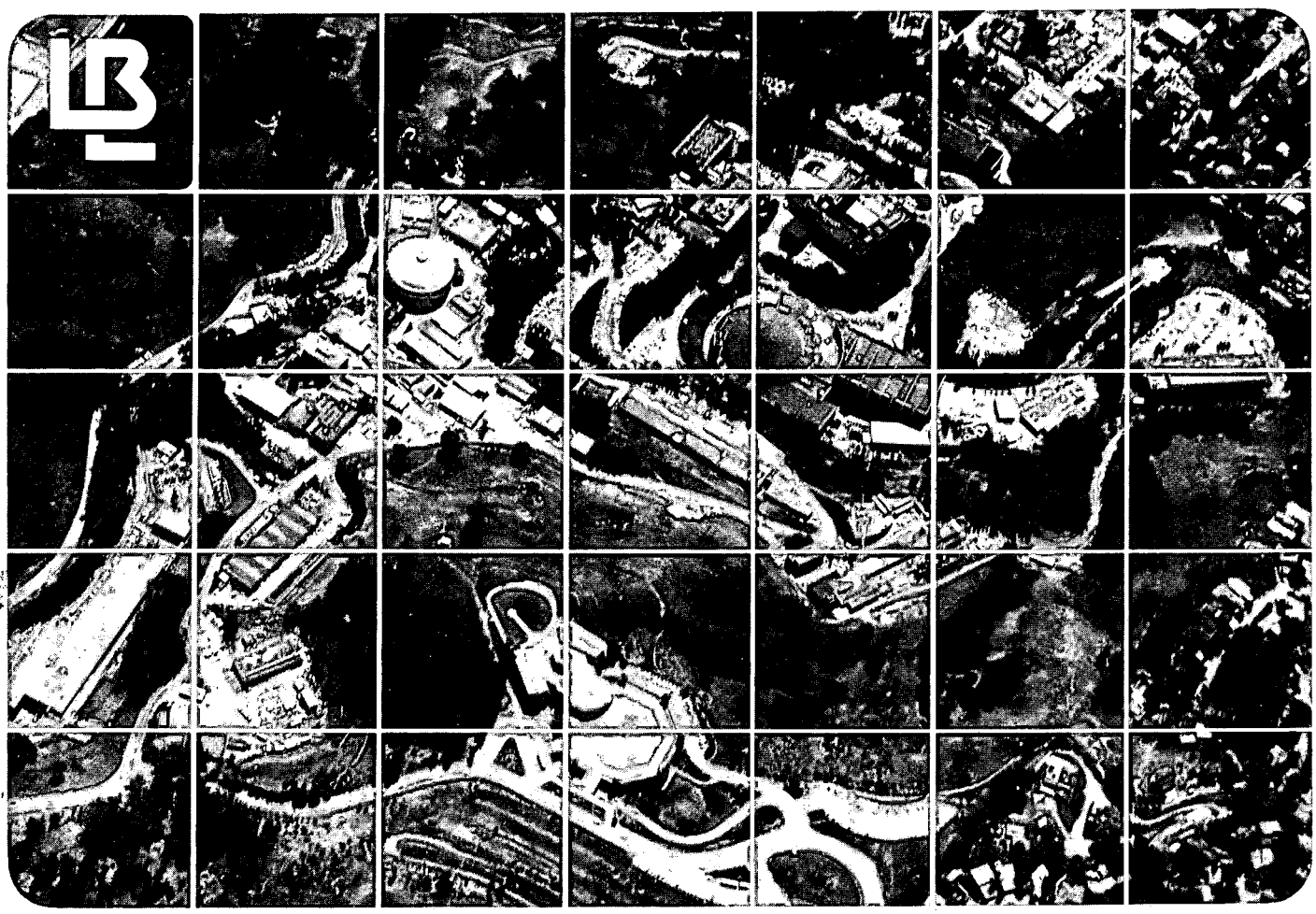

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LBL INSTITUTIONAL PLAN 1979 (FY 80-85)

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SECTION I

INSTITUTIONAL OVERVIEW

DIRECTOR'S OVERVIEW

The Role of the Laboratory

In charting the difficult but inevitable transition from dependence on fossil fuels to an era of sustainable energy sources, the nation will need to rely heavily on research aimed at increasing the efficiency of energy use and the supplies of domestic energy resources during the transition period, and at building an adequate scientific foundation for development of the nation's energy system for the long-term future. The Department of Energy has the chief responsibility for coordinating the R&D effort and must use the resources of the national laboratories, universities, industry and other institutions to achieve its purposes. The national laboratories play a vital role because of their immense technical and managerial capability built up over many decades. The physical plant, the advanced - and, in many cases unique - facilities and the impressive professional and technical staffs give the laboratories the tools to handle complex technical problems at all stages of research and engineering development. The laboratories constitute an exceedingly important national resource not only for the conduct of R&D projects but for planning and technical advice to the Department of Energy and for cooperative efforts with industries and universities.

The Lawrence Berkeley Laboratory is the oldest of the national laboratories and is unique because of its proximity and complex interactive connection with a major university. It thus combines the advantages of the university campus with the access to leading scholars in a wide variety of disciplines and the technical strengths of a national laboratory. This unique breadth allows the Laboratory to contribute to the Department's mission in many important ways.

The Laboratory focuses on the research phase of the DOE mission, although highly technical development work is done in areas where there is unusual or unique LBL capability. The laboratory pursues research of the following types:

1. Fundamental research in the energy-related basic sciences, including nuclear and high-energy physics, and the chemical, materials, biological, and biomedical sciences. Much of this research is done with large experimental facilities.

2. Background research using basic science techniques and concepts devoted to specific energy supply and demand problems within the DOE mission. Examples are geochemical studies related to nuclear waste management, catalysis studies related to synthetic fuels production, atmospheric studies related to environmental effluent standards, and energy end-use analyses related to the national energy conservation program;

3. Applied research in important areas of the DOE mission. Examples are laboratory studies of conversion of biomass to alcohol or oil, field engineering studies of geothermal power systems, field study of geological aspects of nuclear waste isolation, and research in development of energy-efficient buildings, ventilation, and lighting systems.

4. Technological development programs, such as LBL's design and construction of neutral-beam injector systems for the national magnetic confinement fusion test program.

The Laboratory's programs have been molded by a strong tradition of excellence in basic scientific research and in the engineering of complex systems. Today, the program is a coherent mix of basic science and engineering development, and emphasizes the building of a solid scientific base of understanding as a prerequisite to the development of economic energy technologies and the efficient end-use of energy, which our nation requires for the years ahead.

Looking forward, Lawrence Berkeley Laboratory will continue to build upon this tradition of excellence as it both pursues fundamental research and involves its large and diverse research program in contributing to solving the nation's energy problems. As in the past, the specifics of LBL's program will evolve to meet changing national goals, but our commitment to innovation and excellence in the pursuit of knowledge will not change.

Background

Bearing the name of Ernest O. Lawrence, the great pioneer of nuclear science and inventor of the cyclotron, the Lawrence Berkeley Laboratory has, for over four decades, carried out multidisciplinary research in the fields of nuclear and related sciences. In forming his Radiation Laboratory in 1931, Lawrence brought outstanding faculty researchers in physics and chemistry together with creative engineers. They built cyclotrons and exploited the properties of nuclear particle beams and radioactive isotopes for pioneering research in nuclear physics, nuclear chemistry, new element synthesis, nuclear medicine, and the application of nuclear techniques to many scientific and industrial problems. Lawrence's Radiation Laboratory showed the power of multidisciplinary research organized around major experimental facilities. In the 1930s it was the most active nuclear research establishment in the world. In these and subsequent years, members of the Laboratory achieved world renown and received a total of seven Nobel Prizes. Upon the death of Ernest Lawrence in 1958, the Laboratory was renamed Lawrence Radiation Laboratory, and in 1971 it was separated administratively from its daughter laboratory in Livermore and renamed the Lawrence Berkeley Laboratory.

After making a major contribution to the World War II effort, the Laboratory became a national research center of the Atomic Energy Commission for the rapidly developing basic nuclear and fundamental particle sciences. The design and construction of advanced nuclear

particle accelerators in the 1940s and 1950s stimulated the blossoming of high-energy physics throughout the world and, in particular, at LBL during this period. There followed spectacular discoveries of fundamental particles, including the antiproton, the antineutron, and most of the strange particles. The nuclear sciences also reached maturity, with LBL continuing to play a leading role in the understanding of the structure of nuclei and being involved in the synthesis of every one of twelve new transuranic elements. The unexpected continues to happen in particle physics, as for example the recent SLAC-LBL discoveries of the ψ, χ, and "charmed" particles.

The Laboratory has carried on accelerator physics research since its earliest days. Most recently this program contributed to the design of the high-energy positron-electron colliding beam accelerator, known as PEP, now nearing completion at the Stanford Linear Accelerator Laboratory (SLAC). The same technological expertise and resources that were built up at LBL for accelerator research played a pioneering role in developing magnetic confinement fusion science. The Laboratory now occupies an important position in DOE's magnetic confinement program by designing and supplying neutral beam injector systems for large-scale experimental fusion devices and by exploring alternative confinement schemes. As the development of inertial confinement fusion science and technology continues to grow nationwide, LBL is assuming an important role in the investigation of heavy-ion accelerators as drivers for pellet fusion.

Even in the earliest days of the Laboratory, John Lawrence, brother of the cyclotron's inventor, developed a productive relationship between biomedical sciences from the UC Berkeley faculty and the various nuclear-related sciences of the Laboratory. Important contributions to basic biologic science and to diagnostic and therapeutic medicine continue to be made by the synthesis of these skills and research techniques at LBL.

One of the most important unsolved problems of biological science at the end of World War II was the mechanism of photosynthesis. By bringing together faculty researchers from chemistry, biology, and nuclear science, LBL was able to make unique contributions to the solution of this problem. The skills developed in this work at LBL have subsequently been applied to a number of related problems. Currently these include research into more efficient food production, photochemical production of fuels from solar energy, and basic biology related to understanding the causes of cancer.

In the early 1960s, the Laboratory developed a new program in materials sciences. The Berkeley Campus had long been the home of outstanding expertise in various aspects of materials sciences, located in a number of campus departments. LBL recognized that the solution of many important and difficult problems in materials sciences could be facilitated by bringing together these skills into a laboratory milieu that would provide a focus and a high level of research support. Important contributions have been made to basic understanding of materials properties, and unique new materials have been developed. Today these

skills are being applied increasingly to materials problems related to the development of new energy technologies, for example, the fundamental study of catalyst materials for synthetic fuel production. New electron microscope facilities and other advanced instrumentation greatly strengthen the capabilities of this program.

With the emergence of consciousness about environmental problems in the late 1960s, LBL recognized that progress toward understanding many significant environmental impacts was constrained by a lack of adequate analytical techniques for precise measurement of environmental variables. It was evident that many of the techniques LBL developed for the basic nuclear sciences could be applied systematically to environmental problems. This application has been straightforward and often enormously effective, with some LBL techniques now utilized nationwide for environmental or research monitoring. Currently novel physical chemistry techniques are being applied at LBL toward obtaining a fundamental understanding of the atmospheric chemistry involved in atmospheric particulate formation from fossil fuel combustion. The level of analytical skill LBL will continue to bring to the study of these problems exists at few, if any, other places.

Since 1971, the Laboratory has devoted increasing attention to research in the earth sciences, which are central to the economic development of most energy resources. Many of the technical problems with geothermal energy, for example, arise from our lack of fundamental scientific knowledge of subsurface geologic media. The same areas of earth and chemical science are relevant to developing a sufficient understanding of geologic media required for the safe storage of nuclear wastes. Many earth-science related disciplines have long resided on the Berkeley Campus, but without a unified research focus. LBL has brought eminent faculty members together with LBL staff and resources to provide a unique national capability for the study of energy-related subsurface problems. LBL is applying this capability to problems associated with geothermal energy technology and aquifer storage of heat, as well as to research aimed at establishment of a sound scientific basis for geologic disposal of nuclear wastes.

Characteristics

LBL derives a unique character from its location in the immediate vicinity of a major university campus and because of the opportunity for faculty and students to work closely with the distinguished staff of scientists and engineers at LBL. Many faculty members in the physical, biological and engineering departments of the UC Berkeley campus hold key positions of programmatic and administrative responsibility in LBL, including Associate Director status. Dozens of others supervise important research activities, and over 400 graduate students from many campus departments are heavily involved in LBL research. Several programs at LBL involve faculty from the social sciences and the professional schools. LBL has a large population of post-doctoral appointees from American and foreign universities. About 200 foreign PhD scientists are participating guests or regular short-term employees.

Thus, the Laboratory combines the best features of a major national research facility with the diversity of a great university. The extensive involvement of staff, faculty, students, post-doctoral appointees and foreign visitors creates an atmosphere of vitality and renewal in which creativity flourishes. This vitality is illustrated by Fig. 1-1, which shows the very favorable age distribution of the LBL professional staff.

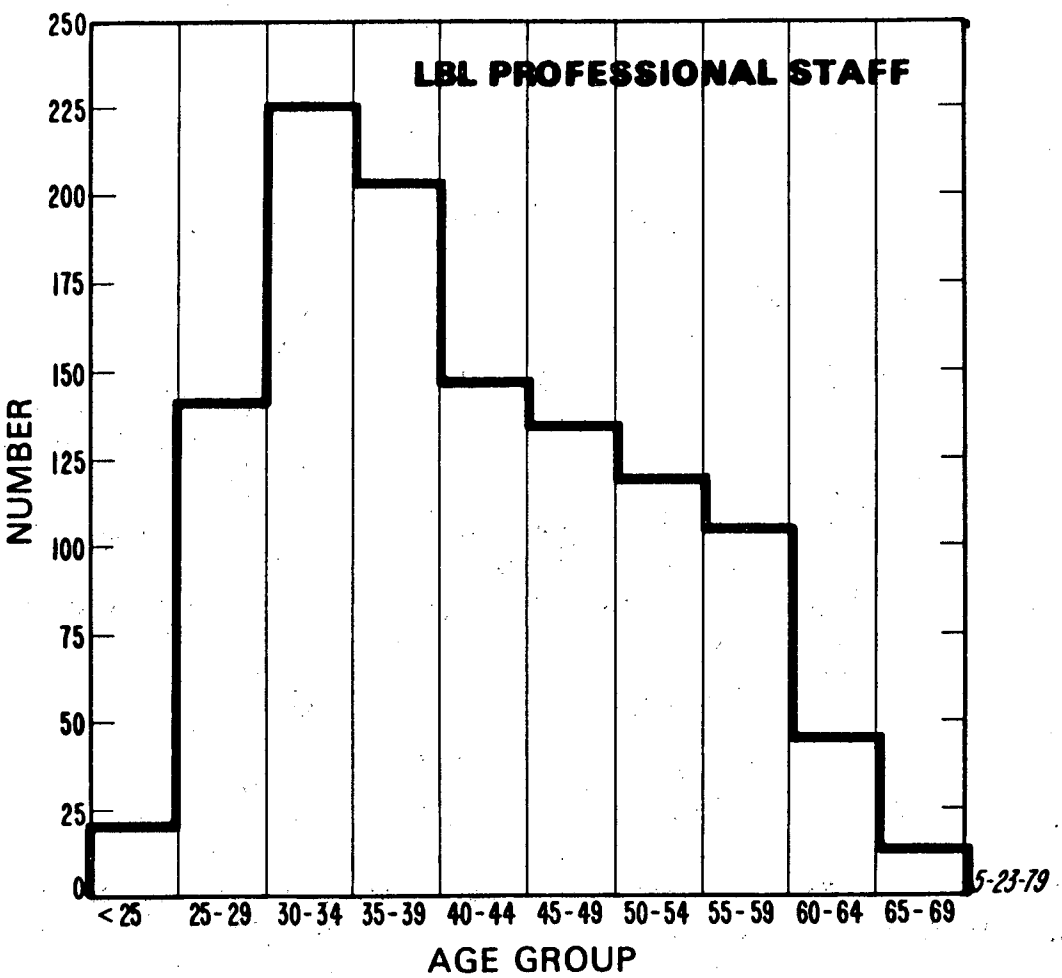

Fig. 1-1. Age Distribution of LBL Professional Staff (excluding 400 graduate students)

Among government laboratories, LBL's role in the educational process has, in fact, been unique. Through four decades more than a thousand PhD degrees in the basic energy sciences have been granted by the University as the result of research done at the Laboratory, and currently more than 400 graduate students are employed at the Laboratory while working towards advanced degrees. LBL expects to continue to be a major supplier of expertise for the nation's growing energy community.

Current LBL Program

A quick overview of the Lawrence Berkeley Laboratory at this stage of its 48-year history is provided by Fig. 1-2 and Table 1-1 which give LBL budget figures for FY 1979 organized by DOE Assistant Secretary.

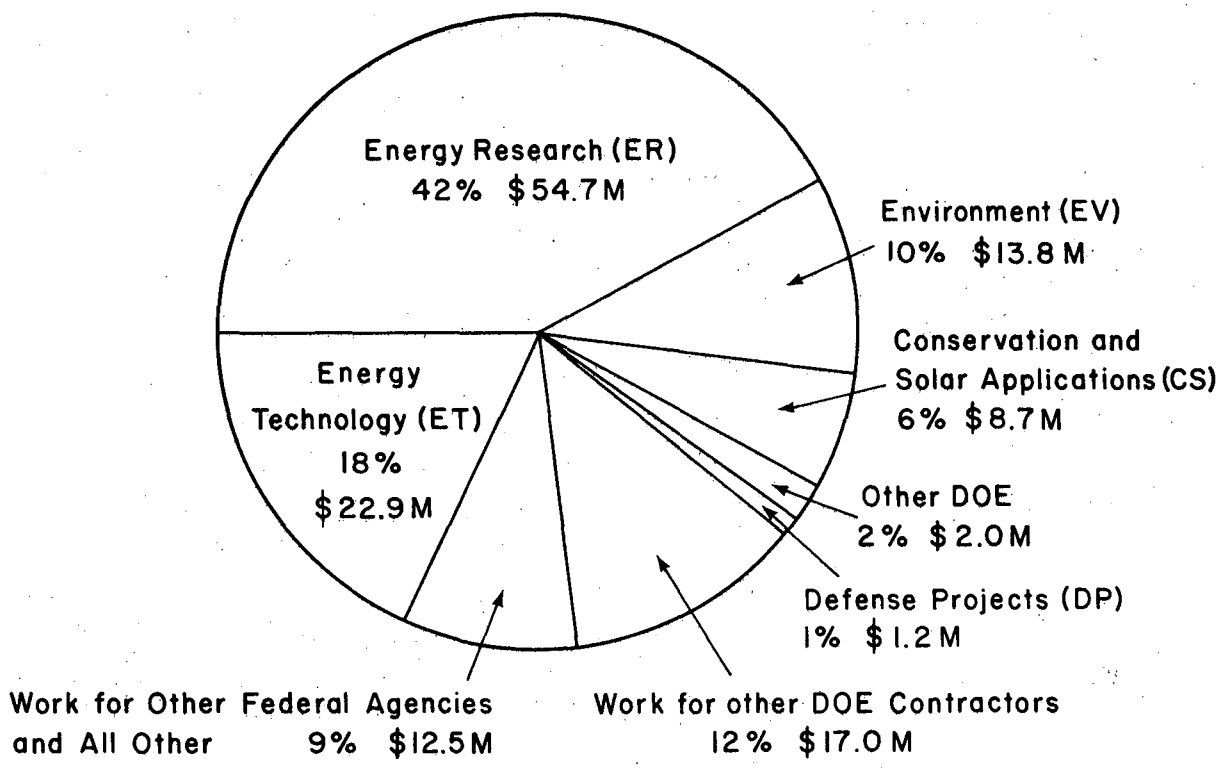

Fig. 1-2. Distribution of LBL Funding for FY 1979 by Assistant Secretary. Dollar figures include Operating (BO) and Capital Equipment (BA).

Table 1-1. Laboratory DOE Funding for FY 1979.[a] (continued)

DOE Asst. Secty.	Program	FY 1979 ($ millions)	Total ($ millions)	% of Total
ER	Nuclear Sciences	2.1		
	Materials Sciences	4.9		
	Chemical Sciences[b]	4.9		
	Engineering, Math., Geosciences	1.6		
	Bio-energy Conversion/ Conservation	0.6		
	High Energy Physics	10.1		
	Nuclear Physics	16.2		
			40.4	47
EV	Environmental Research and Development	6.5		
	Life Sciences Research and Biomedical Applications	6.0		
			12.5	14
ET	Coal	0.8		
	Petroleum	0.5		
	Solar	1.5		
	Geothermal	8.1		
	Magnetic Fusion	8.7		
	Energy Conservation and Storage	1.6		
	Other (Isotope Separation/ Biomass)	0.9		
			22.1	26
CS	Solar	2.0		
	Residential/Commercial Systems	6.0		
	Other (Industrial/Transport)	0.3		
			8.3	10
EIA	Data Validation	1.6		
			1.6	2
DP	Inertial Confinement	1.1		
			1.1	1
IR	Information Services	0.4		
			0.4	1
		TOTAL	86.4	

[a]This is a summary table of Operations Budget only, excluding equipment and construction. Complete data appear in the Appendices.

[b]Includes National Resource for Computation in Chemistry.

One unmistakable feature is that LBL is a major contributor to physical science research including heavy-ion nuclear physics, nuclear chemistry, high energy physics, materials sciences, physical and inorganic chemistry, engineering research and mathematics. These activities were supported at a sum total of $40.4 M in FY 1979. Objectives, special characteristics, and future directions of these programs are summarized in the succeeding sections of this section describing the activities of four divisions of LBL; namely, the Nuclear Science Division, the Accelerator and Fusion Research Division, the Physics, Computer Sciences and Mathematics Division, and the Materials and Molecular Research Division.

Building on its tradition of leadership in nuclear and high energy physics, LBL has become the world's foremost heavy-ion laboratory, with an outstanding trio of heavy-ion accelerators, the 88-Inch Cyclotron, the SuperHILAC, and the Bevatron/Bevalac. Jointly with Stanford Linear Accelerator Center, the Laboratory has constructed PEP, which is scheduled for completion in this calendar year. This positron-electron accelerator is the nation's newest high-energy physics facility. The continuation of this development is seen in the conception of VENUS as an advanced relativistic heavy ion synchrotron and storage ring for the future of nuclear physics.

The LBL computer center is among the nation's best, particularly because of its software system, designed to assist the user whatever his scientific, engineering or other needs and wherever his location in LBL or in the nation. The central CDC 7600 computer is assisted by a CDC 6600, CDC 6400 and mass storage system, plus a battery of peripheral equipment. LBL maintains important data bases for energy research and technology.

LBL is also an important contributor to biological and environmental research, health-effects research on biological systems, life-sciences research and biomedical applications. LBL is a major center for the study of nature's photosynthesis processes and the possible exploitation of this information for practical energy applications in synthetic or modified natural systems. The Laboratory is contributing significantly to the understanding of basic chemical and biological changes in the passage of pollutants from the source to the biosphere, and of the effects of these pollutants on ecological and animal systems. LBL is a major institution for development of high performance instrumentation for study of energy-related pollutants. The LBL activities supported by the DOE Assistant Secretary for Environment total $12.5 M in FY 1979. LBL conducted these activities in its Biology and Medicine Division, its Chemical Biodynamics Division, and its Energy and Environment Division.

The Laboratory carries programs of applied research coupled to specific energy technologies, particularly in areas where the applications rest on a sophisticated understanding of the frontiers of the supporting science. An example is LBL's contributions to fusion research. As the result of the Laboratory's development of neutral beam injector systems for devices exploring the magnetic confinement and heating

of plasmas, LBL has been given responsibility for multimillion dollar engineering developments coupled to DOE's Tokamak and Doublet III projects. FY 1979 total operating funding from DOE's Office of Magnetic Fusion Energy was $8.7 M. Furthermore, LBL is a participant in the exploration of a new concept of inertial fusion employing accelerated heavy nuclear particles. The operating amount for heavy-ion inertial fusion, which in the future will be provided by the Assistant Secretary for Defense Programs, was $1.1 M, but, depending on successful development and policy, this could increase substantially at some budget year past 1979. (LBL activities in fusion energy are described below under the Accelerator and Fusion Research Division and the Engineering and Technical Services Division.)

A second major area of applied research is in nuclear waste management and geothermal energy. These activities are carried out by the LBL Earth Sciences Division under the direction of recognized authorities in geophysics, geochemistry, rock mechanics, hydrogeology and engineering. LBL specializes in hydrothermal resource definition and assessment including surveys, field testing and reservoir modeling. It is involved in unique underground experiments to assess nonsalt crystalline media for burial of nuclear waste. FY 1979 operating funding for geothermal research was $8.1 M, and for the Nuclear Waste Storage Program $5.2 M. (Details appear under Earth Sciences Division below.)

The Laboratory is making significant contributions to the DOE Conservation and Solar Energy programs, with LBL activities in FY 1979 totalling $8.3 M. LBL's innovative research in energy conservation in buildings is pointing the way to cost-effective investments in energy efficiency, with paybacks far exceeding those from similar investments in new energy supply. The Laboratory's extensive capacity for computer simulation and modeling has been applied to the development of DOE-2, a computer model that has been selected by the Department of Energy for establishing the energy budgets of a range of building designs. The imaginative approach of LBL physicists has also been applied to long neglected energy-engineering problems of buildings, windows, and lighting. These programs have the potential to have a substantial impact on the national effort to reduce the growth rate of its energy consumption. (These programs are discussed below under Energy and Environment Division.)

Planning for Future Programs

The Lawrence Berkeley Laboratory will continue to focus its intellectual and technical resources on research related to the nation's energy future. It will maintain a program balance about equally divided between basic physical, biological and engineering research and applied science and technology development. The Laboratory will work increasingly at the interface between the basic and applied sciences so as to make the fullest application of new ideas and results emanating from its basic research. Crucial new directions that must be taken tomorrow in the development of economic energy technologies, for the long-term future may well depend upon having the best possible input today from the basic sciences.

The future mix of LBL programs will evolve as the result of a constant process of weighing and sifting among many interesting new avenues of research proposed by Laboratory staff. The Laboratory will present to the funding agency for review and possible support only those research ideas that meet, or show good potential to meet, the following three criteria:

1. The research is of significant importance to the nation, either in contributing to the solution of short-to-intermediate-term energy-related problems or to the establishment of a fundamental scientific base for long-term energy technology development;

2. The Laboratory can make a highly significant, or unique, contribution to the subject;

3. The research is of the high calibre appropriate to a laboratory based on the campus of a major university, with the participation of distinguished faculty members and internationally recognized scientists and engineers.

Because of the great diversity of the Laboratory's program, the planning and review process is highly decentralized. Each division has an internal planning mechanism, often the senior staff committee, as well as an external review committee that meets once per year to advise the division head and LBL Director on progress, quality and directions of the division's program.

At the Laboratory management level, several mechanisms of program planning and review operate. At the time of the annual budget submission, all programs are reviewed by the Laboratory Associate Directors and ultimately by the Director. This provides a periodic opportunity to assess the program's overall thrust and balance, as well as to monitor growth. The Associate Directors also meet regularly throughout the year and assist the Director to develop policy and specific requirements for manpower and space, as well as for technical support including computers, engineering and shop facilities.

The Director makes use of an appointed Scientific Program Council consisting of active scientists and engineers from throughout the Laboratory. The Council members, who are neither Associate Directors nor representatives of divisions, render critical judgments of ongoing and proposed Laboratory programs. The Laboratory also has an external review committee which advises the President of the University on the status of the Laboratory and also provides guidance to the Laboratory Director on general Laboratory goals and directions.

At present, the Laboratory is contributing substantively to the Department of Energy's programs in geothermal energy, fusion energy, and energy conservation, and it expects to maintain major applied technology programs in these areas as well as to develop new basic research related to them. Responding to national need, the Laboratory has recently been developing a comprehensive program in nuclear waste management, and it

expects this to continue in the future. In the crucial area of fossil energy research, the Laboratory has great potential to contribute to the Department's mission by developing new applied programs out of the LBL basic research on catalysis, surface science, combustion, and chemical engineering. This capability in fossil fuels is underutilized at present.

LBL has unique capabilities to assist DOE in analysis and assessment studies and data system development because of its expertise in information systems, its powerful computer facilities, and its ready access to the intellectual talents of the University of California faculty in economics, social sciences, systems engineering and policy analysis. This capability is being used in a variety of data compilation, analysis, and modeling projects, and we anticipate further commitments of this type.

We envisage a continuing partnership of LBL with the Berkeley faculty. In combination with LBL's capable engineers and scientists, this partnership has given the Laboratory its present programmatic excellence and breadth and, as in the past, will continue to provide an unusual degree of flexibility to investigate important new problems and research possibilities by calling upon appropriate expertise residing in the Berkeley faculty. By its heavy involvement of faculty, students, and post-doctoral fellows, LBL expects to continue to be a major supplier of trained personnel for the needs of industry, government, and other laboratories and universities.

The nation's energy problem cannot be solved quickly or easily. A substantial commitment of resources for research will be required, but this cost will be small in comparison with the total national investment required to commercialize the new energy supply and conservation technologies. The Laboratory has traditionally responded to requests from government for assistance in research, and we believe that it will be even more in the national interest for us to continue to do so in the future. Such response may necessitate modest growth in manpower and funding.

The question of the character of the Laboratory is very much in the thinking of LBL's leaders as they plan for the future. The Laboratory is in a mature state and does not seek growth for its own sake. Most particularly, LBL seeks to maintain its tradition of high-quality science and engineering. Although development of new programs will undoubtedly continue to occur as the Laboratory responds to agency requests, both this response and the Laboratory's own initiation of new programs will be selective, depending on their appropriateness to LBL, as determined by the three above-mentioned criteria, and on support from the Department of Energy.

DIVISIONAL OVERVIEWS

ACCELERATOR AND FUSION RESEARCH DIVISION

Objectives

The objectives of this Division are to operate and develop accelerators to advance nuclear and particle physics and biomedical science; to conduct intensive programs of magnetic fusion energy and inertial confinement fusion research; and to develop applications of accelerators in other sciences.

Special Characteristics

The Division derives its unique identity from the history of the laboratory itself, as Ernest Lawrence and his colleagues created the increasingly sophisticated accelerators and performed the research that these machines made possible. The accelerators became more complex, and essential specialization took place. But the symbiotic relationship between designers and experimenters has continued, as it must to support current research and nurture the ideas that will emerge as future programs. As the physics and the facilities have flourished, the association has extended to such areas as high energy physics, nuclear physics, biomedical science, magnetic and inertial confinement fusion, and the underlying theory of accelerators and plasmas. In a parallel effort, the Division pursues the technology of related components such as ion sources, superconducting magnets, beam cooling and vacuum systems. Leadership in these subjects has led to collaborations with other laboratories: SLAC, FNAL, LLL and GSI (West Germany) are among the institutions with which we have recently undertaken joint efforts.

Program Planning and Guidance

Within the broad area of accelerator and fusion technology, the specific programs pursued by the Division are selected and guided by a continuing process of peer review, consisting of workshops, user and advisory committee meetings, and discussions with agency and program managers. Accelerator operation requires close contact with users to insure that their needs are met. An annual review by a panel of national specialists provides guidance to the Division management and the Laboratory Director regarding the success of the Division's course. Priorities for new programs are ultimately established by DOE program managers with the advice of ad-hoc and general committees representative of the scientific community.

The selection of projects in fusion energy involves many of the elements just described and is also characterized by very strong interaction with the DOE Office of Fusion Energy. This office is advised by the Fusion Power Coordinating Committee, whose membership includes the directors of the major fusion research programs in the United States.

Technical Goals and Future Directions

PEP. The Positron-Electron colliding beam Project, now under construction, will be the nation's most advanced high-energy physics facility. The project is a joint LBL effort with SLAC. Major construction completion is expected near the end of 1979, after which attention will be directed toward achieving the ultimate goals of energy and intensity (luminosity), and insuring operational reliability together with modifications and improvements motivated by experimental requirements.

Advanced Accelerator R&D. Research and development leading to new concepts for future accelerators and accelerator systems is a primary effort. This includes studies for advanced colliding beam systems and major improvements for PEP, such as the provision for electron-proton collisions or for substantial energy upgrading of the electron-positron system. This research activity also involves studies and experiments that are part of the advancement of future accelerator technology. Included are programs for the development of high-field superconducting magnets and stochastic beam cooling. These efforts in advanced accelerator technology are guided by a strong staff in accelerator theory.

SuperHILAC and Bevalac. LBL operates the SuperHILAC, the Bevatron, and their combination the Bevalac, as National Accelerator Facilities, open to any qualified user. These accelerators provide beams of various heavy particles over a broad range of energies for nuclear and particle physics, cosmic-ray physics, biomedical research, radiation therapy, and radiography. Slightly over half of the available research time is utilized by visiting scientists who are also given extensive experimental support. A continuing program of operational research and development is pursued to provide new ion species as needed, new modes of beam delivery as experiments become more exacting, and greater reliability as the entire operation becomes more complex. The major development in progress is the uranium beam capability, which will be accomplished at both accelerators in FY 1981. The Division also provides support for development efforts at the 88-Inch Cyclotron.

VENUS. The future needs of the nuclear physics community are addressed in the new VENUS (Variable Energy Nuclear Synchrotron) dual ring superconducting accelerator and storage ring concept (see the New Initiatives section). After several years of discussion on the merits of relativistic heavy ions and the relevant accelerator design, the VENUS concept is now being reviewed by nuclear physicists and NUSAC. VENUS will offer beams of all ions through uranium at energies from 40 MeV/A to 20 GeV/A (and protons to 50 GeV) in the fixed target mode and from 2 on 2 to 20 on 20 Gev/A for colliding beam interactions. The site of the 230 meter diameter VENUS rings circles beneath the SuperHILAC and the Bevalac, with the former serving as injector. VENUS could be operating by 1987.

Heavy Ion Accelerators for Fusion. The study and development of heavy-ion accelerator systems for inertial confinement fusion is an increasingly important activity. Comparative studies of rf linac and

induction linac systems are being made by LBL, ANL and BNL. As the only one of these laboratories with experience with linear induction accelerators, we have been charged by the Office of Inertial Fusion to place major emphasis on examining the potential of the latter system.

Linear induction accelerators appear to have significant advantages over rf linacs for inertial confinement fusion. They are single pass systems, thus minimizing collisional beam losses; the beam is continuously bunched while being accelerated, obviating the need for a separate buncher; indeed, the accelerator structure is better matched than any other to the requirement of very high current, short pulses. We are pursuing this program with increasing vigor. A close working relationship with accelerator and fusion activities at the Lawrence Livermore Laboratory is maintained.

Magnetic Fusion. Magnetic fusion energy research is conducted in two distinct areas. The first is a large program in neutral-beam injection research and development, carried on in collaboration with LLL, and the second is a smaller effort directed toward alternative confinement concepts.

The neutral-beam injectors, developed largely at LBL, are designed to pump fuel and energy into magnetically confined plasmas in mirror machines and tokamaks. Two major projects based on this development are the neutral-beam injectors for DOE's TFTR and Doublet III experimental fusion devices; both injector projects are managed by LBL's Engineering and Technical Services Division. The neutral-beam injector development program, which also supports the Livermore MFTF experiment, is likely to remain constant in size, but with emphasis shifting to systems of higher energy, necessitating neutral beams from negative ions, continuous operation, and higher efficiency, with direct recovery of ion energy. This development program is backed by a smaller basic research effort to supply information about atomic physics (with experiments partly conducted at the SuperHILAC), and more fundamental ion-source plasma physics. This activity will contribute to the goal of improved species control in general and the efficient production of neutral beams from negative ions in particular.

The second principal area of study is an exploratory investigation of alternative magnetic confinement concepts that could lead to practical fusion reactors smaller or simpler than tokamaks. This combination presents a good balance between high-priority, relatively low-risk support effort for the mainline magnetic fusion program and challenging high-risk exploratory fusion-oriented plasma physics research.

BIOLOGY AND MEDICINE DIVISION

Objectives

The programs of this Division center around basic biomedical research, investigations of health effects of energy production, and

application of large accelerators to medical diagnostics and therapy. Work in nuclear medicine began in the 1930s when Ernest Lawrence brought a biomedical group into the Laboratory to exploit the new sciences emanating from the development of the cyclotron.

Special Characteristics

The major strengths of the Division arise from cross-disciplinary interactions of the physical sciences for the development of biology and the medical sciences, with close collaborations between biomedical scientists and accelerator physicists, mathematicians, computer scientists, and engineers.

Program Planning and Guidance

The formulation of the current program and plans for future work are a function of both the special capabilities of the Division and its interaction with DOE's Biomedical and Environmental program management. The Division management and its Advisory Committee maintain a continuing review of ongoing and planned activities to ensure that the Division's resources are employed in the most effective manner possible with respect to program objectives.

Technical Goals and Future Directions

Biomedical and Environmental Research. This research is related to adverse effects resulting from pollutants arising from energy generation. It deals primarily with clinical and epidemiological studies in humans. The Division made the decision several years ago, as the agency's new research strategies were being developed, to bring to bear its special resources and close working relationships with the public health community in Berkeley, plus a significant staff of physicians, in the development of several studies of the epidemiology of disease related to energy supply technologies. Two that are presently moving ahead are the examination of the health status of workers in the petroleum and petrochemical industries (extraction, refining and transportation), and a retrospective study of the health effects of exposure to high magnetic fields, as might be incurred in fusion power plants. This latter research presently involves populations of accelerator laboratories with large magnets over the past 30 years.

Looking to the future, the Biology and Medicine Division is exploring ways in which it can more effectively bring to bear the special low-level analytic capabilities of the Laboratory for analysis of body burdens of environmental pollutants, particularly hydrocarbons. These skills presently exist at LBL and should be applied to the pressing problem of workplace exposure to environmental pollutants. The Division will continue to explore potential needs for epidemiological studies that it can undertake. The availability at LBL of census tract information, advanced data management systems, and physicians/epidemiologists would make these studies particularly effective.

Health-Effects Research on Biological Systems. To evaluate systems damage in man from exposure to various toxic substances arising from energy sources (both chemicals and radiation) the Division is studying their effects at the cellular and whole animal level. These studies emphasize areas for which LBL has been given special responsibility, i.e., magnetic fields, space radiation, and transuranic element toxicology, but such studies are broadened to include other applications when the Laboratory has special skills and backgrounds that are not generally available elsewhere.

The decision was made early in the redirection of the older AEC programs that it would be inappropriate for LBL to engage in extensive toxicology programs that would commit the Laboratory to the operation of large scale animal facilities. For this reason the Division's studies are designed for highly targeted analysis of the effects of toxic substances on functional physiological systems for which it has special skills. These special areas of expertise include the blood forming organs, the endocrine system, the cardio-respiratory system, and the immune system. These research areas are now well established and productive. Significant expansion of the work on chemical pollutants and transuranic element toxicology is not planned.

Two areas of program development for the immediate future are research on effects of magnetic fields and cosmic ray environments. In both cases the availability of special resources dictates this redirection. Magnetic field research is important to permit the setting of exposure criteria for workers in the magnetic-confinement fusion and MHD technologies. The availability of a number of large, expensive magnets at LBL has made the development of the program at this location obvious. The space radiation program interest is generated by the development of the Space Power Satellite, which will expose a number of assembly workers to substantial doses of cosmic radiation. The only terrestrial resource capable of producing equivalent radiations is the LBL Bevalac; this dictates conducting the research at LBL. In order to carry out these two research programs the Division has terminated several others and reassigned space and personnel.

Other agencies have a significant interest and involvement in the space radiation program, NASA because of its obvious interest in space radiation, and NIH/NCI for its interest in accelerated heavy ions for the treatment of cancer. Because of the commonality of interests between DOE and these other sponsors LBL has sought and obtained support from the interested agencies, with the agreement of the Assistant Secretary for Environment.

Life Sciences Research and Biomedical Applications: General Life Sciences. This research program is based on the application of advanced techniques and knowledge from the natural sciences in exploring the important problems of biology that relate to the DOE mission. Among the LBL life sciences research projects are studies on the development of blood cells, membrane responses to toxic agents, the structure and function of DNA as it relates to cell development and carcinogenesis,

and the genetics of yeast as a test system for evaluation of the mutagenic and carcinogenic potential of toxic agents.

The Division's general strategy for development of the life sciences research program is the creation of a series of related projects centered around the biochemical and biophysical properties of the cell as a substrate for the action of toxic materials. A diversified basic sciences program has been successfully redirected to meet this general goal. The Division is attempting to find application for the special skills and facilities available at the Laboratory, and to use these as the central planning focus for the program. These skills are the interaction of the physical, chemical and mathematical talents within the staff and the University faculty. Among the Division's special competences not commonly available are high-voltage electron microscopy and single cell biochemical analysis.

The Division has engaged in an aggressive program of seeking support from alternate agencies, particularly NIH but also NASA and NSF, to expand the resources available to the DOE missions, and to broaden the base in certain of its special skills. Thus it has been possible to expand support in the areas of pathology and molecular biology.

Biomedical Applications. Medical applications of nuclear technology continue to be a significant part of the Laboratory program. Increasing emphasis is being placed on new techniques with potential application to diagnosis and treatment of human disease arising from exposure to environmental pollutants. Primarily under study are cancer and cardiopulmonary disease.

The program on human applications of nuclear technology is not expanding. The Division will, however, continue to exploit new developments of special instrumentation and techniques that grow out of high energy physics and nuclear chemistry. These find almost immediate applications in some aspect of diagnosis or treatment of disease. Beams of energetic heavy ions (e.g., carbon, neon, argon) appear to have important advantages in radiation therapy because of superior dose localization and high ionization. The Laboratory has a large program on exploring diagnostic and therapeutic applications of the radiations produced at the Bevalac. This is the fourth year of a program for the controlled clinical testing of heavy-ion radiation in the treatment of cancer; work that is funded by both NIH and DOE. Both the 184-Inch Cyclotron and the Bevalac are being used to irradiate patients. It is expected that this program will continue at about its present level for another 5-10 years.

The Research Medicine Clinic plans to continue its long-term followup of patients exposed to or treated with ionizing radiation, (internally or externally). These patients are a large and valuable resource to detect and measure the late effects of radiation on human beings.

CHEMICAL BIODYNAMICS DIVISION

Objectives

The Chemical Biodynamics Division conducts basic research on the dynamics of living cells, on the interaction of radiant energy with organic matter, and on the recognition processes between biomolecules. Many aspects of this basic research relate to problems of environmental and health effects of fossil fuel combustion and to solar energy conversion.

Special Characteristics

The Division started 33 years ago as the Bio-organic Chemistry Group, with special interests in the study of organic reaction mechanisms and the mechanism of photosynthesis. From the outset, such work involved extensive interdisciplinary collaboration. Today this is fostered by the Division's relatively small size (about 100 persons), seminars with a tradition of unfettered discussion and strong effort to communicate across disciplinary lines, and most importantly a cooperative planning and administration process. The availability of the engineering, computing, and other service facilities of LBL has made possible the development and application of sophisticated physical techniques to analysis of cellular mechanisms. Biologists obtain help from biophysicists and chemists in developing fluorescent probes of membrane differences between normal and malignant cells and then measuring and quantifying small differences in fluorescence of treated cells. Biophysicists get help from biochemists in isolating and purifying complex restriction and metalloenzymes to be used in studies involving x-ray crystallography and extended x-ray absorption spectra (EXAFS), both of which will lead to a better understanding of the function of such proteins at the molecular level.

The location of the Laboratory of Chemical Biodynamics (LCB) on the Berkeley campus enhances the Division's interactions with several University departments--Chemistry primarily, and also Biochemistry, Physics, Molecular Biology, Botany, Plant Physiology, and Psychology. In addition, students from several graduate groups such as Biophysics and Comparative Biochemistry receive their training in LCB. As a research resource to many biologists and chemists on the Berkeley campus, the Division provides both an interdisciplinary atmosphere and a range of instrumentation and techniques beyond the capabilities of individual departments.

Program Planning and Guidance

Research plans in the Biodynamics Division are made by the Division Head and senior staff based on their areas of research experience, the capabilities of the Division in personnel, equipment, and budget, and the DOE mission. Scientific input and advice are rendered by University colleagues and students, the Laboratory Director and DOE staff.

Research programs and progress are reviewed by the senior staff and many decisions affecting the direction and implementation of the program are made at the weekly senior staff meetings. These decisions determine the support level of each research project or area, and are made in accordance with both the perceived merit of the research and the available programmatic funding. Weekly seminars by individual scientists before the entire Division staff and written progress reports prepared four times a year provide further opportunities for evaluation of research. Finally, publication in journals and annual progress reports to DOE document scientific progress.

Technical Goals and Future Directions

The research programs of the Division presently center on chemical carcinogenesis and mutagenesis, fuels and chemicals from biomass, and photochemical solar energy conversion. The work on light energy capture and conversion to stored chemical or electrical energy in artificial systems stems from many years of interest in the mechanisms of photosynthesis and from studies of the interaction of radiation with organic matter. Experience with plant photosynthesis and biosynthesis forms the basis for the program on the growth of plants as sources of renewable fuels and chemicals. Techniques developed to study metabolic regulation are being used to determine the control of metabolic pathways to hydrocarbon-like compounds in plants. The mechanisms of effects of carcinogens such as benzo(a)pyrene from fossil fuel combustion are being determined as a part of the research on chemical carcinogenesis.

Support for the research programs of LCB is provided by the Life Sciences, Environment, Chemical Sciences, and Fuels from Biomass programs of DOE. The unique capability for interdisciplinary research on cellular mechanisms of energy and information transfer can be applied to a variety of important problems in basic research in ways beyond the capabilities of most research organizations. At the same time, specific problems related to DOE's interest in alternative energy sources and effects of environmental pollutants can be identified and attacked when the capabilities of LCB are applicable. This established capability can be brought to bear on new, unforeseen problems of cellular biology, biosynthesis and related chemical and physical areas as they arise.

A 1979 outside review of LCB has recommended continuance of this interdisciplinary program. It is expected that the present research philosophy of the Laboratory will be continued with a strong emphasis on basic research in biochemistry and biophysics and related problems in organic chemistry. Some programs appear likely to grow because they combine rigorous basic scientific research with applicability to the concerns of DOE. These are: chemical carcinogenesis and mutagenesis and related animal cell work in molecular biology; solar energy conversion based on artificial systems; biophysical research seeking answers to the basic questions of energy capture and conversion; structure and function of membranes and proteins; use of green plants as sources of renewable chemicals and fuels, with associated basic research on plant genetics and regulation of plant metabolism; and the development of newer methods to incorporate tritium into needed tracer compounds.

EARTH SCIENCES DIVISION

Objectives

The Earth Sciences Division conducts fundamental and developmental research in geotechnical areas relevant to DOE programs. The objective is to provide a basic understanding of geological processes and to apply this knowledge in the resolution of specific scientific and engineering problems. Program applications occur in geothermal energy, fossil resources, nuclear waste isolation, energy storage in aquifers and environmental issues such as induced seismicity and subsidence.

Special Characteristics

The Division's unique strength and focus are derived from the eclectic grouping of UC and LBL geoscientists supported by extensive capabilities in computation, instrumentation and equipment fabrications. Research experience and capabilities are especially strong in the disciplines of geochemistry, geophysics, hydrogeology, geomechanics and geology. Within these disciplines, researchers have specialized in the basic physical and chemical processes occurring in the deep crustal regime. The geological region at multikilometer depths is generally not well understood and man's increasing interest therein is generating significant technical questions and problems. The Earth Sciences Division is uniquely qualified for this research focus based on the strong interdisciplinary team of researchers and specialized LBL support capabilities designed for comprehensive laboratory, field and computational projects.

Program Planning and Guidance

Management and direction of research activities are currently carried out by group leaders and principal investigators in consultation with the Division Head. On-going projects are discussed, specific problems reviewed and new directions informally proposed and evaluated. An advisory committee composed of representatives from universities, the US Geological Survey, and the geotechnical industries, annually reviews the content and quality of Division programs. The management of significant efforts in laboratory or field investigations is accomplished with project management teams composed of a principal scientist and an engineering manager. Such teams have successfully demonstrated attainment of the research goals while satisfying program constraints on cost and schedule.

Technical Goals and Future Directions

The Division has a strong multidisciplinary program in geothermal energy development. Under DOE support it has developed solutions to some of the scientific and engineering problems associated with understanding hydrothermal reservoir systems. These constitute the main technical uncertainty inhibiting near-term commitment by electric utilities and investment firms to commercial-scale hydrothermal exploitation. Economic forecasts and investment decisions cannot now confidently be made because of: 1) imprecise estimates of total reservoir size and

energy content; 2) unproven methods of planning for field exploitation; 3) uncertain characteristics of reservoir response to production and reinjection; 4) many brine chemistry problems of scaling, precipitation, water compatibility, and reservoir plugging; and 5) possible environmental hazards, such as subsidence and groundwater contamination.

LBL has consistently focused on the technical issues thought to be most crucial by both the private and public geothermal sectors. These projects are often done in cooperation with other DOE laboratories, private industry, and other government agencies. Specific strengths have been developed in 1) use and evaluation of surface geophysics of all types for the definition of a geothermal resource; 2) interpretation of borehole geophysical surveys for the evaluation of porosity, temperature, and permeability; 3) hydrothermal well testing, both with regard to carrying out such tests and in the analysis of test data for information about reservoir parameters; 4) geochemical techniques, particularly applied to precipitation of dissolved solids that may act as plugging agents upon reinjection, causing scaling in piping systems; 5) reservoir modeling, particularly to forecast rates of future performance, ultimate recoveries from a resource, and detrimental environmental effects; and 6) geology, in particular to draw together diverse information leading to conclusions about the size of a resource and its possible productive capacity. Additionally, LBL engineers have undertaken a comprehensive effort to develop technologies to improve the operation and efficiency of geothermal power conversion systems. This effort includes system modeling activities, binary power conversion projects and plant component development programs.

Because of the close proximity of LBL and the UC Berkeley campus, and the tradition of joint programs, the fundamental geosciences projects are scientifically oriented and rigorous. All address problems that must be solved before real progress can be made on the engineering or technological front. Examples include: 1) development of a theory to describe the thermodynamic properties of strong mixed electrolytes at high temperatures and pressures; 2) measurement of the physical and transport properties of silicate melts; 3) experimental and theoretical studies to predict homogeneous nucleation of silica from supersaturated solutions; 4) kinetics of mineral dissolution in water at elevated temperatures; 5) theoretical and experimental study of surface adsorption on minerals in aqueous systems; 6) precise measurement of man-made seismic waves in the earth's crust; 7) high precision measurement of isotope ratios of heavy metals; 8) reservoir modeling studies of subterranean aquifers using the most advanced computer codes available; and 9) development of chemical processes for enhancing petroleum resource recoveries.

Based similarly on the complementary LBL/UC expertise and the available laboratory facilities, a program in marine geology and oceanology has been established in support of DOE's Ocean Thermal Energy project. This effort represents many researchers from the marine sciences and is presently working on all prospective OTEC sites.

The development of a national strategy for geological storage of nuclear wastes will require answers to geotechnical questions that must await significant scientific advances in geosciences (i.e., the characterization of rock-water-chemical systems and their response to induced chemical, mechanical, and thermal perturbations). In 1977, LBL's Earth Sciences Division began assisting DOE in assessing the potential of geologic media other than salt for the burial of nuclear waste. As in the geothermal program, it has followed the concept of a two-level program with both R&D activities aimed at near-term applications and fundamental research to develop the scientific knowledge needed for long-term success. A major component of this program is the collaborative LBL effort with Swedish scientists to study the properties of a large granitic rock mass for waste disposal (Stripa mine, Sweden). The project represents the first effort to assess comprehensively the suitability of a non-salt rock type for nuclear waste isolation. Scientists from several nations are participating in the research work, and knowledge gained at Stripa is already being applied in other repository projects.

The nuclear waste storage project will utilize research teams of scientists and engineers from various fields, and include: 1) assessment of the safety of waste storage with regard to underground transport of radionuclides; 2) analysis of thermal loading effects on granitic and basaltic rock masses; 3) investigation of fluid flow in tight-fractured systems; 4) development of instrumentation to evaluate potential repository sites and to monitor operational repositories; 5) measurement of material properties and fracture permeability for selected rock samples; and 6) development of analytical techniques to predict and measure nuclide movement.

EMPLOYEE AND INFORMATION SERVICES DIVISION

Objectives

The principal function of the Employee and Information Services Division is to provide certain administrative and support services to the Laboratory. In addition, a research program in the field of information science has been carried on in the Division for a number of years.

Special Characteristics

Information science emerged as a discipline after World War II as a result of the extraordinary growth of the technical literature which required new methods for its satisfactory dissemination, storage, and retrieval. This Division has brought together information scientists, data analysts, and computer specialists into a combination especially well suited to do information research. The multidisciplinary nature of the Laboratory and its large computer facility provide valuable stimulation and support.

Program Planning and Guidance

Because the information research program is small, planning and guidance are handled simply by the Division Head and the principal investigators. Administration matters are treated as a part of the Division's other activities.

Technical Goals and Future Directions

The Information and Data Analysis Department is responsible for the development and coordination of specialized information centers in diverse scientific and technical subjects. This department oversees the geothermal information project (GRID) and the Information Methodology Research Project, and provides technical support in information handling to other information projects.

The Information Research Group does research in the improvement of computerized information retrieval techniques, using large on-line bibliographic databases, and applies the results to a variety of specialized information services for the LBL research staff and outside users.

ENERGY AND ENVIRONMENT DIVISION

Objectives

The Energy and Environment Division conducts research in six principal areas 1) Fossil Fuel and Synthetic Fuel Processing, 2) Conservation through Energy Efficient Buildings, 3) Solar Energy, 4) Energy Analysis, 5) Electrochemical Battery Development and Environmental Impact, and 6) Mitigation of Energy Technologies. The objective of the Division is to carry out this research in energy production, energy conversion, energy end use, and environmental mitigation by combining applied science, engineering, and analysis with a strong technical component, supplemented by social science expertise.

Special Characteristics

The Division's unique character is derived from both its interdisciplinary approach and composition. Fundamental physics and chemistry, modern analytical techniques, analysis of engineering and building practices as well as socioeconomic factors are brought to focus on central issues relevant to the nation's energy future. The expertise required for this multifaceted approach is drawn from a large and varied staff, supplemented by over forty leading faculty members from UC Berkeley holding joint appointments. Although the Division's research is directed to specific programmatic goals, its emphasis is on research rather than development, as it brings to bear on these problems the same type of scholarship and scientific process traditionally found at the Berkeley Laboratory.

The interdisciplinary nature of the Division is included in its association with the University. The Division has about 100 graduate students, from some 15 different UC Berkeley departments, who pursue doctoral thesis work in subjects as varied as marine science, economics, urban planning, and chemical engineering. The programmatic effort is planned around the student-faculty intertie, whose maintenance and enhancement are important elements of our work. Especially good access to the wide range of campus disciplines relevant to the Division's work is provided by its close ties with the campus's Energy and Resources group (ERG); ERG's three core faculty members are all active in Division projects, as are many of the Group's 50 additional affiliated faculty (spanning 25 departments from Physics and Biology to Sociology and Law), and half of its 40 graduate students. Other examples of such faculty-laboratory cooperation are with the Department of Mechanical Engineering in combustion science, and the Department of Chemical Engineering in Chemical Process R&D. Eighteen faculty members of these departments are either principal or co-principal investigators on various research projects involving about twenty-five graduate students.

Program Planning and Guidance

Planning and guidance are under the direction of the Division Head, advised by a group of senior program leaders. Consideration of new initiatives and significant program alterations is undertaken by this group, to ensure that long-range program emphases are consonant with the Division's goals. An outside Review Committee annually judges the Division as a whole, and each program area also has its own review process to ensure quality and relevance of research.

Staffing policy is governed partially by the long-standing LBL role of providing post-doctoral training. The Division maintains, besides its permanent staff, a large number of temporary positions held by new PhD's on short appointments, during which they obtain important training as they contribute to the technical programs. In FY 1979, the Division had about 50 such staff members. An advantage of this type of arrangement is that, whenever an appointee departs upon completion of his term, there is flexibility to use that position for some other purpose. This flexible staff situation has been a factor in the Division's ability to respond to changes in national research needs.

Technical Goals and Future Directions

The Division has achieved productive relationships with many divisions and offices in DOE, under six different Assistant Secretaries (ER, EV, ET, IR, CS, and EIA). This breadth of contact has made the Energy and Environment Division cognizant of a wide range of current energy issues, and has allowed the work under each sponsor to be more relevant to the larger mission and role of DOE.

The following descriptions summarize the different programs within the Energy and Environment Division:

The Fossil Fuels and Synthetic Fuels Processing Program centers around the utilization of chemical-process principles, thermodynamics, transport, reaction kinetics, and separations. Major areas of emphasis are biochemical engineering, as applied to enzymatic conversion of cellulose to alcohol, and direct liquefaction processes for coal and biomass. Projects related to the mitigation of environmental problems involve removal of both pyritic and organic sulfur from coal before combustion, and processing of foul condensate waters from coal conversion, shale retorting and biomass pyrolysis.

Through this Division, the Laboratory and the San Francisco Operations Office of the DOE are assuming the technical and financial management responsibilities for the Applied Battery and Electrochemical Research Project. This project provides the applied research base which supports all of the Electrochemical Systems missions in the Energy Storage Systems Division of the Department of Energy.

The Energy Analysis Program performs multifaceted studies of energy technologies, national energy plans and policies, and regional energy issues in response to DOE's needs for quantitative assessments in planning RD&D programs and performing the Department's administrative and regulatory functions. These studies, conducted by an interdisciplinary staff aided by UC Berkeley faculty and graduate students, analyze generic issues associated with energy development, and assess the economic, environmental, institutional, and health impacts of energy technologies, plans, and policy. They identify constraints in and measures needed for implementing energy plans and policy, and deploying new technologies. As part of its mission the program constantly improves, augments and validates analytical tools and databases to advance the scope and reliability of energy analysis.

The Energy-Efficient Buildings Program encompasses research and demonstrations concerned with improving the energy efficiency of building envelopes, windows, lighting systems, and ventilation, and the development of a public-domain computer program, DOE-2, for analysis of building energy use. Much of this research is coordinated with related research by the Passive Solar Analysis and Design Group in the Division's Solar Energy Program. The Energy Efficient Buildings Program is directed to gaining an understanding of the factors actually contributing to energy use in US and foreign buildings, and to devising modifications and new technologies for substantial, yet economically effective and environmentally sound, reduction in this energy use.

The Environmental Research Program focuses on investigating the impact of energy-related pollutants on air quality and on freshwater ecosystems. Much of the emphasis is on the development of laboratory facilities, such as ecosystem microcosms and combustion chambers, for studies that can contribute to assessment and mitigation of adverse environmental impacts of fossil fuel combustion, coal gasification, and oil shale conversion. These studies rely heavily on the success of the instrumentation program, which is developing modern and sophisticated techniques for the accurate characterization of energy-related pollutants and for the complete understanding of their fate in the environment.

In this program, research on atmospheric chemistry and physics focuses on urban and background aerosols, clouds, and fogs. Emphasis is on laboratory and field studies of heterogeneous (gas-solid, gas-liquid) reaction mechanisms, speciation of aerosol particles, and the optical properties of aerosols.

Another important part of the Environmental Research Program is combustion science research which is pursued by an interdisciplinary team of chemists, engineers, mathematicians and physicists composed of faculty from the UC Berkeley departments of Mechanical Engineering, Civil Engineering and Mathematics, UC Davis Mechanical Engineering Department, and laboratory professional staff. The group is fortunate to have the unique experimental and computational facilities of both the campus and laboratory at their disposal for the training of graduate students and post-doctoral personnel. The goal of this research is to acquire an improved understanding of combustion chemistry and fluid mechanics for a variety of systems and fuel types, with applications to reduce pollutant emissions, to increase combustion efficiency, and to contribute to the solution of fire safety problems.

Environmental fossil energy research, conducted by an interdisciplinary group drawn from UC Berkeley's College of Engineering and several LBL Divisions, is investigating a range of complex environmental problems associated with the conversion of fossil fuels to usable energy forms. Air, water, toxicological and solid waste problems are being investigated in laboratory and field studies designed to develop new environmental control technology. The research team, which includes experts in underground mining technology, sanitary engineering, reservoir engineering, cement chemistry, and other disciplines, has performed innovative work on trace element emissions, underground retort abandonment strategies and wastewater treatment technology, and has been at the forefront of developing new analytical techniques for oil shale materials. Future goals are to demonstrate environmental control technology at the pilot and field scale while continuing fundamental investigations of environmental problems of fossil fuel technologies.

The Division's Solar Energy Research Program is focused in three areas. The first is providing basic information such as measurement of the solar resource, to assist DOE and the Solar Energy Research Institute (SERI) in evaluating solar options. The second area is research and initial development of new solar conversion techniques with the goal of early transfer to industry. Efforts in this area include the analysis, design and experimental investigation of passive approaches to solar heating and cooling of buildings; the development of solar air conditioners utilizing advanced thermodynamic cycles; and the evaluation of the use of modern electronics to control multi-component solar systems. The third area involves technical support to DOE headquarters, particularly for solar cooling and passive solar systems. LBL's technical support of the solar heating and cooling demonstration program is substantially reduced for FY 1980, and is expected to be phased out at the end of that fiscal year.

ENGINEERING AND TECHNICAL SERVICES DIVISION

Objectives

This division provides engineering and technical services to the Laboratory's programmatic research divisions and conducts certain projects in applied research independently.

Special Characteristics

The staff of the Division has accrued a considerable base of engineering and technical experience through its years of support to the LBL scientific divisions. Typical tasks have involved designing and building complex one-of-a-kind experimental apparatus. This base has expanded in step with the broadening and diversification of the Laboratory's programs. It is characteristic of the Division's operation that the engineering and technical staff are assigned to work in their areas of competence as members of integrated interdisciplinary programmatic teams. Simultaneously they maintain and share the knowledge thus gained through their divisional procedures and supervision.

Program Planning and Guidance

Program planning, under the guidance of the Division Head, is in response to needs for its support services by programmatic groups, or in response to the needs of independent projects that suit the Division's special capabilities. Project management, computer-based scheduling and management information systems are used.

Technical Goals and Future Directions

One part of the Division's R&D activities is directed toward providing and maintaining specialized instrumentation for research programs. Among these are all types of radiation detectors, signal processing by analog and digital systems to improve instrument resolution, and provision of advanced instruments for monitoring environmental pollutants.

Another part of the Division's R&D activities is directed toward evaluating and solving engineering problems in the field. Examples have included the train control systems of the Bay Area Rapid Transit (BART) and the Washington DC Metro, and development of a prototype locomotive data acquisition system for the Department of Transportation (which could become a component of a fuel economy data base for railroads).

The Division prepared proposals for the design, fabrication and testing of neutral beam system prototypes for Princeton's Tokamak Fusion Test Reactor (TFTR) and the General Atomic Company's Doublet III fusion device. Both contracts were awarded to LBL in FY 1977 and the prototypes are scheduled for completion in FY 1979. Each of these beam line systems incorporates sophisticated systems in cryogenics, power supply, ion source technology and computer control. The impact of industrialized copies of these prototypes on the development of fusion

energy research will be enormous and the experience gained by the Division in these engineering projects will be available for future neutral beam system projects.

The Laboratory's Computer Center, which was integrated with the Division in 1979, provides large-scale computational support to the entire Laboratory as well as a number of off-site users at other institutions and agencies nationwide. Future trends will involve a shift in the dominant computing mode from batch to interactive computing and a shift from centralized to distributed systems, both of which can greatly speed and facilitate data reduction, and a greatly increased involvement with word processing. Modernization and replacement of equipment will be required.

MATERIALS AND MOLECULAR RESEARCH DIVISION

Objectives

The Materials and Molecular Research Division (MMRD) conducts basic multidisciplinary research on the physical and chemical aspects of the behavior of materials and the chemistry of atoms, molecules, and solids. The objective is to provide a foundation of scientific knowledge as a basis for development of new energy technologies.

Special Characteristics

This Division derives its particular qualifications from a combination of expertise for research in basic chemical and materials science. Projects are directed mostly by UC faculty members, appointed to Laboratory positions on the basis of their scientific excellence. As an important by-product of its program, MMRD has become a major supplier of young talent in actinide chemistry and materials science within DOE.

Interdisciplinary cooperative projects take advantage of the shared use of advanced research equipment and support staff with specialized capabilities. Applied research in areas of interest to DOE is undertaken as a minor program component in cases where basic expertise can produce technically useful results.

Program Planning and Guidance

Planning and guidance of research is carried out by the Division Head in consultation with the Laboratory Director and the Divisional Council, which meets monthly to discuss new and ongoing projects. This committee also reviews the use and improvement of Division facilities and expertise. Ideas for new and expanded research projects can originate at any level. Day-to-day supervision of research projects is conducted by the Investigators, who report to the Division Head.

Each year a group of specialists from outside LBL reviews the scientific programs and prepares an assessment of the current research

and progress of the Division. Also annually, Program Managers from DOE discuss research activities with individual scientists within the Division. The scientific accomplishments of faculty investigators are independently reviewed by their academic departments.

Technical Goals and Future Directions

Materials Research. The Division is investigating the structure of surfaces and the nature of chemical reactions on surfaces. Surfaces are the first line of defense against external attack on materials by chemicals, nuclear radiation, and other hostile environments. Also, specific catalytic chemical reactions not occurring elsewere can take place at a high rate on surfaces. LEED and electron-loss techniques have recently been used to determine the surface structure of adsorbed ethylene and acetylene on platinum (111) crystal faces.

Another study is seeking to identify the atomic mechanisms underlying grain boundary reactions. This is relevant to the physical and mechanical properties of most commercial materials, which are polycrystals with properties largely determined by the presence of segregated species of phase transformation products at grain boundaries. Many materials could benefit from this research including structural metals and electrical conductors.

Research in physical metallurgy is concerned with the relation of microstructure to physical and mechanical properties of metals and alloys, and with the development and preparation of alloys with new desirable properties. Supportive theoretical work includes analytic and computer simulation studies of phase transformations and mechanical behavior. The objectives of this work are to clarify fundamental principles and to provide guidelines for the design of new engineering alloys h
which tensile properties are essentially independent of the percent of martensite up to at least 40% has been invented. The alloys include Fe/Al/C, Fe/Si/Mo/C, and Fe/Si/Nb/C. The first nickel-free structural steels which remain strong and tough in ambients as cold as liquid nitrogen (77°K) have been developed (Fe-12Mn and Fe-5Mn composition). This breakthrough may solve a recognized materials need in the handling and storage of liquefied gases.

A variety of techniques is used for these programs, including low-energy electron diffraction, Auger, Mössbauer, and x-ray spectroscopy, and high-resolution electron microscopy. The present Laboratory facility includes a 650-kV high-voltage electron microscope (HVEM). A new HVEM with a maximum accelerating voltage of 1.5 MeV, the most powerful of its kind in the United States, is scheduled for installation in January 1980. This instrument will play a vital role in research programs aimed at developing new materials able to withstand the extreme operating conditions met in advanced energy systems.

MMRD is studying the factors that control the mechanical, chemical, electrical, and magnetic properties of ceramics. Researchers are investi-

gating how material parameters influence piezoelectricity, graphitization kinetics, sintering rates, and fracture strengths. The chemistry of ceramic-metal interactions and of refractory deterioration in coal gasification is also under study. Unexpected dependences of the crystalline form and surface area on CO_2 pressure and time have been found for calcium oxide produced from calcite.

The mechanisms of erosion-corrosion, particularly as they relate to the hostile environments of coal gasifiers where materials are subject to high temperatures, reactive gases, and high-velocity solid particles, are being studied. Coal liquefaction slurries, geothermal brines, and oil shale retorting fluids also create severe conditions that lead to erosion and corrosion of structural materials. Cost-effective structural metal and ceramic materials for use under extreme corrosion conditions encountered in geothermal, oil shale, and other conversion technologies are under development. These applied research efforts can be effective because of the strong background of knowledge provided by the Division's basic research programs.

Superconductors and superconducting devices are among the advanced materials being studied at MMRD. A newly developed superconducting magnetometer has been field-tested for use in locating hydrothermal sources. Superconductor specimens of sufficient size for testing in accelerator magnets are being prepared in cooperation with industry. Nonlinear optical materials and processes used in laser technologies and far-infrared detectors for spectroscopy are also being investigated. Electron-hole droplets in ultrapure germanium have been found to be essentially immobile. This phenomenon has many possible applications, for example, in optical memory devices.

The scientific foundations of electrochemical technology and the range of its applications are being extended to the storage of electrical energy, shaping and surface treatment of materials, recovery of basic metals, and preparation of key chemicals.

Molecular Research. Solid-state chemistry research is centered on the study of chemical bonding in solids. Subjects under investigation include the prediction of crystal structure on the basis of electron orbitals, phase transformations, and critical phenomena by nuclear magnetic resonance, and the physical properties of solids under high pressure, high magnetic fields, and low temperatures. Chemical physics projects include the study of atomic and molecular processes by crossed molecular-beam techniques, and photoelectron spectroscopy of atoms, molecules, and solids. Normal photoelectron diffraction from adsorbates on clean surfaces has been observed for the first time, and the utility of this phenomenon as a structural tool has been demonstrated.

Building on LBL's well-known history of the production, isolation, and characterization of all the transuranium elements, the Division is increasingly focusing its studies of actinide chemistry to developing knowledge necessary for their safe use. The program extends from fundamental research (such as the chemical complexing of plutonium) to clinical

trials in cooperation with the LBL biomedical facilities, and includes synthetic work in organo-actinide chemistry, coordination chemistry, and actinide inorganic chemistry.

An isotope separation project, combining molecular-beam and laser technologies, was recently formed in this division. Investigators are developing new methods of isotope separation with a high separation factor and low energy consumption as well as the fundamental research base required for their use. The group's near-term goal is to make significant contributions to uranium and deuterium separation programs in cooperation with Lawrence Livermore Laboratory and Los Alamos Scientific Laboratory. A concerted experimental, theoretical, and computational study of the molecular mechanism for the laser photodissociation of formaldehyde has yielded for the first time a detailed understanding of this mechanism.

Chemical and Materials Science Laboratory. A new laboratory is planned to house an atomic resolution electron microscope and to consolidate various chemical and materials science activities in the Materials and Molecular Research Division. With the insight that atomic resolution microscopy will give, the long-range development of materials for advanced energy systems can proceed on a sound fundamental understanding of atomic structure.

NATIONAL RESOURCE FOR COMPUTATION IN CHEMISTRY

Objectives

The prinicpal objectives of the NRCC Division are: a) to advance chemistry through widespread, innovative, and intensive use of high-speed computational equipment; b) to provide and develop software to expedite and upgrade computer use; c) to support research efforts to build new and more effective computational methods, and d) to carry out an informational and educational program to bring the benefits created through the NRCC to the widest possible scientific public.

Special Characteristics

NRCC was conceived as an organization to serve the needs of both experimental and theoretical chemists throughout the nation. The breadth of this unique responsibility has led to the creation of a professional staff with expertise in most areas of numerical analysis and computer science, as well as major areas of computational chemistry including chemical kinetics, crystallography, macromolecular science, physical organic chemistry, quantum chemistry and statistical mechanics. One of the staff's primary responsibilities is the continued maintenance and extension of the recently established computer software library which now has a base of holdings in the major areas. This chemistry software library is unique in having a professional staff that serves as consultants in its use.

Program Planning and Guidance

The NRCC Policy Board is the governing body of the Division, and is broadly representative of the chemical community in the United States. Its members were selected by the LBL Director in consultation with DOE's Division of Basic Energy Sciences and the National Science Foundation. The Board has responsibility for NRCC policy and for setting scientific goals and priorities.

The Division's Program Committee is constituted to have wide representation of important areas in chemical computation. The Committee's main responsibility is to review the scientific content of all major proposals to NRCC and to recommend relative priorities among competing programs and proposals, within guidelines established by the Policy Board. The Policy Board is responsible for appointments to the Committee, which is chaired by the Division Head. The Division Head is responsible for the operations and management of the Division, subject to recommendations by the Program Committee and approval by the Policy Board.

The User Association consists of representatives from the user community of the NRCC. By providing feedback to the Division Head and the Policy Board, the Association helps ensure that the NRCC is responsive to the needs of the chemical community.

DOE and NSF carry out a joint review of the Division annually with a committee comprised of representatives from the Division of Basic Energy Sciences (DOE) and the Chemistry Division (NSF).

Technical Goals and Future Directions

The technical goals of the NRCC are inherent in its objectives: to progress toward full use of theoretical and computational research in chemistry, to make state-of-the-art software widely available, and to make high-speed computer facilities accessible to chemists. Improvement of codes and application of new computer hardware to computational chemistry are also primary concerns.

The establishment of priorities for additions to the software library and activity in other areas is greatly aided by the NRCC workshops. Some workshops are directed towards advancing the state-of-art in a specific area of chemistry and defining the possible role of the NRCC to assist such efforts. Our nearly completed effort in construction of a general-purpose configuration interaction computer program for quantum chemical applications is an outgrowth of a recommendation from a workshop held last summer on "Post Hartree-Fock: Configuration Interaction." Other workshops make known to the broader chemical community recent advances of significant impact in chemical computation. Our recent workshop on "Methods for Molecular Structure Determination: Theory and Technique" is an example.

A new direction stimulated by recent advances in hardware and the interest of the national chemical community is the development of portable

software for minicomputers. We have identified selected high-activity areas where conversion of large mainframe codes to run on minicomputers should have considerable impact, and have begun the necessary software modifications. These include trajectory codes for chemical kinetics, Monte-Carlo and molecular dynamics programs for statistical mechanics, and self-consistent field and limited configuration interaction programs for quantum chemistry. Also in progress are investigations of the capabilities of array processors and the promise of such machines for computation in all areas of chemical research.

Based on recent analysis of NRCC capabilities and a review of problems of importance to DOE, the NRCC has recently begun the study of the electronic structure and chemical kinetics of selected combustion systems. Such applications provide a plethora of physical systems of basic scientific interest that can serve to identify the need for extension of software capability.

Other activities that will be pursued include the improvement of key subroutines of wide utility as exemplified by our recent modification of a commonly used matrix diagonalization method that achieved improved execution times without loss of accuracy. In addition, computational studies are in progress in such timely research areas as the structure of presumed intermediates in catalysis, quantum statistical mechanics, structure determination of intermediates in chemical reactions, and the calculation of infrared intensities of organic molecules.

NUCLEAR SCIENCE DIVISION

Objectives

The principal objective of the Nuclear Science Division is the experimental and theoretical investigation of the interactions of heavy ions with target nuclei, both for the intrinsic interest in basic nuclear science and for their use in the synthesis of new exotic isotopes and new chemical elements. Complementary programs in light ion nuclear science, in nuclear data compilations, and in advanced instrumentation development are also pursued.

Special Characteristics

Following the development and exploitation by Lawrence of the cyclotron concept on the UC Berkeley Campus, development of heavy-ion accelerators took place at LBL: first using the Crocker Laboratory Cyclotron and then the modern, sector-focusing 88-Inch Cyclotron in the early 1950s and 1960s, the HILAC in 1957, the SuperHILAC in 1972, and the Bevalac in 1974. During much of this period, LBL was almost alone in appreciating the potential value of heavy ion beams at all energies for the study of nuclear reactions and for nuclear spectroscopy. Along with experimental work, a parallel theoretical effort was developed. It concentrated in part upon the understanding of nuclear reactions by the use of macroscopic viewpoints that have given valuable insight

into the phenomena of nuclear fission and heavy ion reactions. This history has given the Division a unique status as a center for heavy-ion research.

A long standing tradition for education of Berkeley students continues in nuclear science, with five UC Berkeley faculty holding joint appointments and with 28 graduate students currently seeking their PhD in research studies with senior scientists in the Division. Three physicists have recently been appointed as Divisional Fellows, two in theoretical research and one in experimental research at the Bevalac. Such appointments in these potentially career positions help maintain the youthful vigor of the research approach in the Division.

Program Planning and Guidance

Planning and control of research is the responsibility of the Division Head in consultation with the Laboratory Director and the Divisional Program Committee. This committee meets monthly to discuss new and continuing projects. Detailed program and budget reviews are conducted by an Advisory Committee, a subcommittee of the Program Committee, with advice from the Scientific Directors of the 88-Inch Cyclotron, the SuperHILAC and the Bevalac. Recommendations for new or revised research projects can originate at any level. Day-to-day supervision of research activities is the responsibility of the Group Leaders, who report to the Division Head.

Operation of the SuperHILAC and the Bevalac as national facilities available for the use of any qualified scientist entails working closely with outside users. The Division organizes users' conferences, procures or constructs special research equipment, and collaborates on some outside experiments. Although the 88-Inch Cyclotron is not a national facility, it supports a large group of outside users in the same manner.

Proposals for research at the national facilities are reviewed by program advisory committees appointed by the LBL Director. The activities of the Division are reviewed annually by a distinguished Visiting Committee also appointed by the Director. DOE representatives attend the presentations by LBL staff members and have full opportunities for discussions with the committee members. Chairmen of users' executive committees are invited to comment on the Division's performance to the Visiting Committee.

Technical Goals and Future Directions

New research areas with relativistic heavy-ion beams are being pursued through major improvements to the SuperHILAC and the Bevalac (to enable uranium beams), and the superconducting spectrometer at the Bevalac (HISS). Other new experimental facilities being developed at the Bevalac are the construction of a plastic ball detector to permit observation of high multiplicity events and the creation of a Low Energy Beam Line to permit high-precision spectroscopy in the 30 to 200 MeV per nucleon energy range. Existing theoretical predictions for such major

new phenomena as phase transitions in nuclear matter, quark matter, high density nuclear matter, and nuclear shock waves will be investigated at higher energies. The fragmentation process observed in early Bevalac experiments is being exploited both in studies of nuclei far from stability and in investigations of fundamental importance to cosmic ray physics. Parallel studies of physics with intermediate-energy heavy ions (20-500 MeV per nucleon) are being undertaken. From experimental results obtained with the 88-Inch Cyclotron and the Bevalac, it is already clear that this energy range will be extremely important. Concurrently, development of an advanced ion source is planned for the 88-Inch Cyclotron. This source will provide high intensity beams of high charge state ions, doubling the heavy-ion beam energies now available and permitting the cyclotron and its users to continue to play a dominant role in heavy ion studies at highly interesting energies throughout the next decade.

Heavy-ion research at the 88-Inch Cyclotron and the SuperHILAC focuses on studying the basic properties of nuclear reactions and spectroscopy. Currently the mechanism of nucleus-nucleus collisions (deep-inelastic scattering) and the behavior of nuclei which are undergoing very rapid rotations are being investigated via a broad variety of experimental approaches. The properties of "exotic" nuclei--whether they are new elements or new isotopes with highly abnormal neutron to proton ratios, and their accompanying unusual radioactive decay modes--are under study at all three accelerators.

Light ion nuclear science at the 88-Inch Cyclotron focuses on investigating spectroscopic properties and reaction mechanism effects in the lighter nuclides and on the exploitation of polarized proton and deuteron beams to study fundamental interactions in the few nucleon system. The Division plays an important role in the Nuclear Data Network and is responsible for preparing a compact Handbook of Radioactivity Data, designed for applied users. Long-range development work on radiation detectors and associated instrumentation is a general theme in the Division's goals. Accompanying this, an exciting concept for a breakthrough in the technical problem of high-speed analysis of multi-parameter data known as the DATA CENTER, which would employ a new configuration of computers and hardware, is being actively explored.

In order to maintain the United States in its overall leadership role in heavy ion nuclear science, the Nuclear Science and the Accelerator and Fusion Research Divisions are in the process of preparing jointly detailed plans for a variable energy nuclear synchrotron (VENUS) capable of producing ion beams from 40 MeV/A to 40 GeV/2A in the center of mass in colliding beam operation. Studies done with VENUS at its highest energies will tend to unify various subfields of physics, bringing together scientists in nuclear matter physics, cosmic rays and astrophysics, and elementary particle physics.

PHYSICS, COMPUTER SCIENCE AND MATHEMATICS DIVISION

Objectives

The Physics, Computer Science and Mathematics Division carries out basic research in experimental and theoretical physics, and in computer science and applied mathematics.

Special Characteristics

The staff of the Division is enhanced by the close association with faculty and graduate students of the University of California at Berkeley. In experimental physics approximately half of the Division's staff is composed of UC Berkeley tenured faculty, while four-fifths of the theoretical physicists have such positions. The Computer Science and Applied Mathematics Department also has a strong complement of UC Berkeley faculty.

During the academic year almost all of the UC Berkeley faculty are supported by the University. In addition to this bonus our research program and the unusual qualities of the Bay Area make it possible for us to attract outstanding, self-supporting scientists from other institutions who make important contributions to the research. Challenging work and a stimulating scientific and cultural atmosphere are unique LBL assets which make it possible to attract scientists of the highest caliber.

Research activities at LBL derive vital support from the exceptional computing facilities, without which none of the far-reaching programs in physics, computer science and applied mathematics could be carried out.

In addition to its use of the computer facilities, the research programs of the Division also rely on LBL programs of instrumentation research and development. Although an important fraction of this research is carried out within the Division we benefit in an important way from other Laboratory work on advanced electronic semi-conductor systems for data readout and control devices.

The high energy physics research program has the objective of advancing knowledge of the fundamental properties of matter. The direction of this research is determined by the distinguished staff of physicists at LBL. These scientists are renowned for their innovative approaches to new fruitful experimental and theoretical research and, very importantly, for their unusual abilities to bring such plans to a successful conclusion. It is the policy of the Division to encourage this creativity by maintaining a management atmosphere in which it can flourish. In the recent past and before, this policy has led to decisively important advances in particle physics, and at present and in the immediate future to plans for important experimental and theoretical research.

Although the major research activity is in the field of high energy particle physics other physics research is devoted to medium energy physics, nuclear science, astrophysics and astronomy.

Program Planning and Guidance

Planning and guidance are the responsibility of the Division Head, advised by heads of the individual Physics Groups and by the Computer Science and Applied Mathematics Department.

The physics research program and progress are reviewed yearly by the external High Energy Physics Review Committee (HEPRC). All members of the Committee are prominent particle physicists. Additionally, DOE-headquarters High Energy Physics staff provide regular review. All of the activities of the Physics, Computer Science and Mathematics Division are subject to the appraisal of the LBL Director's Scientific Program Council. The CSAM department is reviewed by the DOE Applied Mathematical Sciences Research Planning Workshop.

Technical Goals and Future Directions

High Energy Physics. LBL has an especially close relationship with SLAC with whom we are collaborating in the construction of PEP, the 20 GeV positron-electron colliding beam facility nearing completion. The unexpected and revolutionary discoveries made by SLAC and LBL scientists during the last few years of the ψ-particles, the related χ's, the heavy lepton and mesons which exhibit a basic new property called charm, imply that we are now at a new frontier of high energy physics. The LBL-SLAC collaboration at PEP offers a unique and exciting possibility for exploring this region and beyond. LBL's research program is directed toward fully exploiting this opportunity.

While there will be a continuing LBL research effort at FNAL and BNL, maintaining a balanced program, our major effort, as determined by the Divisional Review Committee, is directed toward experiments with the positron-electron colliding beam at PEP. These activities employ advanced techniques and developments initiated and perfected at LBL. We expect that a new spectroscopy of strongly interacting particles will emerge from experiments at PEP and that new and unexpected phenomena will be found, as they have been in the past when increased energy has become available.

There are five major regions at the PEP facility in which electron-positron collisions can occur. Collaborative experiments in which LBL will play a major role have been chosen by the PEP Experimental Program Committee to be carried out in three of these five interaction regions.

These experiments are the Time Projection Chamber, the Mark II Magnetic Detector and the Free Quark Search. One of the accepted proposals, the time projection chamber (TPC) will provide a radically new and powerful device for particle identification and measurement. Its construction requires involvement of physicists, engineers, and highly-skilled technicians, as well as an extensive computer facility. These existing LBL resources will play a major role in the construction and operation of this chamber. The analysis of data from this program will also be a major LBL function.

Our program at FNAL covers work on the rare muon induced reactions utilizing a new type magnetic spectrometer, neutrino and anti-neutrino interactions in the 15-foot bubble chamber with the EMI, and other strong interaction physics. LBL will play a major and continuing role in the studies.

In the area of theoretical physics a new approach to fundamental interactions will have a profound impact on the understanding and interpretation of particle structure and interactions.

The research programs which have been discussed will occupy the Division's attention well into the early 1980s. While these are underway the Division will be concerned with planning for the future. Foremost among these plans will be those for PEP II, a project not yet well defined. The most fruitful approach for LBL will be in a continued LBL-SLAC collaboration in high energy physics. A possible option for PEP II is the addition of a proton ring at PEP as originally planned. Other, more richly promising, possibilities involve the construction with SLAC of a US-LEP facility or a single-pass colliding beam laboratory. Whichever option is chosen by LBL and SLAC will vitally affect the health of both Laboratories.

Medium Energy Physics. The Medium Energy Physics program is concerned with research using mesons and nucleons to probe the properties of matter. Our program is closely related to the programs of the other national laboratories and of foreign laboratories such as Harwell (England), TRIUMF (Canada), and SIN (Switzerland), as well as those of many universities throughout the world. This research is concerned with the study of nuclear structure, nuclear reactions and the interactions between nuclei and electromagnetic radiation and mesons. Experiments are carried out by LBL scientists at the Bevatron, the ZGS (Argonne), at TRIUMF (Vancouver), and at LAMPF (Los Alamos).

Computer Science and Applied Mathematics. Computer Science and Applied Mathematics research provides methods and tools applicable to a wide range of the major DOE mission programs. Broadly applicable methods for mathematical and computational analysis are being developed, with emphasis on ordinary and partial differential equations. Research areas in computer science include software engineering to provide techniques for the synthesis of reliable software systems, data management methods for dealing with large data bases, and distributed computing research centered on integrated approaches to inter- and intra-site linking of computer systems. The Laboratory will be playing a leading role in the development of distributed information systems technology; intelligent systems concepts; and environmental, socioeconomic, and health effects databases, models and policy analysis tools.

Instrumentation research and development and incrementation of LBL computer facilities will be essential for future development of physics and computer science and applied mathematics research. In addition, if LBL is to maintain an effective research program in high energy physics, capable of competing in this area as it always has with the finest in

the world, the research budget must be increased. The present budgetary constraint makes it difficult to plan and build for the future while carrying out today's programs.

SECTION II

LABORATORY TRENDS AND ISSUES

The Lawrence Berkeley Laboratory is the oldest of the national laboratories and in its 48 year history has passed through several distinct periods of development. These can be discussed in connection with Fig. 2-1 which summarizes the yearly trend in manpower.

In the initial period of the 1930s when the Laboratory was supported by University of California and private funds to do pioneering studies in nuclear science it underwent steady growth. Under Professor Ernest Lawrence, the Laboratory played an important role in federally funded weapons research during World War II. In the post-war years under US Atomic Energy Commission sponsorship it was mainly concerned with scientific research in nuclear physics, high energy physics, nuclear medicine, and fundamental chemistry. Manpower reached a peak in 1966 and then dropped off significantly as the nation's budget in the activities in which LBL participated was spread over many competing laboratories and LBL received less support. This shift was dominated by the national trends in support of high energy physics.

In the early 1970s the growing awareness in the scientific community of the need for research in environmental and energy problems caused the Laboratory to broaden its program with a number of applied research initiatives in those fields. It was not until after the 1973 oil embargo however that significant new federal funding became available to carry out this work. Thus, after the formation of the US Energy Research and Development Administration (ERDA) in 1975, LBL and other national laboratories had the opportunity and responsibility to broaden their programs in appropriate ways to assist the nation in meeting the severe challenges posed by the developing energy crisis. Figure 2-1 reflects this by the manpower growth which appears in the years 1974 through 1977. By 1978 the Laboratory's manpower level reached and slightly exceeded the historical peak of 1966. For many reasons this rate of growth could not continue and indeed, during the years since the sponsorship of the national laboratories was transferred from ERDA to the Department of Energy the manpower growth of LBL has slowed markedly. The projection through the next five years, based on DOE guidance, is for a fixed or somewhat declining level of effort.

Underlying these manpower trends of recent years was a conscious and managed shift in Laboratory activities not only in the mix of basic research fields but in the distribution across basic research, applied research, and engineering applications. Up until the early 1970s the entire program of LBL was in basic research, primarily in those areas cited above--nuclear physics and chemistry, high energy physics, nuclear medicine, basic biology and materials science. At the same time impressive engineering capability was developed to support the design and construction of large nuclear particle accelerators and the advanced instrumentation and computer service required to conduct the nuclear physics and high energy research.

In 1979 LBL still had heavy involvement in the same basic research fields as well as a few new ones--notably geosciences and theoretical chemistry. However, in addition, it was now prominently involved in applied research: environmental biology, environmental instrumentation and measurement, geothermal energy, applied geosciences, efficient energy end-use studies, energy policy analysis, nuclear waste management, solar energy, fuels from biomass, fusion energy and combustion. The Laboratory research program can be described as roughly half in basic and half in applied work. Major engineering projects are underway in high energy physics (PEP accelerator) and in fusion (neutral beam injectors). The Laboratory has entered several areas of applied research and engineering where it can build on its expertise in basic research in a significant or unique way. The Laboratory has also entered some other areas of urgent need where it had no previous experience, such as in geosciences and geoscience-based applied research, because it could take advantage of the formidable resources of the UC Berkeley faculty. In all cases of entry into new work areas LBL management has made its selections on the basis of the three criteria mentioned in the Planning for Future Programs part of the Director's Overview Section of this document.

LBL has major engineering capabilities but does not have the resources for conduct and management of engineering projects at the demonstration stage of alternative energy technologies. In this respect it differs from some of the largest national laboratories.

Another significant feature underlying the manpower and program trends at LBL is university involvement. This involvement is repeatedly mentioned in the text of this Institutional Plan because it is of dominant importance. The University of California is the contracting agency operating LBL. All employees of the Laboratory are staff members of the University of California. The history and location of the Laboratory have caused it to seek and nurture the heavy involvement of UC Berkeley faculty in management and in conduct of research. Over 150 faculty members are so involved. This involvement brings with it the participation of approximately 400 graduate students in DOE programs at LBL. This profound involvement of faculty and students with the other staff members of LBL gives a special character to LBL impossible to duplicate in any other institution. Over the past few decades more than 1000 PhD students have completed PhD theses on AEC, ERDA, and DOE programs at LBL.

Thus, in the past 6 years LBL has encouraged and effected a major involvement of academic researchers in national problems of energy supply and use and has helped to train a significant fraction of the body of experts available for employment in industry, government, in academic institutions and other national laboratories. The Laboratory hopes to continue this trend.

Involvement of the Laboratory with private industry has increased notably in recent years as Laboratory programs have become more oriented toward alternative energy technologies and to efficient energy end use. Contracts with industry take many forms, including sub-contracting

joint projects, topical workshops, field work collaborations, exchange of information, and special efforts at technology transfer. This trend is expected to continue.

As was mentioned above in the discussion of manpower trends, there is presently no growth in workforce at LBL, and the Department of Energy's guidance projects LBL's manpower level slightly decreasing through 1984. The major issue faced by the Laboratory in an era of steady-state operation is how to ensure the continuing vitality of the Laboratory's research program. The program must not be allowed to become static; new ideas must always be encouraged, and ways found to incorporate them into the program. The Laboratory's unusually youthful age distribution must be maintained. Continual critical evaluation of ongoing programs is absolutely necessary so that the best programs can be strengthened and less productive ones cut back or terminated. To accomplish this it is vital that mechanisms be worked out between LBL and the Department of Energy to produce an understanding of the Laboratory's performance and relevant capabilities including the possibility of new work assignments.

This discussion of trends and issues has focused, to this point, on the human resources required to get the job done. A second issue of major importance to LBL is the necessity to maintain an adequate level of facilities for carrying out the Laboratory's research efficiently. In recent years, working space at LBL has been severely constrained as the result of the many program changes that have occurred without corresponding changes or additions to facilities. The last major building was approved for construction at LBL in FY 1965. Although efforts have been made continuously to rearrange existing space, move administrative services off-site, and lease off-site laboratory space, the present situation is inefficient, with office space overcrowded and remotely located, and the laboratory space inadequate for present programs. This situation would be greatly improved by the construction of the proposed Energy Research Laboratory, which would consolidate a number of related energy programs and thereby promote the exchange of new ideas and discoveries. This proposed facility is described in Section VI of this document.

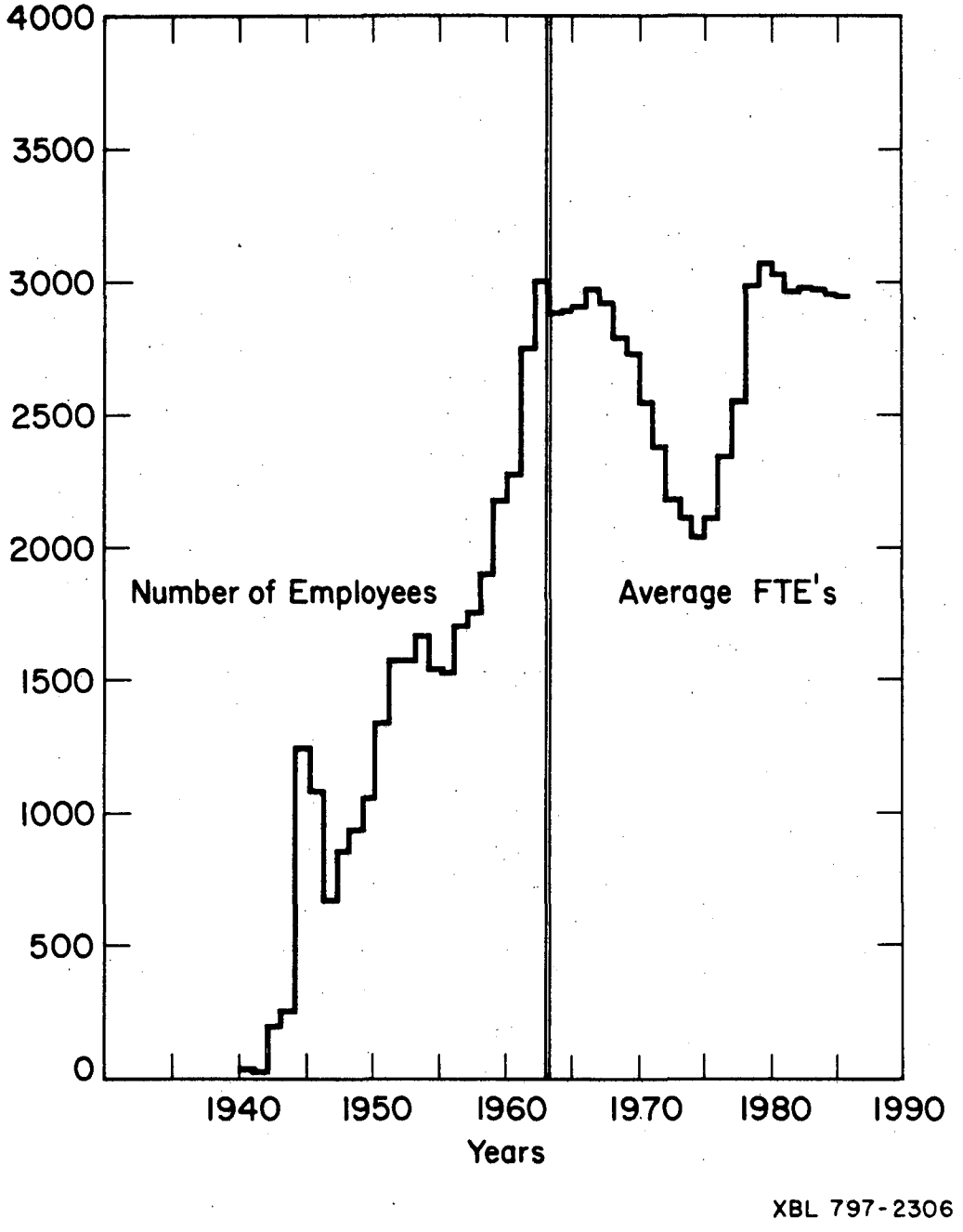

Fig. 2-1. LBL Manpower Trend.

SECTION III

SCIENTIFIC AND TECHNICAL ACTIVITIES

BASIC ENERGY RESEARCH

DOE: Director, Energy Research (ER)

OVERVIEW

Research programs in the energy-related basic sciences occupy a major fraction of Laboratory effort. Basic research done in pursuit of pure knowledge is carried out side-by-side with mission-oriented applied research in energy. The Laboratory's basic research programs encompass the fields of high-energy physics; nuclear, materials, chemical, mathematical, and geosciences; and the engineering sciences.

LEAD MISSIONS

Experimental Program Management for the BEVALAC-Super/HILAC

The mission of this lead laboratory assignment is basic research in nuclear physics using accelerated beams of heavy ions. Three accelerators are operated and periodically upgraded to provide the heavy ion beams required for this experimental research. Two of these (SuperHILAC and Bevalac) are operated as national facilities and the third (88-Inch Cyclotron) supports a major outside user program. Other equipment and facilities are also designed, built and operated to support experimental research by Laboratory and outside users.

This research provides educational opportunities for 30 students in PhD programs and about 20 postdoctoral fellows. Theoretical studies guide the experimental program and interpret its results.

The Laboratory plans and manages the overall program with the objectives of maintaining the most innovative research and the best possible educational opportunities. Management maintains frequent contact with outside user organizations.

A fuller description of this program is found in the section on Heavy-Ion Physics (HK 03 02).

National Resource for Computation in Chemistry

The Division of Basic Energy Sciences and the National Science Foundation have placed responsibility with LBL for implementing a chemistry program in the area of computational methodology, technology, and applications. LBL plans and manages the overall program of the national user-oriented facility. Project funding is designed to stimulate the development, refinement, and distribution of computer codes in all

fields of chemistry. LBL activities play an integrative and catalytic role. These activities include the coordination and administration of a research program for chemists from across the nation engaged in code development and documentation whose computations are supported by the Department of Energy, the National Science Foundation, or other federal agency funding, as well as those with private support. In addition to code design and testing, the NRCC disseminates information through a series of workshops, newsletters, participation in relevant professional society activities, visitor programs, etc. LBL was selected as the host institution for this program by the DOE and the NSF because of the demonstrated capabilities and the innovative research of the LBL staff in chemistry. These factors are enhanced by interaction with the UC Berkeley campus and the Lawrence Livermore Laboratory.

Basic Research Underlying Conservation Technologies

The Laboratory has been given the responsibility under this lead mission assignment of assisting the DOE Basic Energy Sciences Division in developing a program of basic research in energy conservation. The first step in this assignment has been LBL's participation in the BES Technology Crosscut Study, for which LBL has prepared the report "Basic Research Needs in Energy Conservation."

Major goals of basic research in energy conservation are:

1. To obtain a sufficient foundation of physical, chemical, and biological knowledge to make possible the economic development of future energy-efficient conversion and end-use technologies, and to learn how to accomplish tasks requiring energy in entirely new ways rather than by incremental improvements to existing ways. Most of today's uses of energy are far from the limits of efficiency imposed by physical laws; basic research should aim to roll back constantly the limit to efficiency that is compatible with a given energy price.

2. To gain a greater fundamental understanding of how energy is used in this and other societies, in order to reduce uncertainty in assessments of future energy demand and to facilitate the transition to an energy-efficient society. Greater knowledge is needed of how energy use responds to price signals from the market and to non-economic signals from government and social groups, and of how these responses affect social equity, civil freedoms, environment and health, national security, and the levels and time-scales of energy-supply development.

The Laboratory will work with the BES Division in developing a specific research agenda for the BES program, in keeping with these goals, and will itself participate in such research acitvities as are mutually agreed upon.

Basic Energy Sciences (AK 01) (FY 79 $14.1 M)

Nuclear Sciences (AK 01 01) (FY 79 $2.1 M)

The nuclear sciences program at LBL supports basic research in nuclear reactions and fission, transuranium chemistry, compilation of nuclear data, operation of the 88-Inch Cyclotron, and development of advanced detector and instrumentation systems.

88-Inch Cyclotron. This accelerator is used for the production of beams of light ions, including polarized proton and deuteron beams. These are used to study the spectroscopy of nuclei, especially exotic species far from the line of stability (i.e., having an unusually high or low ratio of protons to neutrons). Measurements of the masses and decay schemes of these nuclei can provide very sensitive tests of nuclear structure theories. New high spin states in nuclei have been observed by unusual nuclear reaction studies involving the detection of unbound outgoing systems in resonant final states. Further spectroscopic studies along this line are planned. Polarized beams of protons and deuterons permit exploration of fundamental problems in nuclear physics in which the projectile spin plays an important role. Measurements in this program of several polarization effects in proton plus deuteron scattering have been essential in the successful development of exact three-body calculations; in addition the first accurate determination of the deuteron D-state parameter has been obtained. Improvements in the ion source are planned which will increase the intensities of the polarized beams by a factor of ten and permit a quantitative determination of the weak interaction parity violation in the basic nucleon-nucleon system.

Instrumentation and Advanced Detector Systems. The goal of the program is to anticipate and satisfy the needs of nuclear science programs in regard to radiation detectors and associated instrumentation. Recent work has resulted in new types of detectors for very fast time-of-flight measurements, the development of a reverse-electrode coaxial high-purity germanium detector for gamma-ray spectroscopy with thirty times the radiation life of older coaxial detectors, and a gated-integrator pulse-processing system for improved energy resolution in systems using large coaxial detectors. Long-range development work is expected to focus on detector systems that emphasize good geometry and the ability to detect energetic particles produced in high multiplicities.

Actinide Chemistry. The Laboratory is applying its experience in the chemistry of production, isolation, and characterization of transuranium elements to problems related to nuclear waste management and reprocessing of spent fuel. Chemical sequestering agents for actinide ions are being designed which can facilitate the reprocessing of spent nuclear fuel. Studies of actinide and fission product speciation in very dilute solution are being pursued with reference to the problem of radionuclide migration in the biosphere. This research has the objective of furthering our understanding of potential risks involved in geological isolation of buried nuclear wastes.

Nuclear Data. The availability of up-to-date compilations of nuclear properties is one of great importance both to researchers in nuclear physics and to applied users of radioactivity. The Isotopes Project at LBL plays a major role in the systematic evaluation of nuclear data, continuing a Berkeley tradition begun in 1940 with the publication of the first edition of the Table of Isotopes. The seventh edition, published in 1978, contains over 1600 pages of data from over 30,000 references.

The Isotopes Project is currently coordinating its data compilation efforts with those of other data groups through the US Nuclear Data Network. Berkeley is responsible for the preparation, on a four-year cycle, of comprehensive compilations of 39 mass chains (A = 146 to 152 and A = 163 to 194). In addition, the Isotopes Project will produce a compact Handbook of Radioactivity Data geared to the needs of applied users, to be published in 1982.

Materials Sciences (AK 01 02) (FY 79 $4.9 M)

The goal of this program is to derive improved materials and processes that are crucial to the economical development of new energy supply and end-use technologies. Basic questions of materials behavior are the focus of this interdisciplinary effort, e.g., alloy properties, reaction kinetics, and interface reactions.

Physical Metallurgy. These programs are concerned with the relationship of microstructure to mechanical, electrical and magnetic properties and with the preparation of alloys having predictable characteristics.

Unusual compositions and structures, in particular high field superconductors in the form of ductile wires and tapes, are obtained by powder-metallurgical techniques. Erosion and corrosion damage to materials that have potential use in coal gasification is under systematic study. Major efforts are being placed on alloy design, especially in ferrous metallurgy. A new class of low-alloy silicon steels of increased toughness has been designed for use in automotive construction, where reduced weight is required for more efficient energy use. Efforts to produce nickel-free cryogenic steels have been successful and new tough high-strength low-alloy steels have been developed for applications in mining and other fields. The structure of the solar absorber coating, black chrome, has been shown to consist of minute particles of chromium metal and a dispersion of voids in a matrix of amorphous chromium oxide.

Ceramic Science. Further advances in ceramic science require ever greater sophistication in identification and control of more subtle material parameters that influence ceramic properties and behavior. The influence of materials parameters on piezoelectricity, on graphitization kinetics, on sintering rates, and on fracture strengths are under study at LBL. The sintering study makes use of a high temperature scanning electron microscope developed at Berkeley, and the strength studies apply ultra-high-resolution transmission electron microscopy to identify impurity phases at grain boundaries.

Studies are being carried out of solid oxides that are relevant to energy processes. A comprehensive theory of decomposition reactions, developed here, is being used as a basis for systematic identification of the parameters determining decomposition rates, crystallinity and porosity of solid oxide products. By selected combinations of reactant crystalline size, temperature, and gaseous product pressures, either an amorphous or a crystalline CaO can be produced from $CaCO_3$ decomposition. The results of this work can be applied to sulfur oxide removal, to separation of components of vapor mixtures, and to formation of slags for steel making. The chemistry of ceramic-metal interactions and the chemistry of attack on refractories by environments encountered in coal gasification are also under study. The kinetics and mechanisms of the reduction process of transition metal oxide spinels being reduced by gases are investigated in a temperature range between 500 and 600°C. Martensite transformations are being investigated as toughening mechanisms for ceramics with high erosion, wear, thermal shock and impact damage resistance.

Electron Microscopy. Widespread application to new classes of materials, and development of new experimental methods, continues to be the goal of electron microscopy research at LBL. New LBL research in ceramics, crystal structure determination, and defect analysis have led to the recent addition of a new 1.5-MeV electron microscope, scheduled for operation in 1979. Emphasis on high resolution electron microscopy has permitted important breakthroughs in understanding the fundamental aspects of phase transformations necessary in LBL alloy design projects. It is planned to extend this capability, through the addition of a new 500-kV instrument and support facilities to include atomic resolution microscopy of close-packed structures used in energy technologies. The objectives of the expanded program would be: (1) to attain the highest available resolution in transmission electron microscopy and to direct the application of these methods to the many scientific problems whose solutions require atomic level detail; (2) to make available to qualified scientists from across the nation advanced characterization techniques including the 1.5-MeV instrument and the projected atomic resolution facilities, (3) to promote further research into the fundamental development of high-resolution methods, and (4) to educate potential users of high-resolution techniques in the necessary theoretical and experimental background. A Chemical and Materials Science Laboratory is scheduled to house an atomic resolution electron microscope and related support facilities.

Solid-State Physics. This work is concerned with developing new energy-related uses of advanced materials such as superconductors, superconducting devices, nonlinear optical materials and processes, semiconductors and far-infrared detectors. A recently-developed superconducting magnetometer, which can measure changes in magnetic fields as low as 10^{-10} G, has been incorporated into equipment for locating hydrothermal sources and is now being field tested. Theoretical solid state studies and the far-infrared spectroscopy of solids are being directed to surface reaction and catalysis programs of interest to fossil fuel conversion. The absorptivity, reflectivity, photoluminescence,

Raman and Brillouin spectra will be measured with the precision of a few picoseconds in a study of the relaxation of hot carriers in semiconductors, temporal behavior of Raman and Brillouin scattering in solids, spatial dispersion effects such as in the vicinity of an exciton-polariton in semiconductors, and picosecond nonlinear spectroscopy of solids. The spectrum of the cosmic background radiation from 3 to 24 cm^{-1} has been measured. The results show small but significant deviations from the Planck curve, which have implications for the "big-bang" theory of cosmology. The multi-photon dissociation of molecules with lasers is being studied as an essential part of development of new laser isotope separation processes. Electron droplets in semiconductors are being investigated as a novel state of matter.

Surface Science. The purpose of this research is to study the structure and composition of surfaces on the atomic scale, along with atom charge transport and elementary surface reactions, and to correlate this atomic scale information with the macroscopic surface phenomena of corrosion, mechanical failure, passivation, surface reactions, and electrode processes. Special materials are being prepared with high surface areas, and studies are being carried out of hot corrosion processes, structure of internal surfaces, grain boundaries and intergranular surfaces, and the kinetics and mechanisms of elementary surface reactions. Chemistry and materials problems in energy production technologies behavior of UO_2 as well as an investigation of radiation-enhanced high-temperature corrosion.

Electrochemical Processes and Phase Boundaries. The scientific foundation of electrochemical technology and the range of useful applications of electrochemical transformations are being expanded by: 1) the development of methods by which laboratory observations can be translated into economically viable processes; 2) the determination of means to improve the space-time, materials- and energy-yield of electrochemical reactors; 3) the investigation of critical problems of electrode surfaces and interfaces, and 4) introduction of non-aqueous processes for electrolysis and galvanic cell operations.

Solid State Chemistry. This research centers on the elucidation of chemical bonding and phase transformations in solids. It includes the prediction of crystal structure and phase diagrams on the basis of electron orbitals, the investigation of phase transformations in liquid crystals by nuclear magnetic resonance and the measurement of physical properties of solids under temperatures, as well as in high magnetic fields and at low temperatures. Heat-capacity measurements on graphite intercalated with SO_3F and AsF_5 have shown that the density of states is comparable to that of metals. The scientific foundation for the rf plasma enhanced deposition of thin film are being established in order to create a unique synthetic capability for a wide spectrum of thin film materials in which chemical, physical, and electrical properties can be controlled by variation of deposition parameters. New polymeric materials are synthesized by the technique of plasma initiation. Types of polymeric materials of interest are ultrahigh molecular weight organic polymers, organometallic polymers and inorganic

polymers. In addition, combinations of these polymers through the techniques of block and graft copolymer synthesis are of interest to yield useful "polymeric alloys."

Chemical Sciences (AK 01 03) (FY 79 $4.9 M)

This program addresses basic problems in the structure of chemical compounds and surfaces, atomic and molecular reactions, and chemical theory. Knowledge gained from these efforts is needed not only to advance these basic sciences but also to build a scientific base for new energy supply technologies and environmental impact mitigation.

Inorganic Chemistry. In this program, new compounds are synthesized and characterized by modern physical chemical techniques. Of particular interest are unusually high oxidation states of elements, intercalated layer compounds, and compounds with new structures and bonding that cannot be explained by present theoretical concepts. New research on the chemistry of sulfur dioxide provides basic understanding for SO_2 removal. The structure and bonding of metal carbonyls that are of importance in catalytic processes of fossil material are being investigated by photoelectron spectroscopy.

Other research aims to develop x-ray fluorescence analytical and electroanalytical methods that are applied to support basic energy research programs. Recent work includes developing methods for the determination of trace elements in coal, oil, water, and biological specimens. A method is being developed to use ozone and UV radiation for removal of organics from oil shale retort water before metals analysis. Present capabilities will be expanded to gain improved sensitivities for a broad range of sample types in order to support research programs that require multi-element trace determinations.

Surface Chemistry and Conversion Chemistry. One program is devoted to studying electronic and atomic structure of surfaces, and of catalyzed surface reactions. A major project is aimed at correlation of homogeneous and heterogeneous catalysis to bridge the gap between these two important fields by studying structure and reactivity of similar systems. Another program involving several investigations lies in the field of coal gasification and liquefaction. A study of the effects of catalytic agents at temperatures in the range of 500 to 850°C will be conducted. Of interest are changes of selectivity and inhibition of coke formation in catalytic cracking and catalytic dehydrogenation of aliphatic hydrocarbons. Vibrational spectroscopy will be used to gain an understanding of the chemistry surfaces at high temperatures. The hydrogenation of carbon monoxide is being investigated to establish the mechanism for this reaction, for the purpose of selectively producing organic molecules.. Photon-assisted reactions are also being studied at the solid-vapor interface to elucidate the mechanism of thermodynamically uphill chemical reactions.

In another project, the conversion of coal to liquid products by action of homogeneous catalysts is being investigated at temperatures below the coal pyrolysis temperature. In this way, selective action

on certain bond types in the coal is possible. The objectives of this project are to find catalyst systems and reaction conditions that give high yields of liquid/soluble products, to elucidate the mechanisms and kinetics of the reactions involved, and to use these selective reactions as tools to examine coal structure and reactivity.

Another project is directed toward the bioconversion of the carbohydrate content of cellulosic material (such as whole tree biomass and agricultural waste) to ethanol and other energy bearing products. Fundamental problems in the enzymatic hydrolysis of cellulose and in the subsequent conversion of the resulting sugar solutions to ethanol are being examined. New organisms are also being investigated for direct conversion of cellulose to ethanol. Recent accomplishments include delineating the major cost nutritional requirements for yeast growth and alcohol production, and developing vacuum fermentation for ethanol removal. Future research will involve basic studies on the kinetics and mechanism of cellulase action in degrading cellulose. New organisms will be developed for the direct conversion of cellulose to ethanol.

Solar Energy Conversion. One project deals with artificial photosynthesis. Its goal is to construct artificial systems mimicking the photosynthetic apparatus that are capable of storing solar energy. Photosensitized electron transfer reactions across phase boundaries are being studied with the aim of stabilizing the primary oxidation and reduction photoproducts and preventing their back reaction. The subsequent objective is to channel the stored energy in these products into the production of oxygen and hydrogen from water.

In this project, electron transfer has been accomplished across vesicle walls in a photochemical reaction that produces oxidation inside the vesicle and reduction outside. The reduced product can easily be converted to hydrogen. A similar photochemical reaction has been done transferring an electron across a water-oil interface, and producing oxidized and reduced products on the two sides. Work will continue with such two-phase systems, and different photochemical reactions will be explored that might be more closely related to the ultimate objectives. In particular, the production of oxygen through some catalytic photochemical cycle is a difficult challenge and will occupy much attention during the next year. When the various components have been sufficiently well developed, they will be combined into the final system for the photochemical production of hydrogen and oxygen from water.

Another project seeks to characterize the photochemical conversion of solar energy by bacteriorhodopsin, a stable protein pigment derived from purple membranes of halobacteria that operates via a photocycle to develop a proton current directly. Chemical modification of specific amino acid residues has demonstrated that the conformation of the dark and light adapted forms of the pigment differ and that the aromatic amino acids tryptophan and tyrosine are important for activity. New ESR methods demonstrate that surface electrical charges appear after

light absorption and that these are essential for bacteriorhodopsin's photovoltaic effects developed across planar membrane systems. Future studies will emphasize the molecular aspects of the energy conversion and how surface charge effects may be useful for enhancing the photovoltaic effects of bacteriorhodopsin on stable planar membrane systems.

Chemical Physics. The purpose of this program is to advance our understanding of chemical reaction mechanisms, molecular collision dynamics and molecular structure. Reactions of ions and molecules in the gas phase are investigated by modern experimental methods using lasers and molecular beams. Results are used for the development of a theoretical chemical foundation for elucidating chemical reactions of interest in combustion and MHD processes. The data derived for photochemical and catalytic reactions have found recent application in stratospheric chemistry. Investigation of wider aspects of the ozone problem in the stratosphere, initially undertaken in connection with the supersonic transport, is now considering the atmospheric effect of all energy-related (particularly combustion) technologies. Reaction rates of importance to combustion and associated pollution formation are being studied theoretically using a unimolecular rate theory, and experimentally using a novel steady-state shock wave heating technique.

Chemical binding energies and electronic structure, which determine the properties of materials, are being studied by photoelectron spectroscopy of metals, semiconductors and insulators. This technique has recently been expanded to the investigation of solid surfaces. Other theoretical and experimental investigations are aimed at more effective prediction of thermodynamic properties, energy transport in molecular solids, and radiation-induced reactions of biologically important organic compounds. A number of ongoing programs in surface and catalysis science ranging from the basic to the applied are being consolidated. Transport in concentrated electrolytes, fluid flow and current distribution in electrochemical systems is also being investigated. Experimental and theoretical research has been initiated to determine the phase behavior of aqueous natural-gas systems found in deep, high-pressure reservoirs in the Gulf of Mexico region. A Chemical and Materials Laboratory is scheduled to consolidate chemical science activities.

Photovoltaic effects within certain micro-organisms are the subject of research that will ultimately be related to the development of solar power cells, desalination and concentration cells. Present work involves gaining a basic understanding of these processes within the living cell.

Atomic and Molecular Physics. The validity of relativistic quantum mechanics is being investigated by the use of optical and radiofrequency spectroscopy with highly stripped ions, in a program of precise measurements of physical processes of atoms, molecules, and ions. Among the applications of this work are use of line widths for plasma diagnostics in fusion research. A positive parity violation effect has been discovered in atomic thallium. This effort comprises an important test of gauge theories of the weak and electromagnetic interactions.

National Resource for Computation in Chemistry (NRCC). The NRCC is operated as a user-oriented facility with hardware and personnel dedicated to serving the needs of the national chemical community. The staff documents, tests and improves software, develops new computational methods, and conducts original research in computational methods and in chemistry using such methods. The policies and procedures for the NRCC are determined by a nationally representative Policy Board. Program decisions within policy guidelines are handled by the NRCC Director and a Program Committee.

An important task is development of a library of computer portable software for computational chemistry with holdings appropriate for both large mainframes and minicomputers. Other projected activities include analysis of array processors for computational chemistry (and NRCC's role in implementation), and computational studies of selected combustion systems, which are being done with other national laboratories under the coordination of NRCC.

Engineering, Mathematical, and Geosciences (AK 01 04) (FY 79 $1.6 M)

Combustion Research. The primary goals of this research are 1) reduction of pollutant emission associated with combustion of fossil and alternative fuels and 2) improvement in combustion efficiency. While parts of this research are funded by other DOE divisions and government agencies, it is described here and cross referenced as appropriate.

Research in turbulent combustion is providing experimental data on turbulent flame propagation required to develop numerical models which ultimately will be utilized in the design of combustion systems. A multicomponent laser diagnostic system is being used to measure crucial experimental variables for several systems. Complementary modeling studies based upon statistical theories and vortex tracking techniques are in progress.

Research in combustion chemistry is aimed at determining pollutant formation and destruction mechanisms, obtaining high temperature kinetic data and developing suitable diagnostic techniques for pollutant species. Catalytically supported combustion has been investigated experimentally and computationally, and surface reaction rates have been measured. Comparative in situ and probe-sampled measurements of nitrogen and sulfur containing species have been conducted for alternative fuels. Theoretical studies are in progress to determine kinetic parameters for important combustion reactions.

LBL research in fire safety is aimed at characterizing radiative properties of materials, developing detailed models of combustion phenomena controlling fire growth and propagation, and acquiring experimental data to be used as a rational basis for fire test procedures. Event logic models for fire analyses incorporating fault tree methodology have been developed.

Goals of the engine research programs at LBL are to determine optimum operating conditions for internal combustion engines to produce simultaneously high fuel efficiency and low emissions of carbon monoxide, nitrogen oxides, and unburned hydrocarbons. Studies of elementary fluid mechanics, heat and mass transfer phenomena in IC engines have been conducted through the use of a single-pulse compression-expansion machine. Complementary experimental and modeling studies are underway to explore the role played by radicals in ignition processes. Several novel ignition techniques are being developed and characterized.

Applied Mathematical Sciences. This program is part of the DOE-wide focal point for monitoring and advancing the state-of-the-art in mathematical, statistical, and computer science research. The methods and tools developed from these disciplines pervade the wide range of major DOE mission programs.

Broadly applicable methods for mathematical and computational analysis are being developed, with emphasis on ordinary and partial differential equations, such as those occurring in the theories of turbulent combustion, fluid flow, and capillary phenomena. Some of these methods are being incorporated in a realistic computational model of an internal combustion engine, including boundary layers and combusting turbulent flow, suitable for comparison with experiment and for engineering design.

Software engineering provides techniques for synthesis of reliable software systems from standard modules, and creation of tools to increase the productivity of software systems designers, implementors, and users. Data management research is oriented toward the development of efficient systems for information retrieval and display; with primary focus on logical data models, query languages, specialized access methods for very large, diverse databases and distributed database techniques. An important related area of research is the investigation and development of mass storage systems based on the new, emerging optical disk technologies. Experimental development will focus on data access patterns, storage and retrieval strategies. Distributed computing research centers on integrated approaches to inter-site and intra-site linking of computer systems. A pilot network of distributed minicomputers is being developed to provide localized computer power inexpensively along with ready access to large scale systems via a general purpose network, and to provide the facilities for the conduct of distributed management research.

Geosciences. This program emphasizes fundamental research in geological processes that have a bearing both on specific DOE missions and long-term development of new energy technologies. Although most of the geoscience effort was originally directed towards problems relating to the development of geothermal energy using hot subsurface brines, emphasis is now being placed on a much broader range of potential applications including the isolation of radioactive wastes, the storage of heated or chilled water, and fossil fuel recovery.

Current research projects are concerned with the dynamics of liquid-dominated subsurface reservoirs, characterization of the physical behavior of fluid-saturated rocks under high temperatures and pressures, the theoretical description of the thermodynamic properties of strong, mixed electrolytes as a function of temperature and composition, and chemical reactions between rock forming minerals and groundwater at elevated temperatures. A new project to investigate chemical transport in natural systems has been started in which the physical and chemical interactions between solutes and minerals are studied during solute transport.

Also included in the geoscience program is a research project with applications to the recovery of energy from molten rock. In this project, thermodynamic and transport properties of magmas are being determined from experimental measurements of the physical properties of silicate liquids at high temperatures. Another project provides compilations of scientific data used by engineers and scientists developing geothermal energy.

In the future, the geoscience program will include research on the physical and chemical characteristics of minerals, with the use of nuclear quadrupole resonance spectroscopy. This technique has many potential applications in a broad range of energy technologies. Greater emphasis will also be placed on materials characterization, chemical migration and rock mechanics, in order to provide a scientific basis for solving problems in such areas as radioactive waste storage in rocks, acid mine drainage, in situ leaching of uranium ores, the storage of heated or chilled water in aquifers for energy conservation, and problems associated with deep underground excavations.

Bio-energy Conversion (AK 01 06) (FY 79 $0.6 M)

Bio-energy conversion, by the process of photosynthesis in green plants, supplies virtually all of the energy for living cells on earth. The Laboratory's work in this area is directed to improving our understanding of this fundamental process. The primary processes resulting from the light absorption events, the means by which oxygen is produced from water, and the metabolism and metabolic regulation in plant cells and leaves are being studied by a variety of biological, chemical, and physical methods. Regulation of phytosynthesis beyond primary photosynthesis is investigated by using plant cells in tissue culture and isolated leaf cells.

High Energy Physics (HK 02) (FY 79 $10.1 M)

The LBL high energy physics program is closely related to those at other DOE National Laboratories and foreign laboratories. It focuses on experiments with e^+e^- colliding beams using advanced techniques and developments initiated and perfected at LBL. A balance is maintained by continuing experimentation at FNAL and BNL. LBL has an especially close relationship in the collaboration with SLAC to build PEP, the 18-GeV positron-electron colliding beam facility to be completed in the autumn of 1979.

Physics Research (HK 02 01) (FY 79 $6.1 M)

Physics Research at PEP. Our major effort is the preparation for experiments to be carried out at PEP. We expect that a new spectroscopy of hadrons will be revealed by these experiments and that new and unexpected phenomena will be found as they have been in the past when increased energy has become available.

Three proposals in which LBL plays a key role have been selected by the PEP Experimental Program Committee: 1) the Time Projection Chamber, 2) the Mark II Magnetic Detector, and 3) the search for quarks.

The Time Projection Chamber is a radically new concept for particle identification and measurement. It will have exceptional capabilities for charge particle pattern recognition, momentum analysis and mass identification within high multiplicity jet-like events; neutral reconstruction (λ^o, K_s, π^o, η^o...); electromagnetic calorimetry and muon identification. This broad range of characteristics should give this detector a productive life well beyond the first phase of PEP's operation.

The Mark II Magnetic Detector is an instrument of substantially greater sophistication than Mark I which made numerous discoveries (ψ particles, charmed particles) over a period of four years at the SLAC storage ring SPEAR. Mark II is now continuing the annihilation studies in the 3-8 GeV energy range already initiated by Mark I at SPEAR, and it will be moved to PEP in 1980. Mark II will be the first general purpose facility in operation at PEP and, it is hoped, the experience of the previous running at SPEAR should permit rapid initiation of the research program at PEP. Recent results at Fermilab indicate that there are new structures to be studied in the PEP energy range.

The body of knowledge of present day high energy physics can be best understood in terms of the assumption that quarks are the fundamental building blocks of elementary particles. As yet no quarks have been observed, however. PEP opens up a completely new domain for the search of charged particles, and would be able to detect quarks of mass up to the maximum PEP energy of 18 GeV. This sensitivity should be sufficient that a negative result would raise serious doubts about the existence of these hypothetical objects, the quarks.

In FY 1980 the Time Projection Chamber (PEP-4) facility is expected to yield preliminary data in areas such as new particle searches, studies of interference effects between weak neutral and electromagnetic forces, studies of the limits of applicability of quantum electrodynamics, and studies of the details of hadronic production in electron-positron annihilation at high energies.

Research at FNAL and BNL. Experiments on rare muon-induced reactions are now underway at FNAL. These will continue into FY 1980. Even in the first events seen with the new 470-ton spectrometer designed by LBL, massive dimuon and trimuon final states have been identified.

When the new high energy, high intensity muon beam from the Tevatron is developed the spectrometer will be used for new studies there. Among the studies will be measurement of the inverse neutrino scattering process $\mu^+ + N \rightarrow \nu_\mu + X$ (X = anything). This reaction has never been observed except for leptons at rest. At high energies it would provide a unique opportunity for exploring the existence and properties at right-handed weak charged currents.

Neutrino and anti-neutrino interactions with protons and neon are being investigated by using the FNAL 15-foot bubble chamber. Several different experiments will soon be underway to obtain information about 1) the hadronic system in neutral current events, 2) vector meson production and 3) dilepton production by anti-neutrinos. A dichromatic beam with anti-neutrinos will be used to make precise measurements of the structure functions of the nucleon.

Further experiments with polarized proton and anti-proton beams are planned to study scattering of polarized particle beams from polarized targets. Construction of a polarized beam facility may begin in the near future.

A continuing flow of interesting and timely physics in the kaon nucleon system is possible by exploiting the new high flux kaon beams at BNL. A new experiment is in the initial discussion stage: the measurement of polarization effect in $K^- p \rightarrow K^o n$ elastic charge exchange. This kind of data will be of value in placing further restrictions upon phase shifts in the kaon-nucleon system.

Detector Magnet Design and Instrumentation. The aim of this LBL magnet program is to produce thinner and less expensive superconducting solenoid magnets for use in detectors for high energy physics research. Different schemes are being developed for quench protection of superconducting coils and for testing these schemes on specially built and instrumented test coils capable of triggered quenching. Techniques resulting from the program are being incorporated into the superconducting magnet for the PEP-4 detector and are being considered for magnets to be used in detectors at FNAL and CERN.

LBL work in high energy physics instrumentation is concerned with the development of instrumentation systems having broad and general application. It includes research and development of particle detectors and detector methods, computers and peripherals used for data acquisition in nuclear science and high-energy physics experiments. The future program will be heavily influenced by advances in detector methods and semiconductor technology arising from nuclear science and high-energy physics experiments. Data basing systems will be developed for fast and efficient readout from large-scale experiments. Microcomputers will be used increasingly to make rapid calculations and decisions to sort out data of interest and to improve the efficiency of handling large volumes of data.

Review of Particle Properties. This and other compilations of descriptive and bibliographic information on published articles, preprints, and current experiments are issued by the LBL Particle Data Center. The Berkeley Database Management System is used to maintain and query the various LBL data bases, which are also open to outside users.

Astrophysics and Astronomy. Studies are being made of galactical motion by means of measuring directional variations (anisotropies) in cosmic blackbody radiation. A NASA-sponsored satellite experiment is being designed as a part of this program. Our long range program of observing compact astronomical sources will continue, with observations made in both hemispheres and from x-ray and ultraviolet satellites as needed.

Theoretical Physics. LBL theoretical physics research is concerned with the study of fundamental particles. Particle theory encompasses the strong, electromagnetic and weak interactions of fundamental particles. The techniques employed range from rigorous field theoretical considerations to practical analysis and interpretation of experimental data.

LBL plans to continue a broad program in particle theory. The major areas of activity are expected to be topological expansion in S-matrix theory, gauge theories and quark confinement, applications of QCD, new particle spectroscopy and dynamics, gauge theories of weak and electromagnetic interactions, and the study of heavy-ion beams used for fusion energy applications.

Facilities Operations. Starting in FY 1980 LBL will be engaged in operation of PEP detectors, PEP experimental facilities coordination, computer electronics maintenance and operation of the superconducting laboratory. As the facilities built by LBL at PEP become operational, support will be necessary for operating and improving them and making them available to outside users. The completion of the PEP detectors will take place by the middle of FY 1980. Additional new initiatives are expected as the results from experiments at PEP lead to new ideas.

Accelerator Theory. Theoretical work on accelerators encompasses a broad range of activities, from direct contributions to design and development of operating and proposed accelerator facilities at LBL to collaboration with other laboratories on projects of mutual interest. The first category includes exploration of possibilities for a next phase of the PEP project, studies of high intensity phenomena and refinement of the theory of stochastic cooling. Examples of broader collaborations are participation in planning a $\bar{p}$-p colliding beam system at FNAL and renewed studies with BNL on intensity limitations in high energy accelerators and on the beam-beam limit.

High-Energy Physics Technology (HK 02 03) (FY 79 $4.1 M)

Advanced Accelerator Studies - PEP. After 3-1/2 years of design and construction, the first injected beam in the PEP electron-positron colliding beam facility is expected in October 1979. Circulating beam

will be available for experimenters soon thereafter. The collaboration between LBL and SLAC will continue with research and development activities in support of the operation of PEP. Both theoretical and experimental studies will be directed toward maximizing the operating capability and flexibility of the machine, as well as providing for long and short term improvements to the accelerator systems. Areas of significant LBL involvement include the injection and beam transport system, power supplies, magnets, alignment and beam correction, and computer control. Future developments include studies for achieving much higher energy electron-positron or electron-proton interactions.

Advanced Accelerator Studies: High Field Magnets. Present superconducting magnets for accelerators are in the 4 tesla range, but future accelerators and physics research will profit from much higher fields of 8 tesla or greater. To develop the high field magnets essential for the next generation of accelerators, both exploration of the limits of current materials and creation of new materials for conductors and supporting structures are being pursued. The necessary blend of expertise for this unique program has been gathered through collaboration between LBL specialists in basic materials science and accelerator magnet design. High field superconducting wire with useful plastic ductility in liquid helium is being developed. This project is complementary to LBL research on the cryogenic mechanical properties of structural materials. The magnet systems under study are applicable for such purposes as adding an electron-proton capability at the PEP facility or, particularly, in achieving the next generation of proton accelerators. The overall technology will be applicable to a wide variety of future magnet systems.

Advanced Accelerator Studies: Beam Stochastic Cooling. The new technology of stochastic beam cooling is expected to be important in the future plans at many accelerator facilities. To advance the theoretical and technological base for stochastic cooling designs and applications, LBL has mounted an experimental test of advanced hardware and theory in a stochastic-cooling system in the FNAL cooler ring. (The cooling by electrons is being carried out by FNAL.) Further development and applications at other facilities is anticipated.

Nuclear Physics (HK 03) (FY 79 $16.2 M)

Medium Energy Physics (HK 03 01) (FY 79 $0.7 M)

The Medium Energy Physics program is concerned with research using mesons and nucleons to probe the properties of matter. A major effort in medium energy physics is devoted to the use of mesons, nucleons, and nuclei to study fundamental nuclear interactions and their manifestations in nuclear structure. Experiments are planned for a number of sites, including the Bevatron, ZGS, TRIUMF, and LAMPF. The high energy gamma-ray spectrum produced when pions are captured in nuclei has been studied, and these results are being compared with those from electron scattering and photo-pion production near threshold and muon capture processes on the same nuclei. New phenomena have been seen, including giant dipole states, possible quadrupole excitations and other more complex states.

Heavy Ion Physics (HK 03 02) (FY 79 $14.9 M)

As a leading international center for research in heavy-ion science, the Laboratory pursues a varied program employing its three heavy-ion accelerators, the SuperHILAC, the Bevalac, and the 88-Inch Cyclotron, a combination unique in the world. The DOE Heavy Ion Physics Program supports the operation of the SuperHILAC, the 88-Inch Cyclotron, and two thirds of the operations of the Bevalac, as well as the extensive LBL heavy-ion research programs.

LBL Heavy-Ion Accelerators. The SuperHILAC provides beams from ^{4}He to ^{208}Pb at energies up to a maximum of 8.5 MeV per nucleon; it is the only source of the heavier beams in the United States. Under computer control, the SuperHILAC routinely delivers one ion beam to one or two SuperHILAC users and a second ion species to the Bevalac for acceleration to much higher energies. Both the SuperHILAC and the Bevalac are operated by LBL as national facilities open to all qualified users. Approximately half the available research beam time is used by outside experimenters from many US and some foreign universities and other national laboratories.

The Bevalac is comprised of the SuperHILAC coupled to the Bevatron through a beam transfer line. This combined machine accelerates particles ranging from protons to ^{56}Fe nuclei to energies from 100 MeV per nucleon to 2.2 GeV per nucleon. The capabilities of the Bevalac are found nowhere else in the world, although several proposed machines in Europe, Russia, and Asia would have similar performance.

A major improvement now in progress at the SuperHILAC and the Bevalac is the uranium beams project, whose goal is to permit acceleration of all nuclei including uranium at each machine. This project requires installation of a new high mass injector system at the SuperHILAC to provide reliable operation with intense ion beams of any mass. At the Bevatron, a completely new ultra-high vacuum system (10^{-10} torr) will be inserted within the main ring to allow acceleration of partially stripped very high-mass ions. This project is scheduled for completion in FY 1981.

Although the U-Beams project is a substantial modification, accelerator and facilities improvements are a continuing effort at both machines to keep them at the frontiers of relevant research. Current plans at the SuperHILAC include increasing the duty cycle for the heaviest ions and adding an rf cavity after the poststripper tank to achieve very short time structure in beams for TOF experiments.

At the Bevalac, the first generation of experiments is now complete, and the wealth of information gained is guiding the design of the next level of research. The requirement for high multiplicity, large solid angle detection systems has led to a major revamping of the experimental area. The most impressive new detectors, both of which will come on line in mid-1980, are the Plastic Ball (100 module detector, 4π geometry, built by a GSI-funded group in collaboration with LBL) and the Heavy Ion Spectrometer System (HISS - a 1 meter gap, 2 meter diameter, 3 Tesla superconducting dipole). Another new facility, just

finished, is the Low Energy Beam Line, created to provide exceptionally high dispersion for high-precision spectroscopy and related experiments within the 30 to 200 MeV/nucleon energy range.

Both machines also have substantial programs in development of existing and new types of ion sources to deliver new ion species and greater intensity, as well as continuing efforts to extend computer control and beam time-sharing and splitting to increase operational flexibility, reliability, and research multiplicity.

The 88-Inch Cyclotron accelerates beams of ions from protons to ^{40}Ca ions at energies from 55 to 6 MeV per nucleon, respectively. For light ions this is intermediate between the SuperHILAC and Bevalac. Important advantages of the 88-Inch are that its beams are continuous rather than pulsed and that very high energy resolution can be achieved. A program to boost the main magnetic field of the cyclotron has been completed which increases by 15 percent the upper energy limit for all heavy ions (i.e., the magnet K value will become 160). Although the 88-Inch Cyclotron has not been designated as a national facility, it supports a strong outside user program with about as many hours per year as the two LBL national facilities.

The most significant upcoming improvement project for the 88-Inch Cyclotron consists of the development, construction, and implementation of an advanced high-charge-state ion source. Considerable research in foreign laboratories has demonstrated performance far surpassing our present PIG sources. Such a source will at least double the heavy-ion beam energies now available from the 88-Inch Cyclotron and will maintain a vital role for the Cyclotron and its users throughout the next decade.

Planning for the VENUS (Variable Energy Nuclear Synchrotron) accelerator and storage ring complex is now in progress, and the component R&D will begin in the near future. VENUS will not only cover the Bevalac performance range, but will enormously extend it at both the low and high energy ends, while additionally offering heavy ion colliding beam interactions at very high center-of-mass energies.

Research at the SuperHILAC and 88-Inch Cyclotron. In the research at these two accelerators three areas emerge as of special current importance:

1) The mechanism of nucleus-nucleus collisions. In recent years, a wealth of new phenomena has been uncovered by the study of collisions at low and intermediate energies between heavy ions and target nuclei. Of particular interest is the totally unexpected discovery of "deep inelastic scattering." In these collision events, the heavy ion projectile, rather than being absorbed by the target nucleus, goes into a temporary orbit, loses much of its kinetic energy, then separates again. Currently being explored are attempts to determine the relative importance of giant resonances and of particle transfers in the exchanges of energy, angular momentum, mass, and charge occurring during these

collisions, and in measuring the possible different time scales for these exchanges. There are questions which remain to be answered about the alignment of the angular momentum transfer, and the possible emission of non-equilibrium nucleons. Although the processes involved in deeply inelastic reactions are now roughly established, the connections with microscopic theories remain unclear. In high resolution studies of nucleus-nucleus collisions, a promising new development is the discovery that inelastic scattering of heavy ions at 20 MeV per nucleon excites giant resonances more favorably than the counterpart hadron and electron scattering. Efforts are now underway to study the subsequent fission decay of these modes.

2) The study of nuclei under rapid rotation. In traditional nuclear spectroscopy, the properties of individual nuclear states (energy, angular momentum and other quantum numbers) are measured. In many collisions of heavy ions with target nuclei, the colliding partners coalesce to form a compound system that is highly excited in energy and is also in extremely rapid rotation. Much energy--but little angular momentum--is promptly lost by the emission of particles; this leaves the system relatively "cold" but still rapidly rotating. Further decay takes place by emission of gamma-rays whose detection provides information about the angular momentum, energy and shape of the nuclear system. It now appears that most nuclei, even semi-magic ones in the ground state, eventually deform with increasing angular momentum to show rotational behavior at high spins. In some nuclei there is even an indication of a large increase in deformation towards a two-to-one axial ratio (the same as in the second potential minimum for spontaneously fissioning isomers) at very high spins. The energies available at LBL are sufficient to study the compound nucleus up to angular momenta where the liquid drop limit is surpassed, and the system flies apart in fission.

3) The preparation and study of "exotic" nuclei. The initial impetus for the use of heavy-ion beams at LBL came from their usefulness in the production of "exotic" nuclei, especially those with a large number of protons, i.e., new heavy chemical elements. The discovery and characterization of new transuranic elements continues to be an important activity at LBL. Two approaches are in use--the stepwise synthesis of one new element after another beyond those currently known and attempts to jump directly into the region of elements 110-114 where some nuclear theories predict greater stability. So far, attempts to detect the formation of relatively long-lived "superheavy" elements by chemical separation from targets bombarded with heavy ions have been unsuccessful. It is not yet clear whether this is due to failure of the superheavy nuclei to be formed in the first place or--contrary to expectations--to their lack of stability. Of equal interest in studies of exotic nuclei is the extension of our knowledge of the limits of nuclei with large neutron excess or deficiency. A general system, capable of on-line mass analysis of radioactive species with half lives as short as 50 ms, has recently become operational at the 88-Inch Cyclotron. With this instrument, known as RAMA for Recoil Atom Mass Analyzer, the decay modes of the exotic light nuclei ^{20}Mg

and ^{24}Si have been identified, testing fundamental properties of the charge independence of nuclear forces. The versatility of the system will permit studies of nuclei far from stability for the vast majority of the chemical elements.

Research at the Bevalac. At beam energies from the top of the 88-Inch Cyclotron range up to the relativistic Bevalac beams, nuclear physics enters into totally unexplored territory that merges smoothly with high energy physics. At energies of about 20 MeV per nucleon, two important frontiers are crossed--the Fermi energy and the velocity of "sound" in nuclear matter. When a collision occurs at an energy above the Fermi energy the nucleons of one nucleus can penetrate freely into the second without occupying the same quantum states and therefore without inhibitions arising from the Pauli Exclusion Principle. It is therefore to be expected that nuclear matter at double normal density will be formed. As the collision velocity is increased into the relativistic regime (Bevalac), the Lorentz contraction of the projectile (a factor of 3) should lead to nuclear matter zones up to six times normal density. In the entire history of nuclear physics, it has not been possible to study nuclear matter at densities other than those of normal nuclei. The compressibility of nuclear matter is known only at normal density.

With nuclear collisions at velocities exceeding the speed of sound in nuclear matter, a shock wave front can be formed. This is a transient zone of much higher density. Although no experiment has yet simply revealed this phenomenon, it is known that heavy-ion reaction studies at 20 MeV per nucleon demonstrate a rapid transition in their nuclear structure mechanisms. The importance of deeply inelastic scattering and fusion processes diminishes, with a concomitant increase in the cross section for multibody fragmentation phenomena.

A related area of fundamental importance is the equation of state of nuclear matter: i.e., the energy as a function of density. There have been many theoretical models about how this should behave. These models often predict phase transitions; one possibility in high-energy nucleus-nucleus collisions is the formation of quark matter, in which quarks rather than nucleons are the constituent particles. Prior to the Bevalac experimental investigations, our knowledge of the equation of state was confined to the one point given by essentially ground state nuclei; now, a view of nuclear matter can be obtained under rather different conditions.

It has already become clear that the collision of one nucleus with another leads to the formation in the overlapping region of an intensely hot cloud of nuclear matter--a "fireball." In some respects, this resembles on a microscopic scale the state of the universe at an extremely early stage of its expansion. Studies of how the fireball expands and cools are in progress; the results will be of much interest to astrophysicists as well as to nuclear physicists.

In early experiments with relativistic heavy ions, a fragmentation process was uncovered. When the projectile heavy ion makes only peripheral contact with the target nucleus, it usually breaks apart into smaller nuclei (fragments) that continue to move forward with almost no loss of velocity. This process has been exploited in bombardments of Be targets by ^{48}Ca beams from the Bevalac to discover the existence of 14 new isotopes far from stability, a major step toward delineating the neutron drip line in the lighter elements. The fragmentation process is of great importance in cosmic ray physics. Cosmic ray nuclei observed in satellite experiments have traveled enormous distances through space and have suffered fragmentation by collisions with nuclei in the interstellar gas. It is now possible to correct the observed composition of cosmic rays back to what they must have been at the initial source. The high energy beams of the Bevalac themselves represent an intense and accessible source of artificial cosmic rays. Through special arrangements between DOE and NASA, Bevalac beams are made available at no cost for the test and calibration of instruments that will be flown in satellites. The performance of these sophisticated and expensive devices has been greatly improved, as has the probability that they will work properly after launch.

Continuing emphasis is being placed on providing modern instrumentation and computer analysis capability able to meet the sophisticated needs of experimenters at all three accelerators. The superconducting spectrometer at the Bevalac (HISS) will be a forefront instrument when it becomes operational in 1980. Modular detector systems appropriate to HISS and other Division instruments are being developed with an emphasis on multiparticle capability. The severe problems of sorting and processing the multi-parameter data produced in experiments will be tackled by exploring the development of a new configuration of computers and hardware (DATA CENTER) designed to speed up such sorting and to permit close interaction between the physicist and the data sorting operation.

Nuclear Theory (HK 03 03) (FY 79 $0.6 M)

This program concentrates on areas of nuclear theory that guide and interact strongly with LBL experimental work. In the description above of the experimental work, the importance of the theory program has been emphasized.

For several years the theory group concentrated its main efforts in the new area of relativistic nuclear collisions. With a varied program now underway, an additional area of concentration has been added, deep inelastic phenomena. The work of the scientific staff is divided roughly between these two areas.

The effort in relativistic nuclear collisions is divided between research aimed at the immediate experimental situation, and longer term development of ideas and techniques. In the first category, for example, the theory of identical pion interferometry has been formulated with greater rigor, and the important effects of final state interactions on

the correlation function have been incorporated. It has been demonstrated that in principle the fraction of pions produced in coherent processes (such as pionic instabilities triggered in the dense region temporarily produced in high energy collisions between nuclei) can be measured through observations on the two-pion correlation function. This constitutes the only definite signature for coherent processes that has so far been identified. Future work in this area will involve the calculation of distortions of the correlation function caused by final state interaction of the pions with each other and with the nuclear medium. In the longer term the theory of hot dense hadronic matter will be studied in various approximations including relativistic mean field theories. So far the statics has been studied but the ultimate goal is to understand the dynamical evolution of such matter.

In connection with deep inelastic phenomena the theory of nuclear dynamics dominated by one-body dissipation is being developed. Further investigations will involve analyzing some of the features of the theory with time-dependent Hartree-Fock calculations and comparison with experimental trends in a number of observables.

ENVIRONMENT AND HEALTH

DOE: A/S Environment (EV)

OVERVIEW

The production and use of energy bestows great benefits on society, but has adverse impacts as well. These impacts--to human health and well-being, and to the environment--should be under constant evaluation as our energy system develops in the future. Lawrence Berkeley Laboratory carries out a program of assessment of energy-related risks and impacts in these areas:

1. Study of effects on human health of exposure to energy-related environmental pollutants.

2. Study of the chemistry of formation and transport of particulate and gaseous pollutants from fossil fuel combustion.

3. Development and assessment of instrumentation for monitoring environmental pollutants with increased accuracy.

4. Study of distribution and ecological effects of toxic substances in inland water and marine systems.

5. Analysis of energy systems and alternative energy futures.

Environmental Research and Development (GK 01) (FY 79 $6.5 M)

Overview and Assessment (GK 01 01) (FY 79 $1.5 M)

Energy Impact Assessment. The function of this program is to carry out energy-related analyses and assessments. These interdisciplinary analyses examine the economic, environmental, institutional, social, and health impacts and constraints associated with implementing energy technologies, national energy policies, DOE regulations, and RD&D programs. LBL has collaborated with other DOE laboratories in national assessments of accelerated coal use, geothermal, and solar energy technologies. Present and future assessments include synthetic fuels, oil shale, industrial energy use, and other technological developments. LBL is responsible for the national-level socioeconomic analysis as well as integrated assessments for Federal Region 9. In part this entails maintaining comprehensive data and intimate familiarity with regional characteristics so as to provide input to DOE energy supply scenarios, but the main effort is on analysis of significant regional, state, and local issues, such as siting, air quality, water, regulations, and economics, that conflict with national policy and plans. LBL has developed a Socio-Economic Environmental Demographic Information System (SEEDIS) which provides researchers and planners with a comprehensive, computer-based system for data management, analysis and display capabilities. The SEEDIS system presently contains several large databases

such as the 1970 Census, air quality data, geographic base files and land use data. Expansion of SEEDIS with 1980 Census data will greatly increase the demand for data and for analytical capabilities. LBL will be a unique resource providing access to portions of both the 1970 and 1980 Census for analysis, modeling and time series studies.

Environmental Fossil Energy Engineering. LBL is investigating a range of complex environmental problems associated with the conversion of fossil fuels to usable energy forms. This program is developing and applying fundamental knowledge of the chemistry, physics, and biology of the interaction of fossil energy technologies with the environment. Recently, the program has developed a range of analytical methodologies, techniques and instrumentation to assess unique impacts of fossil energy technologies. These include instrumentation to make continuous on-line measurements of volatile elements in gas streams, a continuous flow laboratory bioassay technique to simulate high mountain stream environments, methods to measure organometallics in complex aqueous matrices and high precision instrumental techniques to characterize process solids.

The program has also demonstrated that oil shale solid waste (spent shale) may be used to remove large quantities of contaminants from process wastewaters, thereby significantly reducing treatment costs. In studies of environmental effects of in-situ oil shale processing, advances have been made in controlling ground subsidence and aquifer disruption. These types of investigations will be continued in the post-1980 period and emphasis will shift from methods development and fundamental studies of environmental problems to the development of control technologies. The basic chemical and physical data developed will be used to assess the environmental impacts, and suitable controls will be identified and evaluated.

In a proposed new area of work, processing technology would be developed for condensate waters from coal conversion, shale retorting, and biomass pyrolysis, to remove toxic constituents and salts, reduce environmental releases of water, and identify efficient and reliable methods of processing. Numerous contaminants have been identified in these waters, some for the first time.

Biomedical and Environmental Research (GK 01 02) (FY 79 $5.0 M)

Human Health Effects. These studies deal with adverse human health effects resulting from exposure to environmentally related pollutants. They include both laboratory and epidemiological approaches to the problem. In FY 1978 a major five to ten year study has been launched on the health effects associated with the petroleum refining, transporting and processing industry. In this study, health effects will be evaluated both from the occupationally exposed and environmentally exposed populations. Early emphasis has been on the development of worker rosters through the cooperation of the involved unions. Work is also underway to sample the health status of people exposed in the regions surrounding processing centers. The Laboratory is also engaged in a major survey

of the health status of workers in national laboratories who have had significant exposure to intense magnetic fields, with the purpose of evaluating the hazards to health associated with such exposure.

A group of LBL studies concern the effect of pollutant exposures on the principal endocrine and neuro-endocrine functions of the living mammalian organism. Attention has been particularly focused on the effects of ozone produced in combustion and by photochemical reactions in the atmosphere. There are significant disturbances of the thyroid gland and its pituitary control as well as actions on the sexual controlling hormones as evidenced by altered fertility and fecundity.

These programs will continue at their present level with respect to laboratory studies. The studies on the effects of petrochemical exposures on human populations will require significant expansion to achieve their goals in a timely fashion. The studies on effects of high intensity magnetic fields on humans will be completed in FY 1981.

The epidemiological factors of both indoor and outdoor air pollution are being investigated by the Populations at Risk to Environmental Pollution project, which involves development of a broadly encompassing data base of pollutant and disease incidence data. A proposed new area of investigation would study the possible association of certain cancers with specific air pollutants in geographic areas. Data from existing surveys (Third National Cancer Survey and EPA surveys) would be correlated. Indoor air pollution, perhaps exacerbated by more tightly sealed buildings designed for energy efficiency, is being characterized as to sources (combustion, building materials and furnishings, appliances, etc.) and types (CO, NO_2, particulates, organic compounds, radon, etc.). Future work on indoor pollution will focus on effects of heating and cooking practices, and sampling target populations for respiratory effects, taking into account such concommitant factors as occupation, smoking, and pulmonary function.

Another proposed investigation would be additional characterization of radon emanations from soil-gas, building materials, etc., by measurements in existing conventional and new energy-efficient buildings. Future studies would relate building design to radon reduction and control, and estimate the risk to populations in conventional and energy-efficient buildings.

Health Effects Research in Biological Systems. A major program goal is to evaluate systems damage in man from exposure to toxic agents arising from energy sources, including both chemicals and radiation. These effects are being studied at several levels: the cell, the organ, and the whole animal. LBL has been given primary responsibility for systems involving magnetic fields and cosmic radiation. The former is relevant to fusion, MHD, and energy storage technologies, the latter to the Space Power Satellite.

Studies are being directed at late and long term effects, including carcinogenesis, mutagenesis, and effects on vision and the nervous and

reproductive systems. In one program, examination continues of a population of primates exposed over the last two decades to plutonium.

The effects of pollutants on lung are being studied, with special emphasis on gases and polycyclic hydrocarbons generated by energy supply technologies. The carcinogenesis and mutagenesis research will increasingly emphasize development of methods and test systems for validation of laboratory findings in human beings.

Atmospheric Aerosol Research. The principal thrust of this LBL program is an understanding of the formation and transport of particulate and gaseous pollutants generated by fossil fuel combustion. The major emphasis is to determine the extent to which primary particulates contribute to the ambient particulate burden, and the role these emissions have in forming secondary aerosol species.

By using a newly developed technique to quantitate the graphitic soot and organic material, it has been found that primary carbon is a major component of the ambient carbonaceous aerosol burden. Other recent accomplishments include a reaction kinetics and rate study of SO_2 oxidation in water droplets containing soot particles. Future directions will focus on the formation of nitrogenous and organic aerosol species by heterogeneous reactions, and on determining the regional and seasonal differences in the concentration of primary and secondary carbonaceous particulate material.

Instrumentation Development and Techniques. At LBL there is close and fruitful collaboration between instrumentation development and research work in the environmental sciences. The goal of the instrumentation program is to increase continuously the precision with which environmental impact of energy technologies can be characterized. The program includes R&D on components for new instruments, development of improved or new methods, and design and demonstration of specific instruments and monitoring systems in the field. Development of instruments and measurement techniques embraces a broad range of physical analytical methods, including laser opto-acoustic spectroscopy. The x-ray fluorescence and Zeeman-effect atomic absorption methods and instruments developed at LBL are now widely used in environmental research and in government monitoring programs. Techniques based on millimeter wave absorption and laser absorption and scattering are being investigated. The further development of electrochemical methods applied to water monitoring is also being pursued.

Capabilities have been developed for radiation monitoring, particulate analysis, and assessing common gaseous contaminants. In the future, increased emphasis will be placed on techniques providing information on the chemical state of elements in plumes, combustion chambers, and the environment. This knowledge is essential for developing an understanding of the pollutant sources and chemical transformation processes in the environment. Techniques for assessing occupational hazards in the energy industry will also be pursued.

LBL is conducting an ongoing survey of available instruments and methods for measuring environmental pollutants, and has published results in a four volume, continually updated report (the Survey of Instrumentation for Environmental Monitoring). The four volumes cover air, water, radiation, and biomedical instrumentation.

The purpose of one project is to develop and investigate the laser optoacoustic spectroscopy of gases, liquids, solids, and aerosols. A primary objective is to develop an ultra-sensitive multiparameter molecular detector for the characterization of trace contaminants. A recent accomplishment was to attain a detection level of 25 parts per trillion for hydrocarbons with a novel design optoacoustic detector that operates in a windowless mode (thus enabling continuous real time monitoring). A second accomplishment is the investigation of urban aerosols by photoacoustic spectroscopy. Future directions include developing optoacoustic detectors for liquid pollutants, an ammonia optoacoustic detector, and an elemental detector for trace metals. Research will continue on the optoacoustics of urban aerosols, and a state-of-the-art capability will be maintained in optoacoustic spectroscopy and detection.

A project on field dosimetry will develop a sensitive and simple magnetic dosimetry technique for occupational exposures to magnetic fields in fusion and magnetohydrodynamic plants. Recently the feasibility of using ferro-nematic liquid crystals as the dosimeter has been proven experimentally, and the sensitivity level established. Future work will extend to ferro-cholesteric liquid crystals and the construction and testing of optimized dosimeters. The final prototype device will be field tested.

Another project is developing a personal dosimeter for exposure to organic gaseous pollutants. Recently a chemically stable temperature insensitive cholesteric liquid crystal mixture was developed, and a range of sensitizers to adjust concentration thresholds was devised. Future research will aim to achieve detector specificity by incorporating a chromatographic column in the detector, and to construct and field test the final prototype. In conjunction with these activities research on the basic physics of the device will continue.

Neutron activation analysis (NAA) is another component of the Laboratory's capability in trace element analysis. Neutron activation analysis is used to provide chemical measurements of high accuracy and precision. Recent work includes measurements of oil shales and geochemical samples. (Analysis of certain sedimentary rocks indicated an extra-terrestrial origin for one of the elements, iridium. The deposition of the iridium coincided with the great extinction of nearly half the life forms on earth about 65 million years ago and may lead to an understanding of the cause of this extinction). Future research will include applications of NAA to waste isolation and ocean thermal energy conversion.

The identification, understanding, and prediction of energy technology effects on terrestrial and aquatic ecosystems is the focus of a proposed

research program. Laboratory ecosystems are being used to develop new measurement techniques for eventual field application, to study changes occurring in the natural environment, and to assess direct toxic effects. In particular, research would focus on energy technology effects on decomposition activity in ecosystems. These processes are a crucial link in the nutrient cycle and would be studied along with other biotic and abiotic parameters necessary to the understanding of ecosystems. The approach to be taken is an outgrowth of a recent accomplishment in microcosm research at LBL--demonstration that systematic manipulations of lake water detritus can be used to measure a number of hitherto unexplored properties intrinsic to decomposition activity. Concomitant theoretical work would explore and predict ecosystem stability properties as they relate to measured parameters, suggest new experiments, and analyze interactions between various constituents of the ecosystems. Beyond 1980, both experimental and theoretical research would focus on applications and development of new assessment methods to realistic environmental concerns with extensions to systems other than lakes. Research would continue on acid precipitation and pollutants from coal-conversion processes.

Structural Biophysics. The goal of this program is to understand the structure-function relationship of several biological systems at atomic resolution. Three lines of research are being pursued, primarily through the use of x-ray crystallographic techniques. These are: 1) recognition complexes between protein and DNA, 2) DNA-carcinogen complexes, and 3) initiation of crystallization of a light-harvesting protein complex and a nitrogen fixation enzyme.

Tumor Promotion: Identification and Mechanism of Action. It is now accepted that chemical carcinogenesis occurs in at least two distinct stages: initiation, usually by chemical carcinogens, and promotion brought about by a vast and as yet not well defined class of compounds termed tumor promoters. A recent LBL proposal is that viral carcinogenesis may also be a multistep process analagous to chemical carcinogenesis, and that the product of the sarcoma specific region of the viral genome could function like a well known phorbol ester tumor promoter. The test system (avian cells transformed by temperature sensitive mutants of Rous sarcoma virus at the non-permissive temperature) will be used for detection of promotion activity of phorbol ester derivatives using a variety of tests including two-dimensional protein gels. Novel derivatives will also be synthesized and isolated from latex of *Euphorbia* species for structure-function studies and for elucidation of the role and mechanism of action of tumor promoters. An eventual goal is the synthesis and identification of "anti-promoters".

Chemical Mutagenesis and Carcinogenesis. Chemicals released into the environment during energy production and utilization have mutagenic and carcinogenic activity. This research strives to understand the mechanism of action of these chemicals. The approach is to determine how chemicals alter the structure of nucleic acids and to study the relationship of these structural perturbations to functional alterations. Various biophysical and biochemical techniques have been used to measure

the destabilization of the DNA helix caused by known mutagens and carcinogens, and these effects are being related to the inhibition of DNA replication. The research will continue to focus on specific lesions in DNA and how they affect DNA synthesis. The goal is to understand how cells process these lesions and whether escape from DNA synthesis inhibition causes changes in cells related to cancer.

Life Sciences Research and Biomedical Applications (HK 01) (FY 79 $6.0 M)

General Life Sciences (HK 01 01) (FY 79 $1.5 M)

General Life Sciences. This research program applies advanced concepts and techniques of chemistry and physics to important problems of biology. The capture, storage, and utilization of energy in biological systems, and their response to environmental agents at both cellular and organismic levels are the principal concern of the program. Also important are the development of research methods such as electron diffraction and high resolution electron microscopy to investigate complex biological structures at the molecular and atomic level. Studies are underway of blood-cell development and their membrane response to various agents; molecular level DNA repair mechanisms; the structure and function of nucleic acids; study of the genetics and biochemistry of yeast toward a more generalized understanding of genetic mapping and recombination, mutagenesis, and x-ray sensitive mutants; an evaluation of human cancer risk from exposure to carcinogens and possible modifications to this risk from such factors as demography, age, time of occurrence, and the degree of exposure to carcinogens; and examination of light excitation and photochemical energy transfer in both green-plant and bacterial photosynthesis.

Biochemical Studies. The goal of this research is an understanding of the processes involved in initiation and propagation of environmental damage to mammalian cell membranes. The investigation focuses on how damage is spread intracellularly and which metabolic activities are most affected. Research is proceeding on the effects of several oxidants, 1) oxygen species produced by visible light activation of endogenous membrane photosensitizers and 2) ozone, probably the most damaging pollutant in the urban environment.

Another investigation addresses the goal of enhancing ammonia and food production by improving the bioproductivity of blue-green bacteria culture systems. Several species of algae are being examined in studies of the functional relationship between hydrogen consumption, nitrogen, fixation, and photosynthesis in these organisms.

Cellular and Molecular Biology of Cancer. The goals of this multifaceted task are to understand the fundamental mechanisms involved in cell-cell and cell-environment interactions that regulate gene expression in normal and malignant tissues. The approach is to set up both fibroblastic and epithelial model systems with relevance to the physiological state of the tissue *in vivo*. Through this research conditions have been created for high levels of collagen synthesis in avian tendon cells, and

studies are being made of the regulation of this important function by ascorbic acid, oncogenic viruses, and tumor promoters. Conditions are also being defined for mammary specific functions in both human and mouse systems. A critical evaluation of how cells interact with their environment should lead to elucidation of how cells retain their normal state under hostile conditions or how they become diseased and cancerous, and how they age. Appropriate biological indicators of hazards to man cannot be developed without understanding the underlying cellular mechanisms that keep him functioning and healthy.

Molecular Biology of Nerve Cell Function. This research examines the response of the nervous system to environmental and chemical stimuli. The principal areas of study are 1) use of selected toxins as probes to study the structure and function of receptors for nerve transmitters (particularly in the mammalian central nervous system), 2) influence of drugs on brain chemistry (with emphasis on the neurochemical steps of long-term memory function in the brain), 3) brain changes associated with brain stimulation, including hibernation, and 4) recovery of function after brain damage.

^{3}H and ^{14}C Labeling for Bio-Medical Research. In order to follow the uptake and metabolism of compounds in living systems there is a great need for available, high-specific-activity radiotracer compounds. Such high-specific activity chemicals permit rapid progress in understanding the basic mechanisms of carcinogenesis and mutagenesis, in estimating the hazards from energy-related pollutants (such as the emissions from diesel engines), and in developing additional methods for the diagnosis of human disease.

LBL has two unique facilities for pursuing ^{3}H and ^{14}C labeling studies: a laboratory in which ^{3}H labeling may be safely studied at the 10^{4} curie level, and a carbon ion accelerator that can irradiate organic substrates at any kinetic energy from zero to 5 keV. Present LBL tritium labeling studies are directed toward understanding the mechanisms of, and enhancing the utility of, the microwave discharge method, by which T atoms (from T_2 molecules) react with organic targets. Any organic compound may be tritium labeled by this procedure. Correspondingly, any organic compound may be labeled by $^{14}C^{+}$, $^{14}CH^{+}$, $^{14}CH_2^{+}$, or $^{14}CH_3^{+}$ ions in the ion accelerator.

Biophysical Chemistry. The purpose of this research is to apply a variety of biophysical techniques, including magnetic resonance, optical, and x-ray absorption spectroscopies; theoretical modeling; and chemical synthesis to study fundamental processes of membranes, cells, nucleic acids, proteins, and nerves. The results are applicable to problems of solar energy, nitrogen fixation, carcinogenesis, drug-membrane interactions, DNA replication, and damaging effects of pollutants produced from fossil fuel combustion and from nuclear energy production. The x-ray absorption spectroscopy will become far more valuable in 1980 when the PEP project at the Stanford Linear Accelerator becomes operational, and the SPEAR storage ring becomes available for roughly half-time dedicated synchrotron radiation research.

Effects of Pollutants on Membranes. This program seeks to characterize the early effects of environmental toxicants and to develop new methods to detect effects of pollutants on membrane structure of mammalian cells. The effects of hazardous environmental agents including free radicals generated by visible light and by atmospheric gases like oxygen and ozone are being investigated to determine the temporal sequence of damage at the membrane level. A further objective of our study is to develop efficient biochemical protection mechanisms.

Results demonstrate that oxygen radical species participate in damage propagation of flavoprotein systems of membranes and in the photodestruction of the heme protein catalase. A new method for determining ozone damage to membrane lipids based on electrical conductance measurements has been developed. In future studies the mechanism of the photodestruction processes, including use of spin trapping techniques for hydroxyl and organic radical detection assessing photooxidative damage will be emphasized.

Biomedical Applications (HK 01 02) (FY 79 $4.5 M)

Medical applications of nuclear technology continue to be a significant part of the Laboratory program. Emphasis is on development of new diagnostic techniques for detection and quantification of disease. Methods with potential application in the diagnosis and treatment of disease arising from exposure to environmental pollutants are a particular research goal. Studies primarily are cancer, cardiovascular and pulmonary disease.

A major constituent of LBL biomedical programs is the Bevatron/Bevalac, the only facility in the world where heavy ion beams are produced and investigated for therapeutic applications. The principal objective is the initiation of full-scale patient therapy trials, and in support of this objective radiobiology and dosimetry studies are providing precise evaluation of the physical and chemical interactions of heavy ions with biological systems. The advancement of heavy ion radiodiagnostic techniques is an associated goal as are space biology studies to characterize the potential hazards of heavy cosmic rays.

The Research Medicine Clinic is continuing its long-term follow-up of patients exposed to or treated with ionizing radiation. Animals are used to develop research techniques which will be applicable to the study of environmental effects on man. The LBL Metabolic Ward provides a safe, controlled environment for the performance of investigative endocrine and metabolic testing on tumor patients. The acute and long-term effects of localized heavy ions on normal tissue as well as pituitary tumor tissue will be derived from study of this population. High energy alpha particles are used successfully to control pituitary hormone secretion and reduce the mortality and morbidity of acromegaly, Cushing's disease, Nelson's syndrome, and more recently, prolactin-secreting tumors.

The Laboratory plans to continue development of radionuclides and radiopharmaceuticals for scintigraphic and dynamic quantitative physiological studies. Three-dimensional reconstruction of the organ distribution of injected or inhaled material will be facilitated by new instrumentation and computer applications. Specific applications include the study of flow and metabolism in the brain, heart, lungs, kidneys, and bone marrow.

Irradiation of pituitary tumors with heavy ion particles is the parent program for the use of heavy ions in the treatment of cancer. With the use of helium ions or other heavy particles, it has been possible to overcome the relative insensitivity of the pituitary to externally delivered radiation without irradiating the hypothalamus and large volumes of surrounding brain tissue. This project is providing data on acute and long-term effects of heavy particles on normal and tumorous tissues and is expected to make further contributions to the understanding of the endocrinopathies associated with the pituitary.

A new direction is investigation of the feasibility of using high-energy radioactive beam particles for diagnostic procedures. Human patients will not be involved in these studies, and phantoms will be used to simulate bone, tissue, air and fat. The technique uses high-energy radioactive beams and gamma-ray coincidence detection. The problem of initial interest is the localization of a Bragg ionization peak in a heterogeneous medium such as human tissue. Later, this method can be extended to diagnostic procedures such as local blood circulation rate in a microregion, or to examine heart valve action.

As an element of the Laboratory's continuing search for methods of assessing the biological impacts of energy production and use, three-dimensional reconstruction is being developed of the organ distribution of injected or inhaled material at various times after administration. As the major site of damage from gaseous pollutants, the lung is being studied with respect to immune system response, effects on lung pathology, and blood-borne effects on other organs. The objective is not only to advance understanding of the basic growth and regenerative processes in the normal and damaged lung, but also to develop an immunologic method for assessing the magnitude and type of pulmonary damage in the human population.

ENERGY SUPPLY TECHNOLOGY RESEARCH AND DEVELOPMENT

DOE: A/S Energy Technology (ET)

OVERVIEW

Under the sponsorship of the Assistant Secretary for Energy Technology, the Laboratory carries out applied research programs in a number of resource areas. The largest efforts are in geothermal energy and magnetic fusion, with smaller programs in fossil and solar energy.

The strategy of the Laboratory's geothermal energy program is to assist in the commercial utilization of hydrothermal resources through earth sciences and engineering, engineering design and development of wellhead systems, program management for various joint projects, technical liaison with the geothermal industry, and development of a geothermal database. LBL has been assigned major responsibilities in the areas of binary systems development, hydrothermal reservoir engineering, and investigations of subsidence.

The LBL program in fusion energy has four components: These include the development of systems to heat and/or ignite the hot plasmas of large experimental fusion devices by injection of neutral particle beams; exploration of new concepts in magnetic confinement; theoretical and experimental studies on magnetic confinement, heating, and relevant atomic processes; and development of heavy-ion accelerators as drivers for inertial confinement fusion.

The Laboratory's program of solar energy research encompasses three elements: basic research to build a solid scientific base for economic solar technologies; development and assessment of a variety of solar technologies, and assessment of the environmental, health, and socio-political impacts of solar energy development. The program is conducted in close coordination with the Solar Energy Research Institute.

Coal is the nation's most abundant and versatile fossil energy resource, from which virtually every means of delivering energy can in principle be derived. Before coal can fulfill its potential to be one of our major energy sources, however, economically sound ways must be found to convert solid coal to more convenient and environmentally cleaner liquid and gaseous fuels, as well as to use solid coal in a manner consistent with acceptable levels of environmental and health risks. Because of its expertise in chemistry, chemical engineering, and combustion science, LBL has the capability to contribute substantially to both of these program objectives. As can be seen from the funding levels, however, this capability is underutilized at present.

Through the next several decades, liquid fuels will be the major energy source for transportation; therefore, petroleum demand will probably continue to increase. In contrast, US domestic production will probably resume its decline in the mid- to late 1980s unless

more efficient recovery methods are developed or new sources of oil such as shales are exploited. The Laboratory carries out research in both of these areas.

LEAD MISSION

LBL, together with the San Francisco Operations Office (SAN), is assuming field management responsibility for the contracts comprising the Applied Battery and Electrochemical Research Project supported by the Energy Storage Systems Division (STOR) of the Department of Energy. This project provides the applied research base which supports all of the electrochemical systems missions in STOR, and the general objective of the project is to help provide electrochemical systems that satisfy economic, performance and schedule requirements of these missions. The specific goal of the project is to identify the most promising technologies and transfer them to industry and/or another DOE program for further development and scale-up.

This project started in July 1979, and an implementation plan has been prepared, describing how LBL and SAN will conduct the planning and management responsibilities, delineating appropriate managerial controls to meet the project objectives. LBL will contract with (through SAN, as appropriate) and direct the activities of project participants. LBL will oversee the technical status, costs and schedules of the technical programs, provide reports of same to STOR, and establish corrective actions as required. LBL will maintain overall accountability for successful field management of the project.

The technical direction of the Applied Battery and Electrochemical Research Project for FY 1980 and beyond is described in the implementation plan and is designed to support the DOE Electrochemical systems missions: electric vehicles, solar electricity, dispersed electric load-leveling, and energy and resource conservation. General problem areas addressed by the project include the identification of new electrochemical couples for advanced batteries, the determination of technical feasibility of the new couples, improvements in battery components, and the establishment of engineering principles applicable to batteries and electrochemical processes. Major emphasis will be on applied research which will lead to superior technical performance and lower life cycle costs.

The project is divided into three major research areas: Exploratory Battery R&D, Engineering-Science Research, and Materials Research. The Exploratory Battery R&D area provides for the study of new electrochemical couples, or of new approaches to known battery systems, and offers the prospect of developing better-performing, simpler, longer-life, safer, and/or lower-cost batteries. Engineering-Science Research will include morphological studies of battery electrode materials, phenomenological studies to provide basic information needed for the design of electrochemical cells, development of physiochemical methods for electrochemical research, and modeling studies aimed at the quantitative prediction of cell behavior. Material Research seeks to identify, characterize and

improve the materials and components to be used in batteries and electrochemical processes.

COAL (AA) (FY 79 $0.8 M)

Mining Research and Development (AA 10) (FY 79 $0.2 M)

Coal Preparation and Analysis (AA 10 03) (FY 79 $0.2 M)

Coal Desulfurization. The objective of this program is to evaluate at least four (Ames, PERC, Kennecott, and TRW) oxydesulfurization processes for the removal of pyritic and organic sulfur from coal before combustion. The experimental program will be carried out at the Colorado School of Mines Research Institute (CSMRI) with supporting research, planning and analysis at LBL.

An LBL study has shown that physical cleaning followed by chemical treatment can reduce the total cost of coal desulfurization to within the range of gas scrubbing costs. LBL tasks will include assessment of analytical requirements: coal selection, acquisition, and preparation; statistical experimental design; and preliminary scheduling of the CSMRI evaluation program. The reactor system will be modeled at LBL, based on principles of mass transfer, reaction kinetics and fluid dynamics. The model will be tested and evaluated with the experimental data. Investigation of other catalytic processes is anticipated.

Advanced Research and Development (AA 60) (FY 79 $0.6 M)

Liquefaction (AA 60 01) (FY 79 $0.2 M)

Determination of Coal Composition. In this project, a non-destructive method utilizing nuclear magnetic resonance (NMR) is being used for identifying chemical changes in the solid coal structure produced by processing.

Chemistry of Coal Liquefaction. The chemistry and morphology of coal liquefaction reactions is under investigation in the following areas: selective synthesis of gasoline-range components from synthesis gas and preparation of catalysts for this; electron microscope study of coal during hydrogenation; catalyzed low-temperature hydrogenation of coal by use of evaporated transition metals; organic and organometallic approaches to coal liquefaction, chemistry of coal solubilization and liquefaction; and coal conversion catalysts-deactivation studies.

Materials and Components (AA 60 03) (FY 79 $0.4 M)

Metals in Shale Retorting and Coal Liquefaction. In this project the erosion-corrosion behavior of materials used in the flow passages of coal liquefaction systems will be studied under simulated operating conditions. The objective is to advance the criteria for material design and component operation.

PETROLEUM (AB) (FY 79 $0.5 M)

Enhanced Oil Recovery (AB 10) (FY 79 $0.2 M)

Environmental Studies and Other Support (AB 10 05) (FY 79 $0.2 M)

The goal of this LBL project is development of chemical processes for enhanced oil recovery from underground domestic sources by flooding these sources with chemicals that lower interfacial tension and improve mobility. Laboratory studies with oil field systems are being carried out. Future work will include enhanced laboratory experiments and field testing of candidate chemicals.

Oil Shale (AB 20) (FY 79 $0.3 M)

The purpose of this project is to assess groundwater impacts of in-situ oil recovery, develop methods to protect groundwater aquifers during in-situ processing of fossil fuels, and model pollutant transport. The research evaluates in-situ grouting, intentional leaching and surface leachate treatment, chemical modification of spent residuals, and hydraulic modification of aquifers through laboratory and computer modeling studies. (A summary of the Laboratory's environmental fossil energy program appears under GK 01 01.)

SOLAR ENERGY TECHNOLOGIES (AD) (FY 79 $1.5 M)

Technology Support and Utilization (AD 02) (FY 79 $0.4 M)

Environmental and Resource Assessment (AD 02 01)

The Ocean Thermal Energy Conversion (OTEC) project is funded jointly under AD 02 01 and AD 03 04. See project discussion under AD 03 04.

Solar Electric Applications (AD 03) (FY 79 $1.1 M)

Solar Thermal Power (AD 03 01) (FY 79 $0.1 M)

Concentrating Solar Energy Systems. This program obtains basic information needed to evaluate solar energy conversion systems that use lenses or mirrors to concentrate solar radiation, and explores innovative means of utilizing the concentrated sunlight.

In the Circumsolar Radiation project*, measurements are provided of the solar and circumsolar (around the sun) radiation for input to considerations of the performance of concentrating systems. The circumsolar radiation results from the scattering of direct sunlight from atmospheric aerosols. Four instrument systems have been constructed and are obtaining data at locations of interest to DOE's concentrating

*This project is jointly supported under AD 03 and BD 01.

collector program. The data are processed to determine the effect of the circumsolar radiation on generic designs of concentrating systems. In addition, the data are used at other national laboratories (e.g., SERI and Sandia Laboratories) in detailed computer simulations of specific designs. The measurement program is beginning to provide real-time data for concentrating collector test facilities. Future efforts include characterizing the circumsolar radiation in terms of atmospheric conditions. The circumsolar work has led indirectly to an effort to exploit the light absorption (as opposed to light scattering) properties of suspensions of small particles. In the Small Particle Heat Exchange Receiver (SPHER) concept, very small particles would be injected directly into a gas stream to absorb the concentrated sunlight and to heat the gas. An experimental program has been initiated to study the production, reaction, confinement and physical properties of the particles. The near term goal is to investigate the characteristics of a receiver capable of producing a high temperature gas for operating a heat engine. In the longer term, the goal is to understand and develop the use of small particle systems for a variety of solar related applications.

Photovoltaic Energy Conversion (AD 03 02) (FY 79 $0.1 M)

Circumsolar Radiation. Information is provided on the amount of solar and circumsolar radiation available to concentrating photovoltaic collectors. (See above under AD 03 01.)

Ocean Thermal Energy Conversion (AD 03 04) (FY 79 $0.9 M)

Environmental Impacts of Ocean Energy Technologies. This project addresses the environmental effects of ocean-based energy systems, chiefly the Ocean Thermal Energy Conversion (OTEC) system. The major work, thus far, is LBL's development and implementation of an environmental plan as lead laboratory for OTEC for the Ocean Systems Branch/Division of Central Solar Technology (DCST). The plan summarizes existing ecological knowledge, integrates pertinent data from on-going OTEC projects, identifies topics for future research, and provides engineers with ecological criteria to ensure that the system can be operated within environmental regulations. To implement this plan LBL is operating an environmental measurement program to evaluate physical, chemical, geological, and biological attributes at potential OTEC sites; monitoring biostimulation and toxicity studies; and supervising preparation of environmental permit documents. In addition, LBL reviews or monitors other aspects of the Ocean Systems program where they relate to the environment or resource evaluation. The work includes both direct research by LBL and subcontracted research by investigators in federal or state agencies, academic institutions, and the private sector.

In the future, the Laboratory's role with the DOE Ocean Systems Branch will expand to include program planning, parameter measurement, operations monitoring, dissemination of information concerning the environmental effects of other ocean energy technologies such as wind-wave energy, tidal energy, ocean current energy, and salinity gradient

energy. The present OTEC ecological program will continue, with the focus changing from preoperational to operational test facilities, then to working plants.

GEOTHERMAL ENERGY (AE) (FY 79 $8.1 M)

Hydrothermal (AE 10) (FY 79 $0.5 M)

The Laboratory provides technical assistance to the public and private development of hydrothermal resources. Recent emphasis has been on reservoirs of moderate temperatures where near term opportunity exists for utilization in process heat systems. Such projects, while of small scale, may make significant energy contributions if appropriate exploitation strategies are adopted. The LBL effort will continue to be modest.

Geopressured Resources (AE 20)

Resource Definition (AE 20 01) (FY 79 $0.1 M)

Hawaii Energy Development Plan. Hawaii presents a special opportunity to investigate, design, and demonstrate practicable energy supply alternatives to reduce the dependence of a state on petroleum. In collaboration with the Hawaii State Government, LBL is investigating Hawaii's energy supply and use options for the next few decades. The objective is to develop a practicable plan that takes into account constraints, incentives, and realistic lead times to commercial development of local energy sources and that phases in new supply sources to a level that is technologically and economically feasible. Applications of the analysis and plan development procedures to other selected areas is contemplated beyond FY 1980.

Geothermal Technology Development (AE 30) (FY $7.5 M)

Component and Technology Development (AE 30 01) (FY 79 $7.0 M)

Utilization Technology. The LBL program in utilization technology is to develop and apply a general thermodynamic cycle simulator to the analysis of energy conversion processes, develop economic design information on direct-contact heat exchange, accumulate field experience with the direct-contact process by operating a 500 kW pilot plant, conduct field tests of conventional heat exchangers, and develop basic fluid properties data on binary cycle working fluids.

The computer code GEOTHM has gained wide acceptance as a tool for the analysis of geothermal power cycles. At LBL it has been used with an optimization subroutine to study the cost of electricity produced from geothermal energy as a function of resource conditions. Laboratory heat transfer data have been taken and published. Field tests of small direct-contact heat exchangers and hydrocarbon turbines have been performed and the results published. The 500 kW pilot plant and the conventional heat exchanger field tests will be started in FY 1979.

LBL's reservoir engineering and utilization technology personnel will continue to work with DOE and its contractor for the Geothermal Demonstration Plant to enchance the success of the demonstration. A reservoir and plant performance program for the Demonstration Plant will begin in FY 1980. In future years, the program emphasis will continue to be distributed among theoretical, laboratory and field activities. Cooperative field projects will involve larger experiments as the technologies move toward commercialization.

Brine Chemistry. The major chemical problems in geothermal energy utilization are now known to be 1) plugging of injection wells by suspended colloidal amorphous silica, 2) carbonate sealing in production wells, and (3) the emission of hydrogen sulfide from condensate cooled power plants. LBL has proposed continuation of previous work on the kinetics and control of amorphous silica precipitation and new work on hydrogen sulfide abatement. The proposed silica work will consist of developing a complete predictive capability regarding the flocculation of colloidal silica in geothermal fluids and a systematic evaluation of possible means of silica removal by controlled flocculation. The proposed hydrogen sulfide abatement work will center on building a laboratory scale physical model of a functioning condensate-cooled power plant. This model will be used to study chemical treatments for hydrogen sulfide emission control.

Geothermal Case Study at Cerro Prieto, Mexico. Under a five year agreement between DOE and the Comision Federal de Electricidad de Mexico, LBL is conducting geological, geophysical, reservoir engineering and geochemical studies of the area at the Mexican geothermal plant at Cerro Prieto, located in Mexico about 25 miles south of Mexicali, as well as coordinating the US technical activities sponsored there by DOE. This plant, which has been in operation since 1973, had an output of 75 MW until early 1979, when it was increased to 150 MW.

The objective of this project is to develop a throrough understanding of the Cerro Prieto geothermal resource, and to study various problems related to its exploration and development, e.g., life and production capacity of wells, longevity of the resource, induced seismicity, and subsidence. An understanding of the behavior of the Cerro Prieto field can be applied directly to the several geothermal areas already identified in the neighboring Imperial Valley and to other fields of similar geological setting throughout the United States.

Progress has been made in a number of areas, notably, the development of a subsurface geological model, computer models for circulation of fluids, improved geophysical techniques for defining the dimensions and structure of reservoirs, improved instrumentation for field measurements, and geophysical monitoring.

Resource Exploration and Assessment. Magnetotelluric Investigations: This project involves developing and testing new concepts in instrumentation, data acquisition, processing and interpretation regarding magnetotelluric (MT) surveys for geothermal exploration. LBL developed the reference

MT technique which is now being offered commercially. LBL has also developed and is using an in-field processing system, the details of which are available to industry. Future directions are toward development of 1) better SQUID magnetometers, 2) SQUID gradiometer and 3) better interpretation techniques.

Electrical and Electromagnetic Modeling: The main objective is to develop more efficient, accurate and generalized (i.e., 3-dimensional) computer programs for interpreting electrical and electromagnetic survey data. Thus far LBL has developed many programs for treating dc resistivity, dipole-source EM and plane-wave source EM over one-, two- and three-dimensional earth models. Because of the high cost of excercising some of these programs, future directions aim toward reducing computer costs by improving algorithms or implementing the programs on small dedicated computers with large computing power.

Passive Seismic Systems: The project goal is to fabricate and test a multi-channel, passive seismic system with the capability of in-field data processing in real time. Properly programmed, the system would have application in geothermal reservoir exploration, monitoring (including injection and subsidence) and many other practical engineering problems.

Controlled-Source EM: The project goal is to fabricate and test a very large moment, EM prospecting system that will permit deep exploration in areas where, for various reasons, conventional systems cannot be used. The system has been tested and the engineering information has been distributed. Tests will continue to improve field techniques, e.g., the use of a reference magnetometer for low-frequency, natural-noise cancellation.

Reservoir Engineering. Reservoir Evaluation: The goals of this program are to acquire empirical data through field measurements and cooperative research projects; to develop theoretical, analytical, and numerical models for use in interpretation of reservoir and aquifer behavior; and to transfer the technological developments to industry for use in determining resource characteristics. LBL projects range over the entire western portion of the United States and the Gulf Coast. International cooperative projects include formal joint research programs with the governments of Mexico, Italy, and New Zealand.

Field Measurements and Equipment: In this program LBL assists city governments, government agencies, and private industry in making hydrothermal measurements that will aid in defining the behavior, extent, and lifetime of a resource. In support of these measurements LBL carries out an active program of equipment evaluation and modification to ensure that the most advanced techniques and tools are available to the geothermal community.

Analysis and Interpretation: Analysis and interpretation of hydrothermal measurements requires detailed geological and geophysical data synthesis. In addition, the drilling and completion data must be collected and evaluated. Often the lithology, faults and fractures, and unique well completions introduce complexities that can only be

analyzed with computers. Additional complications arising from variable flow rates and two-phase wellbore and reservoir flow also require computer calculation. LBL has developed computer programs to address all of these complexities, and is making these programs available to the geothermal community.

Resource Management: The LBL reservoir engineering group has developed new methods and computer programs for determining the optimal management of the underground resources. Injection of fluids, reservoir depletion, fluid reserves, and expected lifetime of a resource for specified production of fluids have all been the subject of study. The results of these studies have been made public through published reports and presentations at technical meetings. Both hypothetical studies and real case histories have been presented.

Subsidence Research. The ultimate goal of research on subsidence caused by production of geothermal resources is to be able to forecast its occurrence reliably and to control and mitigate its consequences within predictable limits. This research will establish bases for understanding how subsidence can be forecast, controlled, and, most important, planned for.

Plans for future research include four major elements: 1) subsidence characterization, 2) measurement of subsidence, 3) prediction of subsidence, and 4) review of possible operating policies for a geothermal field that would assure minimal adverse effects in view of anticipated subsidence.

Research to date has addressed the following topics: a) development of computer codes to forecast subsidence; b) preparation of subsidence case histories for Wairakei, New Zealand; Chocolate Bayou, Texas; The Geysers, California; and Raft River, Idaho; c) preparation of a manual on techniques for monitoring displacements associated with compaction and subsidence; d) review of subsurface vertical distance measurement techniques in hostile, particularly high temperature environments; and e) appraisal of the environmental impact and the economic consequences of subsidence at specific sites including Baldwin Hills, California, San Joaquin Valley, California, and seven other locations.

Work in these areas is carried on as a combination of in-house research and subcontracts with outside consultants, laboratories, and universities.

Interagency Coordination and Management (AE 30 03) (FY 79 $0.5 M)

Geothermal Development Policy Studies (includes AE 30 01). The Laboratory is undertaking policy studies on the development and commercialization of US and foreign geothermal energy sources. Information documents are being prepared, as are program and policy planning papers. Numerous legal, social and institutional issues affecting commercialization of geothermal energy are addressed. Among these issues are the effects of recent changes in leasing and permitting processes, the implications

of the 1978 National Energy Act and other recent legislation, public utility regulation of geothermal energy suppliers, and commercialization prospects in industries requiring heat sources.

Other related studies explore the potential roles of the US government and US firms in the development of geothermal energy resources in less developed countries (LDCs). Particular emphasis is paid to Indonesia and the Philippine Islands. These studies will examine not only geothermal energy development mechanisms within these countries, but also potential roles for the US government and opportunities for US firms.

Geothermal Resource Information and Data. The National Geothermal Information Resource (GRID)* compiles and maintains an extensive database on the status of geothermal resource development. The principal application of this data base is to provide information for the emerging National Progress Monitoring (NPM) system. The GRID project also performs analyses of the resource potential and resource development based on these data.

FUSION - MAGNETIC FUSION (AF) (FY 79 $8.7 M)

Confinement Systems (AF 01) (FY 79 $3.0 M)

Tokamak Systems (AF 01 10) (FY 79 $3.0 M)

LBL is developing the Neutral Beam System (NBS) to be used on the Doublet III Tokamak at General Atomic Company, San Diego. The prototype beam line Unit No. 1 design goals for the Doublet III NBS are 80 kV, 80 A, 0.5 sec pulse every 5 minutes and 28% of the accelerator grid power to be delivered to the plasma as hydrogen neutrals (17% as full energy 80 keV hydrogen neutrals). Design and fabrication of Unit No. 1 will be completed in FY 1979 with initial operation scheduled at General Atomic in September, 1979.

LBL will also provide design and procurement information to General Atomic and TRW to facilitate construction and procurement of the "production" beam lines for Doublet III. LBL is working with industrial suppliers to ensure that there is sufficient transfer of neutral beam technology to permit competitive bidding for the follow-on beam line units required by General Atomic.

When fully operational, these neutral beam systems will represent a highly significant advance for fusion and neutral beam technology.

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*In FY 79, funding for this project was transferred from ET to RA.

Development and Technology (AF 02 20)*

A major effort at LBL is concerned with research and development for application of high energy neutral beam systems to heating and fueling plasmas in fusion experiments, and to meet specific needs of users such as the present TMX experiment, the MFTF, Doublet-III and TFTR systems now under construction, and the ETF (Engineering Test Facility) now in the planning phase. Primary goals in the neutral beam program are achievement of long, multisecond pulses and eventually DC operation, the improvement of electrical efficiency and gas utilization, and extension to higher energies, possibly into the MeV range.

Thus far, this work has concentrated on the development of large high intensity and high quality positive-ion based systems for energies up to 100 or 150 kV. Current plans call for a phasing out of positive-ion source development, after reaching the goals, perhaps five years from now, of improved ion species mix, many second pulse duration, and direct energy recovery. The future research effort will be devoted increasingly to the development of negative ion sources that will be suitable for efficient neutral-beam injectors at energies well above 100 kV.

Applied Plasma Physics (AF 03) (FY 79 $1.2 M)

A unique LBL effort in Applied Plasma Physics is the development of the Toroidal Magnetic Cusp experiment (TORMAC), which is an alternative confinement concept combining features of both the tokamak and mirror devices. Establishment of the configuration is a complex matter, and several different approaches are under study. TORMAC P1 (Puffer), for example, uses an annular plasma gun for injection of a ring-shaped, current-carrying plasma into the confining field. Another promising method under consideration makes use of very high temperature electrons heated either by resonant rf fields or by beam-generated turbulence.

In the theoretical program, basic plasma theory is being developed for application to magnetic fusion in the related areas of stochasticity, wave interactions, and Lie transforms. In addition, effort in the theory of plasma equilibrium, stability, transport and heating is carried out in support of the work on alternative concepts.

Reactor Projects (AF 04) (FY 79 $4.5 M)

Design and fabrication of LBL's Neutral Beam System Test Facility to be utilized on Princeton's TFTR was completed in FY 1979, and assembly, checkout and initial operation of the prototype beamline were accomplished by the third quarter of FY 1979. The fourth quarter of FY 1979 and all of FY 1980 will be devoted to the operating phase of the NBSTF. This

*Research and development of neutral beam systems is performed as a subcontract for the Lawrence Livermore Laboratory, and therefore appears also in the LLL Financial Plan. Data appear in Appendix B.

will consist of comprehensive testing of the prototype beamline in addition to demonstration of the source capabilities. Concurrent with the prototype beamline operations will be an extensive training program for the Princeton personnel who will operate four TFTR beamlines. LBL will utilize the highly instrumented NBSTF to condition and test the ion sources that will be used on the TFTR beamlines, and will also provide design performance and purchase information to Princeton to facilitate the procurement of the "production" beamlines for the TFTR. LBL is working with industrial suppliers to ensure that there is sufficient transfer of technology to industry to permit competitive bidding for the production equipment to be installed at Princeton.

The neutral beam design goals are a 120 kV, 65 A, 0.5 sec pulse every 5 minutes, and 20 percent of accelerator grid power to be delivered to the plasma as deuterium neutrals. Neutral beam development work at LBL in FY 1978 indicates that these values will be attained with the NBSTF. The development effort in FY 1979 has been directed toward enhancing the output of the ion sources. To upgrade the performance of the TFTR, the NBSTF will go into an improvement program in FY 1980 to increase the Neutral Beam System pulse length to its optimum. This program is expected to conclude by the end of FY 1980. A necessary part of this improvement is additional electrical equipment for compatible power consumption with other pulsed facilities at LBL.

The NBSTF will be highly significant for the development of high energy neutral beam technology, and also for the national fusion energy program. Furthermore, the NBSTF, the support systems and all of the knowledge gained in design, fabrication and testing of this major facility will remain available to LBL for application to future neutral beam and fusion energy research and development programs. The NBSTF will complete its transitions to R&D work by the end of FY 1981, and further R&D activity will be funded under AF 02 thereafter.

FISSION (AG)

Advanced Systems (AG 40) (FY 79 $0.3 M)

Advanced Isotope Separation (AG 40 10) (FY 79 $0.3 M)

Resource availability poses a potential major constraint on the expanded US use of nuclear power. Therefore it is important to investigate ways to increase the efficiency of fuel use in all parts of the nuclear fuel cycle. The development of advanced techniques for isotope separation could make possible more efficient use of uranium ore, by increasing the efficiency and economy of uranium isotope enrichment.

Selective photochemistry research at LBL is aimed at the demonstration of new laser isotope separation (LIS) methods and the development of the fundamental research base required for the use of new and existing laser isotope separation techniques. Isotope separation techniques under study at LBL include multiphoton dissociation of polyatomic molecules,

selective dissociation of van der Waals molecules, chemical reactions of selectively excited molecules, and selective condensation of molecules. This program uses unique crossed molecular and laser beams to study isotope separation, an approach that avoids molecular collision and chemical reactions which often confuse the experimental results.

The spectra of ionized uranium will be determined and classified according to the degree of ionization and configuration. Time-resolution methods will be used to determine the degree of ionization. Lifetime measurements of some of the stronger lines will be attempted.

BIOMASS (AJ)

Fuels from Biomass (AJ 01) (FY 79 $0.6 M)

Agricultural and wood wastes constitute a potentially significant national energy resource. Toward this end LBL is studying the feasibility of cultivating plants for their hydrocarbon yield, the possibility of genetic engineering for increased yield, and biological process development for conversion of plant cellulose to liquid fuels. The Laboratory is also assisting DOE in assessment of a pilot biomass liquefaction facility.

Biomass Plant and Catalytic Liquefaction. The objective of this program at the Albany, Oregon Biomass Liquefaction Facility is to assess the technical and economic feasibility of converting biomass into liquid fuels. A major goal is to provide a data base of fundamental thermochemical information on the chemical conversion of biomass to liquid fuels. An experimental program at LBL is being coordinated with the development project at Albany and with supporting research elsewhere.

Specific objectives are to:

1. Obtain data relevant to f nding the most favorable conditions for operating the Albany Biomass Liquefaction Facility.

2. Upgrade the product crude obtained at Albany.

3. Separate unreacted biomass from the product crude.

4. Study process modification alternatives.

5. Study the fundamentals of catalytic liquefaction of biomass with such catalysts as K_2CO_3, Na_2CO_3, HI, HCl, $ZnCl_2$, and other metal salts recognized as effective decarboxylation catalysts.

The Laboratory has the responsibility for issuing the technical operating directives for the Albany Pilot Plant Facility. In May 1979, the first barrel of purely wood derived oil was produced at that facility.

Process Development Studies on Bioconversion of Cellulose and Production of Ethanol. This program provides processing concepts and design data for the bioconversion of cellulose, in the form of whole tree biomass and agricultural residues, to ethanol for use as a transportation fuel. Processing concepts under study include acid and enzymatic hydrolysis of raw materials to produce sugar solutions, and subsequent fermentation of these sugars to ethanol. Low-energy, high-rate fermentation processes are being developed.

Recent accomplishments include developing an HCl solvolysis process as a pretreatment prior to cellulose degradation, completing initial studies on vacuum distillation for continuous alcohol separation, and developing organisms for hemicellulose conversion to ethanol. Future work will complete pilot plant scale studies on HCl hydrolysis, develop low-energy vacuum fermentation systems for ethanol production, and develop optimal fermentation for pentose conversion to ethanol.

Hydrocarbons and Energy from Plants. This project involves the cultivation of hydrocarbon-producing crops, such as certain *Euphorbias* for the purpose of determining feasibility of production of hydrocarbons and related materials from them for fuel or chemical feedstocks. Since these and many other latex-producing plants have never before been cultivated or studied for commercialization of their chemical content, various kinds of basic information are being sought, including 1) crop yield and cultivation conditions, 2) optimization of oil yield, 3) analytical method development, 4) process chemistry, and 5) economics.

MULTISECTOR (C8)

Technology Development (C8 03) (FY 79 $1.6 M)

Battery Storage (C8 03 01) (FY 79 $0.9 M)

The LBL program for development of electrochemical synthesis and energy storage aims to provide basic engineering-science background for the development of economical processes for electrochemical energy storage and conversion, which are not limited by Carnot efficiency. With the recent assignment to LBL of field management responsibility for the Applied Battery and Electrochemical Research Project, supported by STOR, the in-house electrochemistry research program has been expanded to provide a broader base of research expertise. The following topical areas are presently being worked on: surface morphology of metals in electrodeposition; anodic surface layers on battery materials; metal couples in nonaqueous solvents; analysis and simulation of electrochemical systems; current inefficiency in aluminum reduction cells; engineering analysis of gas evolution in electrolysis; bifunctional air electrodes for metal-air batteries, electrochemical properties of NASICON; and battery electrode studies.

Improved Conversion Efficiency (C8 03 03) (FY 79 $0.7 M)

Catalyzed Combustion. Catalytically supported combustion is investigated both experimentally and computationally at the Laboratory. (For an overview of the LBL combustion research program see AK 01 03 and 04).

Nitinol Engine Development. The objective of this project is to determine the feasibility of applying the thermally-activated shape-memory phenomenon in certain alloys (particularly the nickel-titanium compound 55-Nitinol) to thermal-to-mechanical energy conversion at low temperatures and moderate temperature differences. Prototype engines have already demonstrated the principle. The focus of the project is currently centered on determination of the thermodynamic limitations (conversion efficiencies) and sensitive mechanical parameters to be considered in design of solid-state heat engines of a commercially significant scale. A potential advantage of such heat engines over competing fluid-cycle systems (e.g., Rankine-cycle turbines) is the possibility of achieving equivalent conversion efficiencies at lowered capital costs through elimination of the need for separate heat exchangers. Applications of interest include conversion of industrial waste heat, low-temperature geothermal brines, solar thermal sources, and ocean thermal gradients.

Electrode Surface Chemistry (C8 03 04)

Physical and chemical understanding are being sought of oxygen-platinum-ligand interaction of oxygen-reduction catalysts that are catalytically more active than platinum supported on graphitized carbon black. Fundamental studies of the alloy-electrolyte interface using modern surface science techniques should provide the means to optimize the alloy ligand or to redirect the search for more active materials along the most rational paths. Alloying may have significant beneficial effects on electrode performance above and beyond effects on oxygen reduction kinetics, such as reduced platinum dissolution and surface area loss. Other alloying effects, e.g., surface reconstruction and surface self-diffusion, will also be studied at the atomic level.

DEFENSE PROGRAMS

DOE: A/S Defense Programs (DP)

The only LBL program funded by this department of DOE is the Inertial Confinement Fusion program, which is an offshoot of the laser development program, traditionally funded by DP.

FUSION (JF) (FY 79 $1.1 M)

Inertial Confinement Fusion (JF 01) (FY 79 $1.1 M)

One of the most important applications of accelerators at LBL is heavy-ion fusion. This program has been funded for just over two years, and the Laboratory intends to pursue it vigorously during the next decade. In comparison with other possible inertial fusion driver systems (lasers, electron beams, light ion beams) which have been under study for a longer period, the high energy heavy-ion approach appears to offer great advantages in being able to meet the goals of high efficiency, high repetition rate, and high availability that will be essential requirements for a practical fusion power plant driver.

Because the beam-current needs for an accelerator driver lie in a range significantly beyond present practice, a graduated approach to demonstrating scientific and engineering performance is desirable. A sequence of five limited-risk experiments and tests of increasing scale in beam energy (approximately 4 J, 500 J, 100 kJ, 1 MJ, 10 MJ) is now believed to provide a realistic set of milestones on the path to a large demonstration reactor driver.

There are two chief driver candidates: one based on the rf linac with storage rings, and the other based on the induction linac. In a small program in support of the first, we have built and operated a 65 mA high-current Xe^{+1} source, accelerated the beam through a 500 kV Cockcroft-Walton pre-injector, and shown that beam current and beam quality were adequate for injection into an rf linac driver.

Since March 1979, we have devoted our efforts exclusively to the single-pass induction linac system, for which much higher beam currents (amperes) are needed. A large 500 kV Cs^{+1} contact-ionization source has been developed here and run at 1.2 amperes; it is capable of a 1 Hz repetition rate with good reproducibility. Three pulsed drift tubes are now being installed downstream of the source; they will boost the beam voltage to 2 MeV and provide a demonstration of this new pulse-power-based acceleration system. This will constitute the 4 J first step, and will provide a one ampere beam for experiments on high-current beam transport in magnetic focusing channels.

The second step 500 J system, to accelerate 20μ C of Cs^{+1} to 25 MeV, is under design now. This set of parameters for the second step in the induction linac test series has recently been endorsed by the Foster

Committee and the Office of Inertial Fusion. Details of the funding profile for the 500 J system are as yet unclear; it could be operational for accelerator and plasma experiments either early or late in FY 1983.

Planning for the third step, HIDE, a device large enough for pellet experiments in the breakeven range, is expected to begin in FY 1982 shortly before the 500 J test bed is operating. The program includes a substantial effort on developing systems design and cost optimization routines that span the entire range of the third, fourth and fifth steps (100 kJ to 10 MJ).

While proceeding with the implementation of any single step, it is planned to continue a base-level R&D program, emphasizing experiments with the operating test facility, theoretical and systems studies, and the development of engineering models, components and sub-systems with new materials and lower cost and, perhaps, higher risk in preparation for the succeeding step.

To meet an authorization date of FY 1984 for a facility of the magnitude of HIDE ($100 M plus escalation and contingency), a significant expansion of the accelerator study activities must take place.

DOE plans include selection of a lead laboratory in the next few years. LBL would be an appropriate choice because of the strength and experience of the accelerator group and the variety of accelerator skills possessed within LBL. Also, ever since the founding of Lawrence Livermore Laboratory, there has been a steady history of technical interchange between LBL and LLL on a succession of accelerator and fusion projects. Recent examples include the ATA and the FXR induction linacs just coming into operation at LLL. The mutual interaction lately has been extended to the subjects of beam propagation and target and reactor design for inertial confinement fusion.

ENERGY DEMAND AND END-USE

DOE: A/S Conservation and Solar Applications (CS)

OVERVIEW

The Laboratory's research in Conservation and Solar Applications concentrates on the buildings sector, which has a very high potential reward in terms of energy savings. This sector consumes about 30% of US primary energy, or about 27 quads in 1976. Many opportunities exist for increasing the efficiency of energy resource use in buildings. These include a wide variety of design improvements as well as passive and active solar heating and cooling systems. The Laboratory is carrying the lead role for research in windows, lighting, ventilation, and building modeling, and in addition has programs for the study and evaluation of building and appliance energy-performance standards.

LEAD MISSION

LBL has been designated by the office of Conservation and Solar Applications to have the lead mission assignment in the following program areas which are described below:

1. Infiltration/Ventilation
2. DOE-2
3. Windows and Lighting.

SOLAR ENERGY (BD)

Solar Applications (BD 01) (FY 79 $2.0 M)

Demonstration (BD 01 01) (FY 79 $0.3 M)

LBL provides technical support to DOE's Solar Heating and Cooling Demonstration Programs in design review, project liaison and monitoring for commercial, hotel and motel demonstration projects. LBL's technical support for this program is expected to be phased out by the end of FY 1980.

Systems Development (BD 01 02) (FY 79 $1.6 M)

The solar applications being investigated at LBL include both active systems that are used to heat and cool buildings by the addition of solar equipment to buildings of conventional design, and passive systems in which the building itself is designed to take maximum advantage of natural energy flows.

Active Systems. The emphasis in this area is the development of advanced components for solar heating and cooling, and the investigation of the dynamics of multi-component systems. LBL is developing advanced-cycle concepts for ammonia-water air conditioners. The objective is to develop chillers that can operate efficiently over a large range of input temperatures from solar collectors. A prototype single-effect chiller has been designed, fabricated and is under test. Currently under preliminary investigation are new advanced double-effect and single-effect absorption systems. Future work includes detailed design, construction and testing of prototypes utilizing these advanced cycles.

LBL has been given primary responsibility for technical support of the Active Cooling part of the DOE National Program. In this role, LBL provides project monitoring, conducts special technical studies, assesses solar cooling technology options and recommends technical strategies, reviews unsolicited proposals, and assists in program planning.

LBL is also investigating advanced control strategies as a means of increasing the efficiency of multi-component heating and cooling systems. Such strategies would be implemented by modern micro-electronic devices (controllers) coupled with sensors and various control mechanisms. A test facility has been constructed at LBL that features pseudo-collector heat input and building load simulators that allow testing of control strategies over a wide range of insolation, building load and weather conditions. The facility will be used to test an electronic controller developed at LBL, and to evaluate commercially available controllers and control strategies.

The LBL primary technical support role in the controls area ended in FY 1979 when it was phased into a combined Solar Systems Analysis and Control Program under the leadership of SERI. LBL continues to provide technical assistance to SERI in this area.

The Circumsolar Measurement project provides information on the amount of solar and circumsolar radiation available to concentrating collectors used for active cooling and for agriculatural and industrial process heat. A description of this project is under A/S Energy Technology (AD 03).

Passive Systems. The goal in this area is to provide a sound technical basis for passive solar concepts, and from this base to develop innovative approaches to heating and cooling of buildings.

The objectives of the Passive Systems Analysis and Design project are 1) to determine the impacts on energy consumption that result from applying passive solar design concepts to non-residential buildings and 2) to develop thermal analysis capabilities and design tools for commercial buildings that will allow architects and engineers to use these concepts in their designs. Activities are underway in basic heat transfer analysis, computerized building energy analysis, and in the definition and evaluation of innovative passive systems that are appropriate to use on large-scale buildings.

The heat transfer studies have led to thermal models that are being incorporated into the public-domain energy analysis computer codes BLAST-2 and DOE-2. This portion of the project is being performed in conjunction with the Los Alamos Scientific Laboratory. Accomplishments to date include the development of natural convection and ventilation cooling algorithms that are being added to BLAST-2, and verification of BLAST-2 for direct-gain passive systems. Other accomplishments include the joint preparation by LBL and SERI of an "Interim Report: National Program Plan for Passive and Hybrid Solar Heating and Cooling of Buildings." Future activities include application of these analysis capabilities to evaluate and optimize the design of buildings that use these concepts. Future planning efforts in support of DOE headquarters and SERI will focus on commercial buildings and basic physical systems.

In the Passive Cooling project a process is being studied by which heat storage materials (e.g., on the roof of a building) would be cooled by radiation to the sky, then would provide "coolness" to the building. The effectiveness of this technique depends on the infrared properties of the atmosphere (which are highly climate dependent) as well as on the spectral emissivity of the radiating surface and the transmissivity of any glazing material used to reduce convective heating of the radiating surface. Atmospheric infrared properties are being measured at four locations in the US with instruments developed at LBL. The measurements are being compared with results from a computer model of atmospheric emissivity. An outdoor radiator test facility is under construction and will provide data on the effect of materials properties and radiator configurations on cooling rates.

LBL has the primary technical support role in the area of Passive Cooling. In this role LBL monitors DOE supported projects at other institutions, continually assesses passive cooling developments and options, reviews unsolicited proposals, and participates in DOE's program planning.

Solar Commercialization (BD 02) (FY 79 $0.1 M)

Commercialization Planning (BD 02 01)

This program is designed to evaluate aspects of solar energy economics that depend upon interface with public utilities. Public utility regulations and roles can act as either a barrier or an incentive to solar energy commercialization. Recent work has concentrated on analysis of regulatory options for utilities to act as financial intermediaries for solar heating technology. Future work will concentrate on the role of federal tax policy in structuring utility incentives for new technology. Methods will be developed for the analysis of public utility financial and economic risk assessment of solar technology.

BUILDINGS SECTOR (C3)

Buildings and Community Systems (C3 01) (FY 79 $6.2 M)

Residential and Commercial Buildings (C3 01 01) (FY 79 $1.2 M)

Buildings Envelopes and Ventilation (BEV) Program. Funding divided between C3 01 01 and C3 01 02. (See description below.)

Hospitals. Since educational facilities and hospitals account for 30% of institutional building energy consumption, special attention is being focused on obtaining data on which energy-efficient ventilation standards can be based. Retrofits are being evaluated that would be cost effective and have a positive effect on occupant health and comfort.

Performance Standards (C3 01 02) (FY 79 $2.9 M)

Building Envelopes and Ventilation (BEV) Program. LBL has the lead mission assignment in the Infiltration/Ventilation area. The goal of this LBL program is to identify areas in the physical structure of buildings as well as the heating, ventilating, and air-conditioning systems where modification in construction and/or operation will result in cost-effective energy savings while not interfering with the design use of the building. Recent experiments have shown comfort levels can be maintained while energy consumption is reduced by 40-60%, at little or no increase in first cost.

It is generally understood that conduction losses in building envelopes can be greatly decreased through insulation. Therefore the next major areas to address are conduction losses through windows, flues, etc., and the energy required to heat infiltrating fresh air. The infiltration rate averages 0.5 to 1.5 air changes per hour and accounts for one third of the energy use of present insulated homes. There is great interest in constructing tighter residences, and goals of 0.3 air changes per hour are frequently stated. However, combustion products from gas stoves are already often above tolerance levels in existing homes, and reduced fresh air may lead to problems with moisture, mold, odors, chemicals outgassed from building materials and plastic, and radioactivity from radon in concrete, soil and water.

The Laboratory is conducting experiments with tighter homes, and is also studying the mechanical introduction of fresh air and recovering heat from exhaust air streams with the objective of evaluating optimum trade-offs between energy efficiency and indoor air quality. Studies are also being carried out on indoor pollutants and their control.

In the future specific building retrofits will be evaluated, as well as new design, construction and operating features that are cost-effective and can be implemented by the building community. The Energy Diagnostic and Indoor Air Quality (ENDAQ) vans and the Watt Watchers database will measure and record air leakage and indoor air quality in existing residences, modeling and calculating regional

potentials for conserving energy and peak power in the buildings sector. As the cost-effectiveness and energy-saving potential of program results are verified, they will be compiled in an updatable computer-based file which will also include international data. Reports, tailored to the best strategies for different US regions, will be issued regularly and results will be conveyed to the design and building community by seminars and other media. The data and experience collected by the program will enable government agencies to establish and update energy-conserving standards for buildings and appliances.

Building Energy Analysis. LBL has the lead laboratory assignment in the development of DOE-2, a cost-effective computer program in which a variety of building types are modeled so that energy use of buildings can be analyzed or predicted. Building designers can use this program as a tool in adjusting parameters to determine the building configuration of minimum energy use while satisfying design requirements. The program is in the public domain and is currently being implemented on nationwide time-sharing networks. The program will be improved continuously, based on feedback from designers, new standards, and equipment developments.

DOE-2 already treats solar collectors and thermal storage in water-tanks and rock beds. Passive solar features are now being added. DOE-2 will become a unique program in that economic trade-offs among improved building envelope, active solar collectors, passive solar designs, and increased thermal mass can all be evaluated without prejudice.

The Department of Energy has used this program to determine the 1980 Federal Building Energy Performance Standards, (BEPS), and will use it for energy analysis of its buildings. The technical assistance in its application will be provided by LBL, including training workshops, advice on modeling specific buildings, and assistance in running the program at the LBL Computer Center via remote access.

The major efforts of the Building Energy Analysis Group will consist of consulting with states using DOE-2 to develop their individual BEPS; assistance to regional DOE-2 user's offices; maintenance and extension of DOE-2 software; development of major new energy analysis software; applications of DOE-2; and, production of design aids.

Building Energy Performance Standards. This program provides analysis in support of DOE's development of energy standards for buildings. It deals specifically with residential buildings. The goals of the program are to 1) assess the energy and economic impacts of implementing energy conservation measures in houses; 2) develop and apply a framework for deriving alternative sets of residential building energy performance standards; 3) assess the performance and cost effectiveness of new conservation measures for buildings; and 4) analyze ways which future or updated standards can encourage the use of new energy conservation measures in residences. To date, the program has been a primary source of information and analysis for

DOE in its process of setting residential building energy performance standards.

The directions for the project after 1980 will depend in large measure on the public reaction to the Notice of Proposed Rulemaking and Notice of Final Rulemaking, scheduled in late 1979 and early 1980 respectively. The anticipated emphasis after 1980 will be analysis of future energy conservation measures.

Consumer Products and Technology (C3 01 04) (FY 79 $1.7 M)

Windows and Lighting Program. Under its assigned lead mission, LBL plans and conducts a research, development, and demonstration program in these areas to complement and accelerate efforts in the private sector to introduce energy efficient utilization in both new and existing buildings.

The primary thrust of the Energy Efficient Windows program is a research effort leading to the development and demonstration of cost effective innovative window designs, optical coatings, and window accessories that will make window heat loss comparable to that of an insulated wall. Design methods and strategies will be developed, tested, and disseminated to ensure that new and existing products are used effectively, and that technical tradeoffs between daylighting savings and thermal losses are accurately assessed. Development of computer codes for thermal/optical analysis, as well as test capabilities for window components and complex fenestration systems, support all elements of the program and provide unbiased third party judgements on complex technical issues. Current laboratory and field testing activities are leading to the development of new and improved diagnostic tools and approaches to understanding and assessing all energy-related aspects of building performance. In addition, the LBL role encompases overall program planning and assessment of research priorities and technical management of subcontracted research activities.

The LBL program supports research, development and demonstration activities designed to: 1) provide cost effective lighting products and design practices to replace less efficient options; 2) improve operation and maintenance of lighting systems consistent with sound energy conservation and economic practices; 3) provide the technology and design methods to increase use of natural lighting when applicable, and 4) accelerate commercialization of new energy efficient products, including lamps, ballasts, fixtures and lighting controls. The program also supports research efforts to develop a sound technical basis for technical performance judgements concerning lighting quality and quantity. Computer codes, test facilities, and a field program of data collection and analysis are the essential elements of the program. As a major national laboratory for lighting, LBL develops program plans, assesses R&D priorities, and provides technical management of subcontracted research activities.

The Energy Efficient Light Bulb Program at LBL will support RD&D leading to the commercialization of cost effective replacements for the incandescent lamp. New lamp systems with efficiencies in the range of 40 to 60 lumens/watt appear possible in the near term based upon preliminary investigations already supported by DOE and by the strong interest in the success of such a program expressed by the lighting industry. The program will proceed in two phases: Phase I will assess laboratory performance of prototype devices, systems, and components. Phase II will advance the most successful candidates from Phase I to a pre-manufacturing prototype and will assess the actual performance of a large number of devices in a field demonstration.

Home Energy Conservation. Proposed new work will quantify the progress of energy conservation in the residential sector. Changes in energy intensity for heating and appliance use will be compared with changes in energy prices and other variables for the period 1972-79. Existing data bases will be assessed, indicators of progress will be developed and tested, changes in the United States will be compared with changes in other countries, and policy oriented assessment of the conclusions will be made. It is expected that output from this project will be immediately applicable to an ongoing monitoring of residential energy use in the United States.

Technology Transfer and Commercialization (C3 01 05) (FY 79 $0.2 M)

Appliance Efficiency Performance Standards (C3 03) (FY 79 $0.1 M)

The Appliance Energy Performance Standards program provides analysis for the development of appliance efficiency standards by the Department of Energy. The specific goals of the program include 1) assessment of factors that influence appliance energy demand, under conditions with and without appliance efficiency standards; 2) analysis of how variations in weather and house construction affect the setting of appliance efficiency standards; and 3) estimates of the effect of alternative appliance efficiency standards on growth of peak-electricity loads. These goals will be achieved, in part, through the use of two existing computer models: the ORNL Residential Demand Model, which projects energy use by end-use device in the residential sector, and the LBL DOE-1 model, which analyzes building energy use.

Program emphases after 1980 will be on technical and economic issues relevant to updating the standards or developing future standards.

Technology Development (C5 06 04) (FY 79 $0.1 M)

The Dual-Mode All-Electric Transportation System terminates with FY 1979.

High Temperature Processes (C4 20 01) (FY 79 $0.1 M)

This project terminates with FY 1979.

Appropriate Technology (C8 08) (FY 79 $0.1 M)

LBL is working with the DOE San Francisco Operations Office in support of the DOE Appropriate Energy Technology Pilot Program for Federal Region 9. The Laboratory's role includes offering technical assistance to the San Francisco Office, providing technical evaluations of proposals, monitoring certain projects throughout the Region, developing a methodology and data base for assessing their energy savings, developing a format for a Fact Book describing the projects, and adapting the regional strategies and techniques for the National Program.

ENERGY POLICY, MANAGEMENT, AND INFORMATION

DOE: Administrator, Energy Information Administration (EIA)

ENERGY INFORMATION (FK) (FY 1979 $1.6 M)

Applied Analysis (FK 01) (FY 79 $0.2M)

Energy Analysis and Forecasting (FK 01 01)

International Conservation Analysis. The goal of the program is to collect and analyze a comprehensive data set on residential energy use in several large non-OECD countries. These data are essential for better energy-use forecasting, and for investigation of important conservation technologies and policies, both domestic and foreign. In future years this information will be updated and analyzed to provide information on the progress of conservation in other countries; on the overall relationship between energy prices, incomes, lifestyles, and residential energy use; and on the prospects for conservation in this large energy sector in the major energy-consuming countries.

Energy Analysis (FK 01 02)

Energy Scenario Review. The function of this program is to review and assess the impacts of the regional and national projections of energy supply and demand formulated by the EIA as part of its annual report to Congress. LBL critically reviews energy supply/demand projections for Federal Region 9 (California, Nevada, Hawaii and Arizona); assesses economic implications of national supply projections; and analyzes the regional economic, environmental, institutional, and health and safety impacts of projected energy development and use. The program further assists EIA's energy scenario development functions by providing inputs of critical information for Federal Region 9, including energy forecasts derived from state and industry plans and projections, and analysis of economic and other factors affecting energy supply and demand. This program's functions are anticipated to increase in scope to meet EIA's growing needs for information and analyses to improve the reliability of DOE forecasts and scenario development.

Analysis Access and Development (FK 01 03)

Energy Models Validation. DOE's Regional Demand Forecasting Model (RDFOR), was developed to estimate future annual energy demand by type of fuel, sector of use and DOE region. The present study of RDFOR aims to assess the uncertainty in forecasting over varying time horizons as a result of possible errors in the parameters used and assumptions made in this econometric model. The Hirst (ORNL) model of residential energy use contains a detailed structural model of behavioral and technological relationships. This study examines some of the equations in the model and the precision with which the numerous model parameters can be estimated. The predictive performance of the Hirst model will be compared with that of the much simpler RDFOR model.

Data Validation (FK 03 01) (FY 79 $1.4 M)

The Data Validation project terminates with FY 1979.

INTERGOVERNMENTAL AND INSTITUTIONAL RELATIONS

DOE: A/S Intergovernmental and Institutional Relations (IR)

OTHER (KN)

Intergovernmental & Industrial Relations (KN 02) (FY 79 $0.4 M)

Technical Information Services (KN 02 01) (FY 79 $0.3 M)

The Information Methodology Research Project conducts research in several areas of information science. Primary research emphases include thesauri and indexing, automatic content mapping among databases, and intelligent information systems. The products of this research have application to bibliographic and to numerical/fact data systems; these applications are being stressed, with the goal of providing timely support for DOE programs. Additional work includes thesaurus development for the Office of Administration (Executive Office of the President), a study of computerized word-processing, and participation in the ANSI X3J6 Committee, which is developing a national standard for text processing.

The Information Research Group (IRG) project performs research in areas of information science such as improvement of computerized storage and retrieval techniques using bibilographic databases, and applies the results of such research by providing information service to Laboratory research staff and non-LBL users. Major goals are: 1) to refine IRG's Selective Dissemination of Information System to improve search precision and recall; 2) to expand the fee computerized search services offered by IRG's Western Regional Information Service Center (WRISC); 3) to participate in the development of a series of Energy Information Centers being established in DOE regional offices; and 4) to participate in improving the effectiveness of DOE's RECON online bibliographic retrieval system through training seminars, newsletter publication, feedback from the RECON User Group, and fast document delivery systems.

Education and Training Programs (KN 02 02) (FY 79 $0.1 M)

LBL Co-op Program. The purpose of this program is to promote interdisciplinary education in energy technology. Students and faculty work at LBL under this program and receive training in energy related research. Nearly all the undergraduate students trained in a year-round program have been subsequently hired in energy-related projects. Participating faculty, predominantly from colleges and universities with large minority enrollments, have returned to their institutions to develop programs related to the energy research they undertook at LBL. In the future, the program will investigate the feasibility of working with the industrial sector in a nation-wide student training program.

University Programs. This program is intended to provide interdisciplinary energy education. These activities include: 1) summer faculty programs, 2) part-time employment of undergraduate students in the Energy and Environment Division during the school-year, and 3) summer participation by outstanding undergraduate students in Energy and Environment Research Programs.

WORK FOR OTHERS

Work for others at LBL includes work for other DOE contractors, work for other federal agencies, and work for state and local governments and agencies in the private sector. This work is described below under the respective organizations.

OTHER DOE CONTRACTORS

Lawrence Livermore Laboratory (LLL)

Research and development of neutral beam systems is performed as a subcontract for Lawrence Livermore Laboratory. LBL's effort is described on page 3-43.

Battelle Columbus

The ongoing program in nuclear waste management is funded by DOE through Battelle (Columbus), which has the lead mission assignment in the Commercial Waste Management Program.

Geologic Isolation of Nuclear Waste

A major requirement for the utilization of nuclear energy is the early development and implementation of a national waste management strategy. To assure the isolation of nuclear waste material from the biosphere for thousands of years many scientific and engineering questions need answering. This program encompasses several basic and applied research activities which address critical scientific issues related to the mechanical and hydraulic integrity of geologic repositories, the movement of waste nuclides through and interaction with host rocks, and the design of engineered systems to isolate further the stored waste from the biosphere.

US-Sweden Cooperative Project. This project is a cooperative research effort with Swedish scientists in which an abandoned mine at Stripa, Sweden is being used to determine the suitability of granitic rock for repositories. These first-of-a-kind experiments in "hard" rocks are located about 1000 feet below the surface, a depth approximating those envisioned for repositories. LBL researchers, along with cooperating university and industry scientists, are pursuing various experiments focused on: 1) thermal-mechanical response of the rock mass to heating patterns similar to waste canister implacements; 2) precise determination of a complex fracture system; and 3) movement of water through discreet fractures and through the macroscopic rock mass. The heater experiments will phase down in FY 1980 as geomechanical efforts focus on large-scale laboratory tests, analysis of Stripa data and correlation of experimental data with the detailed fracture mapping. Research activities in hydrogeology will continue stressing the problems in fracture flow and will move onto developing improved instruments and techniques for measuring fluid flows in nearly impermeable rock systems and for detecting fracture patterns remotely from the surface.

Rock-Water-Waste Interaction Studies. Complementing the Stripa field and laboratory work, is a program of fundamental research into the complex reactions between candidate repository rock materials, ground water and high-level waste chemicals. The program includes laboratory studies of aqueous actinide chemistry, analytical modeling of radionuclide migration, experimental analysis of the physical properties of various rocks, laboratory measurement of radionuclide sorption on natural minerals, development of new techniques to age-date ancient groundwaters, theoretical studies of the physical-chemical interactions between solutes and solid phases in natural flow systems, remote assessment of virgin rock systems, and improving the sampling and analysis techniques utilized in geochemistry investigations.

Solar Energy Research Institute (SERI)

International Program in Solar Cooling. SERI has been assigned primary responsibility for much of the US International solar energy program, including the joint US-Saudi Arabian SOLERAS program. One of the main thrusts of this $100 million, five-year program is solar cooling, including both active and passive cooling approaches. At SERI's request LBL will be providing the technical support necessary to carry out the program. This support role is based largely on the technical expertise at LBL manifested in the established solar program (see BD 01). In particular, LBL currently has the primary technical support role for DOE in both the active and passive cooling areas.

Electric Power Systems Reliability. This program is designed to develop mathematical tools for the evaluation of electric power system reliability. Emphasis is on closed-form analytic techniques to reduce the computational complexity associated with measuring the reliability impacts of solar electric technologies. The feasibility of this approach has been demonstrated by recent work on modeling wind turbine generators. Goals are to extend existing techniques and test their validity in specific applications. In the longer term, applications will be made to power systems of greatly differing size. Use of the techniques for economic evaluation is ultimately planned.

Photoacoustic Characterization of Hydrogenated Amorphous Silicon. This project is investigating the optical and electronic properties of hydrogenated amorphous silicon, by photoacoustic spectroscopy, particularly very near the band gap. Results should have direct bearing on the question of achieving higher conversion efficiencies from solar cells made of this amorphous material. It has recently been determined that with this technique and use of thin samples (1 μm thick) absorption coefficients of 0.1 cm^{-1} are detectable. This is four orders of magnitude smaller than measured previously. In the future, work on detailing the exact nature of the absorption edge and gap states will continue. The electronic properties of the material will be investigated to determine the mechanism of photoconductivity. Recombination mechanisms will also be investigated.

Morgantown Energy Technology Center

Solution Thermodynamics of Sulfites and Sulfite Oxidation Mechanism. A physical-chemical database which can be incorporated into a model sufficient to explain the operation, performance, and failure modes of aqueous lime (CaO) or limestone ($CaCO_3$) scrubbers for flue gas desulfurization (FGD) will be acquired. Information to be obtained includes: identification of calcium-sulfur adducts which can exist under various FGD scrubber conditions; thermodynamic properties of calcium-sulfur (IV) adducts, and of metal-ligand complexes of sulfur (IV) species with iron (II), iron (III), manganese, copper, calcium and magnesium; and kinetics and mechanisms of sulfur (IV) oxidation under conditions which prevail in lime/limestone FGD scrubbers.

Process Chemical Parameters in Aqueous Sulfur Dioxide Removal by Lime/Limestone Scrubbers. Physical-chemical information on the kinetics of complex formation and calcium sulfite-sulfate precipitation will be acquired for incorporation into a general chemical model which adequately and successfully predicts the operation and failure modes of aqueous FGD scrubbers. In order to assemble such a data base for a scrubber performance model, information must be obtained on the kinetics of calcium (II) reactions with sulfur (IV) derivatives and with sulfate (SO_4^{2-}) and the kinetics of precipitation from solution. Additionally, information on the kinetics of metal-ligand complexing between sulfur (IV) derivatives with iron (II) and iron (III) species shall be acquired as part of investigations and assessments of sulfur (IV) oxidation mechanisms.

Argonne National Laboratory

Assessment of Satellite Power System (SPS) Non-Microwave Impacts and Program Coordination. This project has the dual objectives of 1) assessing the impact of the Satellite Power System (exclusive of effects caused by microwave radiation), on workers in space, and 2) managing, coordinating, and guiding the nonmicrowave space worker effects program and complementary efforts by the Laboratory and other subcontractors to assess the nonmicrowave effects on terrestrial workers, the public and the ecology. The program is designed to implement part of the DOE-NASA research program on the Satellite Power System.

A Study of the Cataract-Inducing Potential of High-Energy Heavy Ions (HZE). This project will examine the potential damage to the lens of the eye (opacification and/or cataract induction) from exposure to high-energy, heavy ions. Data will be furnished that provide an estimate of the probability of this type of damage to space workers. The program is designed to implement part of the DOE-NASA research program on Satellite Power System.

OTHER FEDERAL AGENCIES

National Institutes of Health

In Vitro Electrophysiology of CNS Toxicity. This project is concerned with *in vitro* use of spontaneously active cerebellar Purkinje cells as a bioassay for determining the relative central nervous system toxicities of various environmental pollutants. The effects of hypoxia, carbon monoxide and methyl mercury are being studied. Our primary concern will be to understand the toxic effects on the energy generating mechanisms in the mitochondria of these cells.

Asymmetry of the Inner Mitochondrial Membrane. This project seeks to develop new spin-label techniques for determining the electrical topography of the inner mitochondrial membrane. A series of spin probes have been synthesized, purified and tested as part of the implementation of the dual probe method for measuring electrical surface potentials of biological membranes. Preliminary measurements of potentials of model lipid and red cell membranes were correlated with a mathematical model of ion binding. In the future, procedures for the quantitative analysis of surface charge heterogeneity will be developed and applied to the mitochondrial membrane. The effect of environmental mediated free radical membrane damage on surface charge will be investigated.

Role of Ligase and Other Enzymes in DNA Replication. The overall objective is determination of the roles in DNA-replication of various gene products (gp) of bacteriophage T4, with special focus on their mutual interactions. Special attention is placed on gp32 whose role in replication is thought to be unwinding of the ds-DNA template ahead of the replication fork. Other roles assigned to gp32, including control of ligase and nuclease activities, are studied. This work is intimately related to research on mechanisms of carcinogenesis from fossil fuel effluents under DOE category GK 01 02.

Structure of DNA-Unwinding Protein. The overall objective is study of the structure of DNA-unwinding proteins. Knowledge of the structure and functions of these substances is necessary to understand the mechanisms of DNA-replication, recombination and repair, which are in turn involved in carcinogenesis. This project is closely related to several DOE-funded investigations in GK 01 02.

Kinetics of Megakaryocyte and Platelet Turnover. Research centers on the kinetics of platelet regulation. There is a particularly strong relationship to the DOE-funded study "Effects of Pollutants on Growth and Differentiation in the Lung" (HK 01 02) because work on that project has shown that one of the earliest responses in the lung to pollutant exposure, particularly ozone, is the rapid removal of platelets during their passage through the lung. Platelet control is also the most important parameter responsible for death following acute exposure to ionizing radiation.

Purification of Erythropoietin. This research examines the physical and biochemical nature of the hormone responsible for controlling production of the red cell. The final goal is to develop a highly purified product, the biological properties of which could be examined in a number of systems presently in use in the Laboratory. There are several ongoing DOE-supported projects that are closely related to this project: "Pollutants and Hemopoiesis" (HK 01 02); "Endocrine Physiology and Energy Related Pollutants" and "Long Term Effects of High LET Radiation" (both GK 01 02).

Biological Structure Analysis by Electron Microscopy. This project uses the methods of high resolution electron microscope (HREM) structure analysis to determine the three-dimensional structure of several cell membranes. Using specimens which have a two-dimensional crystalline or periodic substructure, work is undertaken on a variety of eukaryotic and prokaryotic membranes and on ordered arrays of peripheral as well as integral membrane proteins. In tandem, studies are directed at developing several aspects of HREM structure analysis including solution of the hollow cone problem; development of computer software and data management capabilities to extend HREM structure analysis to small, crystalline patches; and extending structural resolution from the presently proven level of ~7 Å down to the EM instrument limit of 3.5 Å to 4.0 Å. This program relates to and complements activities under HK 01 01, particularly "Electron Diffraction/Structure Analysis."

Lipoprotein Methodology and Biomedical Applications. The objectives of this research are to investigate the basic chemical and physical properties, the structure and ultrastructure, the biochemical and physiological behavior, and distribution patterns of macromolecules (proteins and lipoproteins) as they relate to health and cardiovascular disease.

The information and methodologies acquired in this effort are used to study the effects of pollutants (hydrocarbons and heavy organometallic complexes) on these macromolecules (DOE category GK 01 02 02 3 Systems Damage). Specifically studied are: 1) the degree of damage measured by changes in composition and concentration of serum macromolecules; 2) the initiation of membrane and cellular damage by pollutants; and 3) changes to the enzyme systems associated with lipoprotein metabolism as a function of pollutant exposure.

Lipoprotein Methodology, Structure and Function. The purpose of this program is to train postdoctoral fellows in various lipoprotein methodologies and their biomedical applications so that they will be able to assume independent and responsible careers in the field of arteriosclerosis research. By participating at the bench in Laboratory programs, these trainees are making a significant contribution to the programs with which they are involved. These relate to DOE category GK 01 02 02 3 (Systems Damage).

Myocardium Infarct Sizing by ^{82}Rb Emission Tomography. The objectives are to evaluate the ability of rubidium-82 and the Donner 280-crystal positron emission tomograph to quantitate the extent of myocardial

ischemia and infarction and to image myocardial integrity (perfusion) in infarction and ischemic heart disease (IHD) subjects before and after exercise conditioning. A third objective is to develop a method for evaluating myocardial wall motion. A fourth objective is to investigate amino acid metabolism of the myocardium; in particular, the uptake of carbon-11-methionine in the normal and IHD patients will be assessed and the relationship of methionine metabolism to the occurrence of taurine in the heart will be investigated. The relative uptake of glutamic acid and valine will also be measured. This program relates to and complements activities under HK 01 02, particularly "Experimental Medicine Development of Radionuclides," "Experimental Medicine Clinical Diagnostics," and "Instrumentation for 3-D Tomography."

Physical Structure of Viruses, Chromosomes, and Cell Nuclei. The objective is to study the structure of viruses, nucleo-proteins and chromosomes, with particular emphasis on the internal organization of their nucleic acids. This will be attempted by using the optical properties of both DNA and RNA in their various chemical states, employing the methods of regular circular dichroism (CD), large angle of acceptance CD, fluorescent CD methods, and fluorescence detected circular dichroism (FDCD). Information will be obtained concerning the interaction between bases, nucleic acids, and protein complexes; electrical properties of protein coat; and hydrodynamic behavior of viruses in solution and changes in such behavior under alteration of chemical environment. This program relates to and complements activities under HK 01 01, General Life Sciences.

Quantitative Cardiovascular Research. The purpose of this project is to provide a nuclear medicine training program for selected trainees, who pursue their own related areas of interest. Current trainees are engaged in 1) speciality training and research using electron microscopy for purposes of looking at the architecture of white blood cells from normal subjects and subjects with blood diseases; and 2) the development of methodology for examination of early myocardial infarction, as well as the investigation of the kinetics of megakaryocytes. This program relates to and complements activities under HK 01 02.

Radioassay of Erythropoietin. This project has recently achieved advanced development and critical validation of a radioimmunoassay for erythropoietin. The general objective of the future program is to use this erythropoietin radioimmunoassay in a broad spectrum of clinical and physiological studies. These studies will include: the time sequences for the initiation of erythropoietin production in response to hypoxia and cobalt administration in lab animals; circulating erythropoietin levels in lab animals exposed to ionizing radiations; and several other related studies designed to increase knowledge of erythropoietin radioimmunoassay as a diagnostic tool. This program relates to and complements activities under HK 01 02, particularly "Pollutants and Hemotopoiesis," and GK 01 02, particularly "Endocrine Physiology and Pollutants."

Stem Cell Kinetics and Marrow Transplantation. The ultimate purpose of this research is the facilitation of marrow transfusion in man for

non-malignant conditions by reduction of the amounts of marrow needed for transfusion and, if possible, without whole body irradiation or general immunosuppression. More specifically, the project will focus on the kinetics of pluripotential stem cells in the mouse after partial body irradiation following marrow transfusion, using the difference between male and female karyotypes for identification of donor cells. The program relates to and complements activities under GK 01 02, particularly "Long Term Effects of High LET Radiation," and "Pollutants and Immune System."

In Vitro Electrophysiology of CNS Toxicity. This program involves the development and use of in vitro electrophysiology of spontaneously active cerebullar Purkinje cells as a bioassay for determining the relative central nervous system toxicities of various environmental pollutants. Hypoxia and carbon monoxide (CO) have been shown to have marked effects on the activity of these cells; these studies will be quantified and extended to include methyl mercury poisoning. This program relates to and complements activities under GK 01 02, particularly "Endocrine Physiology and Pollutants."

Alkylating-Carcinogen Mutagenesis in Mammalian Cells. This project has undertaken the development of a model system for studying mutagenesis produced by alkylating carcinogens in asynchronous and synchronous mammalian cells in vitro. Using asynchronous cells of different species and tissue origin, the project will measure the production of mutations by ethylnitrosourea (ENU) and related environmental carcinogens. The effects of cellular recovery and repair processes on the induction of mutations will be determined, and the loss of carcinogen-produced damage measured. Moreover, the induced frequency of certain specific mutations during cell cycle will be measured to test whether specific mutagenic changes are associated with specific cell-cycle times. This program relates to and complements activities under GK 01 02, particularly "Tritium Damage in Mammalian Cells," and "Damage of Mammalian Cells by Solar Energy."

Studies on T4 Phage Gene Product 32 Protein-DNA Complexes. This project is part of a multi-phase program on the structure of DNA as related to radiation damage and DNA repair. The program objective is to study the interaction of nucleic acids (native and synthetic) with the gene product protein 32 of T4 bacteriophage by spectroscopic methods, including circular dichroism, flow oriented and fluorescence detected circular dichroism. These methods will afford information on the secondary and tertiary structure of the nucleic acids in the complex and the structure of the active sites of the protein. This program relates to and complements activities under HK 01 02, particularly "Electron Diffraction and Structure Analysis," and GK 01 02, "Molecular and Cellular Mechanism of Heavy Ions."

Heavy Ion Radiation and Multicellular Spheroids. The project will examine the relative biological effectiveness of heavy ion radiation on cell lines grown as multicellular spheroids. These spheroids have some properties associated with organized tissue systems. The mechanisms

underlying the apparent fraction of radioresistant cells in spheroids will be examined. The role of cell cycle redistribution and anoxia will be evaluated and potential for repair of sub-lethal damage and potentially lethal damage will be determined. The equivalent of a tumor cure dose for this in-vitro system will be measured, along with growth delay as a function of LET of the heavy ion radiation. Alteration of cell cycle distribution in regrowing tumors will also be evaluated. This program relates to and complements activities under GK 01 02, particularly "Long Term Effects of Heavy Ions."

Megakaryocyte Differentiation. This project aims to provide a basic understanding of the pathway of platelet formation, and ties in with research being done on the effects of pollutants on the blood platelet and its physiological capacity. We propose to investigate the kinetics and ultrastructure of megakaryocyte maturation under a number of experimental conditions: 1) humoral stimulation without concomitant alteration of circulating platelet levels; 2) during and after hypoxia, and 3) in in vitro systems. This program relates to and complements activities under HK 01 02, particularly "Pollutants and Hemopoiesis."

Dietary Effects on Serum High Density Lipoproteins. This project will study diet-induced changes in high-density lipoproteins (HDL) and other lipoproteins that would allow better design and interpretation of diet therapies aimed at reducing the risk of cardiovascular disease. This research is important in determining the nature of lipoproteins in human serum and the role that they play in the transport and metabolism of toxic substances and will provide elegant base line data on the lipoprotein levels in human serum. It relates to and complements activities under GK 01 02.

National Cancer Institute

Treatment of Cancer with Heavy Charged Particles. The objectives of this program are:

1. Evaluate the potential of heavy charged particle radiotherapy of human cancers through critical analysis of biophysical parameters relative to tumor sites selected for irradiation.

2. Develop the physical and dosimetric bases for heavy charged particle therapy including beam modification, beam line dosimetry and radiation therapy treatment planning.

3. Develop effective, reproducible treatment techniques for large field, multi-fraction, spread out Bragg peak radiotherapy.

4. Establish the framework for a cooperative clinical trial of heavy-charged-particle radiotherapy utilizing a network of university and community radiotherapy facilities.

5. Compare the effectiveness of heavy charged particles to the best available low LET radiotherapy techniques by designing and carrying out a clinical trial of these beams in human cancers.

This program relates to activities under GK 01 02 and HK 01 02, particularly "Molecular Mechanisms of Cell Effects of Heavy Ions," "Long Term Effects of High LET Radiation," and "Bevalac Biomedical Operations." The activities under this NIH-funded program represent one of the most important goals of these DOE-supported projects.

Tritium Damaged Mammalian Cells In Vitro. This project involves research on the basic mechanisms that lead to mutagenic alterations in cells exposed to potentially mutagenic and carcinogenic chemicals. Chromosome damage, DNA repair, and mutation in several mammalian cell lines are examined. The work is directly applicable to DOE research objectives on mechanisms of mutagenesis in mammalian systems, and will contribute to DOE goals of increased understanding of chemical mutagenesis and the development of potential mutagenic screening methods (GK 01 02).

The Response of a Rat Rhabdomyosarcoma to Heavy Ions. This research consists of the study of the response of a solid rhabdomyosarcoma tumor system in rats to high-energy heavy charged-particle beams. The objectives are: 1) to compare tumor response from irradiation in vivo and in vitro by various charged particle beams in both single and fractionated exposures in order to aid in the selection of the most promising beam (or beams) for clinical application; and 2) to study in depth the heavy-ion radiation response of this tumor via several end points, including TCD_{50}, radiation-induced growth delay, cell survival (in vitro assay) after irradiation in vivo, cell survival of both oxygenated and hypoxic cells after irradiation in vitro and, in addition, several cell-kinetic end points. This program relates to and complements activities under GK 01 02, particularly "Molecular Mechanisms of Cell Effects of Heavy Ions" and "Long Term Effects of High LET Radiation"; and "Bevalac Biomedical Operations" under HK 01 02.

Investigation of Human β-Lipotropin. The objective of this project is to investigate the physiology and pathophysiology in man of Beta-Lipotropin (β-LPH), a pituitary hormone whose function is still virtually unknown. By measuring β-LPH in normal subjects and in patients with pituitary tumors and other disorders under various physiological situations and in response to experimental challenges, the research aims to gain insight into the normal function of this hormone, its possible role in the pathogenesis of certain diseases, and its utility for diagnostic purposes. This program relates to and complements activities under HK 01 02, particularly "Metabolic Ward," and "Pituitary Particle Radiation."

Physical Characteristics of Heavy Ion Beams. The purpose of the research is to measure the physical characteristics of high-energy ion beams as a function of absorber depth, i.e., charge, velocity,

and relative fluxes of heavy-charged particles and secondary fragments produced in tissue-equivalent materials, ridge filters used to spread out the Bragg peak, and beam flattening filters. The results will be interpreted to obtain the quality of radiation fields from beams used in biomedical research at the Bevalac. This program relates to and complements activities under HK 01 02, particularly "Bevalac Biomedical Operations."

Heavy Ion Radiobiology Related to Oncology. This program involves the investigation of the effects of accelerated heavy particles (such as carbon, neon, and argon ions) on biological material. The research is intended to provide information on the fundamental nature of the interaction of ionizing radiations with biological matter, and on the use of such heavy ions in the treatment of human cancer. The principal accelerator facility used is the Bevalac, which is capable of producing biomedically useful heavy-ion beams to 1 GeV/nucleon kinetic energy. Cellular and molecular studies include the effects of heavy-ion beams on survival of mammalian cells in tissue culture; the modification of these effects by oxygen and by pharmacological radiosensitizers and protectors; and the yield of single and double strand scissions in DNA and its repair. Tissue radiobiology encompasses an initial study of the effects of heavy-ion beams on normal mammalian tissues. Both acute and chronic effects will be considered because they relate to eventual application of the beams to human therapy. Tumor radiobiology is concerned with the kinetics of cell proliferation in animals that receive therapeutic doses. Pretherapeutic physics will make preparations for human applications, including construction of a computerized beam delivery system. This is a core program, and it is the center of several satellite investigations dealing with special aspects of the same subject. This program relates to and complements activities under GK 01 02, particularly "Molecular Mechanisms of Cell Effects of Heavy Ions," and "Long Term Effects of High LET Radiation"; and "Bevalac Biomedical Operations" under HK 01 02.

Studies in Human Mammary Tumor Virology. This project is part of a continuing study of etiology of human mammary cancer, including the development of stable cell lines derived from human mammary epithelium. The goal of these studies is to identify morphological and biochemical markers that correlate with each stage of malignant breast disease, and to provide new insights into the mechanisms of mammary carcinogenesis. This program relates to and complements activities, under HK 01 02, particularly "Growth and Differentiation in Lung," HK 01 02, particularly "Chemical Mutagenesis and Carcinogenesis," and GK 01 02, particularly "Environmental Cancer Risk Evaluation."

Environmental Protection Agency

Cocarcinogenesis in Mice. This research investigates the possibility that NO_2 and SO_2 increase the incidence and/or shorten the latent period of lung adenomas, and that the cellular changes preceding overt tumors induced by a chemical carcinogen are influenced by these gases. If these air pollutants are found to increase the incidence or shorten the latency

period of lung tumors, the data will be relevant to air pollution standards. This project contributes directly to the goals of DOE research under GK 01 02, and was in fact funded by DOE in that category until the large shift of such projects from DOE to EPA during FY 1979.

Baseline Studies to Support Carcinogenesis. Recent epidemiological surveys on radiation-induced cancer in human populations exposed to low level ionizing radiation raise important questions on the validity of existing dose-incidence models (particularly the linear, no-threshold hypothesis), and thus on the estimation of excess radiation-induced cancer risk for public-health protection. This project focuses on analysis of cogent aspects of selected epidemiological surveys currently in progress, or recently completed, on radiation-induced cancer in man exposed to low levels of radiation and emphasizes the interrelationships of cancer incidence and radiation dose, and how these interrelationships are affected by 1) radiation factors; 2) host factors; 3) other factors which may be cocarcinogenic or synergistic, particularly at low levels of radiation exposure. This project contributes directly to the goals of DOE research under GK 01 02, and was in fact funded by DOE in that category until the large shift of such projects from DOE to EPA during FY 1979.

Participation in MAP3S Program. This project conducts laboratory experiments to study pollutant transformations in raindrops. Recently a prototype fog chamber has been constructed and the first experiment on conversion of SO_2 to sulfuric acid has been completed. In the future the chamber design will be improved and experiments extended to NO_x, NH_3, and organic vapors.

Baseline Studies to Support Metabolism. This project defines the effects of environmental pollutants (such as O_3, NO_x, SO_x, and aromatic hydrocarbons) in animal and model systems by observing changes in serum macromolecules and blood transport of lipid soluble hydrocarbons, carcinogens, and mutagens. In addition, lipid and lipoprotein methodology development will be focused to provide simplified, accurate, and microtechniques for use with animals, as well as for potential screening of human populations at risk. The project is directly related to DOE category GK 01 02 02 3 (Systems Damage).

National Aeronautics and Space Administration (NASA)

Carcinogenesis and Life Span Studies with Mice Exposed to HZE Particles. The objective of this study is to provide information needed for predictive modeling of the excess risks of carcinogenesis and other deleterious late effects from space related radiation. The fundamental driving force for production of this information is the need to understand the risks to human beings exposed to HZE radiations (cosmic rays) in space. The program relates to and complements activities under GK 01 02, particularly "Acute and Late Effects of Heavy Ion Radiations on Normal Tissue," and "Cellular and Biophysical effects of Heavy Ions."

Measurement of the Production of Neutrons by High Energy Ions. The objective is measurement of fragmentation processes and interaction leading to emission of neutrons or other secondary particles when heavy ions interact with tissue equivalent absorbers. It is supportive of DOE's environmental interest in the Satellite Power System, and is complementary to research being done under GK 01 02, on delayed and late effects of heavy ions and on cellular and biophysical structure of heavy ions.

OTHER ORGANIZATIONS

Electric Power Research Institute

Optimization of Microcosm Design. The goal is to discover and evaluate appropriate design, initiation, and operation procedures for freshwater microcosm systems so as to optimize their effectiveness as tools for environmental impact research. Recent accomplishments include development and initial assessment of operating procedures, the most significant development being the use of a pouring strategy to eliminate problems of surface growth. Future work on optimization of microcosm design will include improvements to allow the inclusion of a benthos in microcosms without inducing severe distortions in system behavior, and the development of better initiation techniques to improve tracking.

High-Strength Austenitic Alloys for Generator Retaining Rings. Improved high strength, high toughness austenitic alloys are to be developed for potential use in generator retaining rings. The goals of the program were established in recognition of two current needs: 1) higher strength allows for use in retaining rings for large electrical generators and 2) alloys which could be processed into ring geometry without cold expansion so as to encourage the re-entry of domestic firms into retaining ring manufacture. This project specifically envisions a non-magnetic alloy which could be thermally processed to strengths above 200 ksi yield while retaining good toughness, resistance to both dry and damp hydrogen, and such subsidiary properties as would be needed in an alloy to be manufactured into retaining ring geometry.

Substructure and Properties of Sodium Beta Alumina Solid Electrolytes. The objective is to determine the mechanism(s) of failure initiation and propagation in the polycrystalline β'' alumina that are currently used for advanced sodium-sulfur battery development. A close liaison between this program and the currently active sodium-sulfur battery development programs is to be maintained to ensure optimum benefit from accomplishments attained.

Oxygen Reduction in Concentrated Phosphoric Acid by Carbon-Supported Platinum Alloy Catalysts. New catalysts for use in first generation electric utility fuel-cell power plants are to be investigated. These catalysts are expected to show high activity and low rate of coalescence, which results in a loss of performance. A metallic catalyst which is

more strongly bonded to the carbon substrate than pure platinum is expected to show reduced surface migration and tendency to sinter, with enhanced corrosion resistance. Alloys with platinum of the intermetallic type, whose stabilities may be enhanced compared with the parent metal, will be investigated. This research aims to verify the stability and suitability as electrodes for phosphoric acid fuel cells with higher activity than platinum in equivalent amounts.

SECTION IV

NEW INITIATIVES

This section contains descriptions for new LBL work as proposed by the Laboratory to DOE in its preliminary submission of April 19, 1979. We believe that these proposed projects are of great importance to the national energy effort and that the Laboratory can bring unique expertise to their pursuit. We continue to urge that they be supported by the Department of Energy.

The Laboratory has received guidance concerning the degree to which these programs will be supported by DOE in FY 1980. These guidance statements are included, as appropriate, at the close of each individual project description.

NUCLEAR WASTE ISOLATION

The Laboratory, in close collaboration with UC-Campus faculty, initiated in FY 1979 a long-term multidisciplinary program of fundamental research in the storage of high-level nuclear waste. This program is being developed through ONWI-Battelle and comprises a number of research areas amenable to LBL expertise.

These and other nuclear waste research efforts are being undertaken within the matrices of two Laboratory divisions: the Earth Sciences Division, comprised of hydrologists, geophysicists, geologists, and geochemists, and the Materials and Molecular Research Division, comprised of chemists, nuclear scientists, and materials scientists. The efforts of LBL-UCB scientists have resulted in the three topical research areas noted below which are presently at early development phases but have the potential to become major DOE programs.

Waste Form and Radionuclide Migration

Candidate mineral hosts for isolation of radioelements will be characterized by nuclear quadrupole resonance techniques. The problem of leakage of radioelements from a repository into and through the hydrologic system will be investigated by laboratory studies of actinide chemistry, analytical modeling of radionuclide migration, theoretical studies of the physical-chemical interactions between solutes and solid phases during transport in natural flow systems, and the investigation of the state-of-the-art of tracer techniques.

Models used for the prediction of radionuclide migration in geologic media over very long time periods, by specifying rock-nuclide interactions, must have as input parameters reliable data on the species, oxidation states, and concentrations of the radionuclides in solution. There are, however, no comprehensive or consistent sets of experimental data on the chemistry of the anticipated actinide and fission product ions and their compounds under conditions found in underground geologic formations.

As part of this program, a long-term, systematic study will be undertaken to determine the oxidation states of the various radionuclides and to identify and measure the formation constants of the principal monomeric and polynuclear chemical species formed in aqueous solutions of compositions common to geologic formations.

Hydrology and Radioelement Transport

Techniques to investigate the effects of the hydrologic regime of nearly impermeable rock on radioelement transport will be developed by a project incorporating field surface and subsurface measurements in crystalline rock environments. Complementing this will be detailed studies of fracture hydrology, utilizing the large-core test facility presently operating on the University of California's Berkeley campus. This facility is the first generation of a laboratory to simulate in-situ temperature and pressure conditions in the testing of meter-scale rock core and block samples. Determination of isotope ratios in the Uranium-238 decay series, by use of high-sensitivity mass spectrometry, will help discern the pathways actinide elements follow in the hydrologic system and may permit definitive determination of the ages of groundwaters. This study will be complemented by examination of natural concentrations of uranium and the accompanying distribution of radioelements in surrounding rock, as analogs to the occurrence of radionuclides in a repository environment.

Thermodynamic Properties of Chemical Species in Nuclear Waste

Thermodynamic properties of anticipated actinide and fission product ions and the compounds they may form in geologic environments will be determined so that their chemical behavior, and potential migration, in a nuclear waste setting can be assessed. Monomeric, polynuclear and colloidal chemical species formed in aqueous solution will be identified as a function of pH, temperature, ionic strength, concentration of radionuclides, and concentration of environmentally important complexing ligands. Formation constants of species and oxidation states of radionuclide will be determined. Chemical effects of materials introduced in the repository by canisters, fuel rods, and packing materials, which may react with the actinides and fission products under conditions of elevated temperature and pressure expected in the repository, will be identified.

Geomechanics

New techniques to determine properties of the rock mass encompassing a repository will emphasize nonpenetrative methods. The intensity and orientation of fractures and elastic moduli will be investigated by utilizing seismic methods. Acoustic emissions associated with the propagating of fractures caused by rock stresses from thermal transients will be monitored and analyzed by a real-time multi-detector, telemetered seismic system. The ability to detect fracture patterns in a rock mass by seismic signals generated in one drill hole and detected in another (Cross-hole techniques) and by ultrasonic reflection techniques will be investigated.

Implicit in many of these projects is the employment of numerical and analytical modeling, first to predict behavior of the rock mass under thermal loading and permeabilities and flow paths of a fracture-dominated hydrologic system; then to refine the models as field and laboratory test data are acquired.

To carry out this research program, instrumentation for in-situ measurements of rock deformation, stress and displacement, and borehole pressure probes for hydrologic properties will be upgraded. Gamma-ray detectors to monitor radioactivity in a high temperature (200°C) environment will be developed. Geophysical equipment, for example, a high-resolution acoustic logging system for slim holes (6 cm) will be developed to evaluate the fracture pattern surrounding a repository site, prior to and during the thermal loading.

Several of the projects are field-oriented, and in this respect require operations at one or more in-situ test facilities. For example, the response of a large rock mass to thermal loading and the determination of macro-scale rock permeabilities are being investigated through a Swedish-American cooperative program carried out in the Stripa mine in Sweden. In exploration and evaluation of repository sites it will be required that drilling and excavating be kept to a minimum to ensure the future integrity of the repository. Through employment of test facilities in crystalline and argillaceous rock types, we can develop and assess techniques by comparing results of detailed surface and subsurface measurements, which will then form the basis for choosing the appropriate methods and degree of detail to be employed in evaluation of repository sites.

Requirements:

FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
$2900 K	3900	5000	5800	6500	7000

Direct Manpower Increase:

+25	+10	+8	+8	+8	+6

DOE GUIDANCE: "The new initiative on nuclear waste isolation is not among those to be funded in the near term. LBL participation in developing computer models predicting radionuclide migration in geologic media is of interest."

FOSSIL FUELS RESEARCH

Chemical Processing Research

LBL possesses unique capabilities for research on critical fundamental problems relating to the development of fossil-energy

resources. Strong ties with the Departments of Chemical Engineering, Mechanical Engineering and Chemistry of the Berkeley campus provide well-respected Principal Investigators with a wide range of pertinent expertise. These departments are highly rated in academic research, and the Engineering departments are distinguished for their broad coverage of the spectrum from fundamental engineering science to processing applications. This faculty resource, coupled with LBL professional staff and analytical and instrumentation facilities, gives LBL a unique potential for basic scientific studies and exploratory process research on fossil-energy problems. At the same time this research accomplishes the important mission of training top-flight graduate students for work in the energy field. LBL capability in these areas is presently under-utilized.

Several key fossil-fuels problems hinge upon principles and research in chemical processing. Existing research at LBL concerns development of novel and more effective catalysts for coal liquefaction, as well as fundamental studies of existing catalysts so that ways of utilizing these can be improved. Associated research deals with improvement of process configurations and operating conditions to take advantage of catalyst properties, and with development of improved materials to withstand the unusual conditions encountered in fuels-conversion processes. Existing work on catalytic liquefaction of biomass has yielded useful concepts which are transferable to coal conversion processes, and also strongly suggests that coal studies can profitably be extended to peat, lignite and other lower-grade fuels.

Sulfur presents a major problem in coal conversion or direct combustion. Present work is evaluating alternative coal-desulfurization processes on a common basis. A profitable complement to this work will involve physical and chemical characterization of the pore structure of coal, and the accessibility and chemical reactivity of different forms of sulfur in coal; this approach has a high likelihood of leading to improved desulfurization methods through better fundamental understanding. This work will also have a direct bearing upon studies of coal reactivity in conversion processes. LBL also possesses strong capability for fundamental studies of chemistry and mass-transfer factors underlying flue-gas desulfurization (FGD) processes. FGD processes are needed for the foreseeable future to remove residual sulfur from stack gases. However, they are poorly understood from a fundamental viewpoint, and this holds back development.

All fossil-fuel conversion processes (coal gasification, coal liquefaction, oil-shale retorting) produce condensate waters in a large volume. These are highly contaminated and must be processed by means other than simple biological oxidation to allow water release and/or reuse in the process. Several substances (phenols, ammonia, etc.) have important chemical value when recovered. Processing these waters is complex and requires innovative approaches involving a number of classical chemical engineering separation processes. The opportunities for substantial advances through processing innovations are high.

LBL faculty investigators are particularly qualified for this task by virtue of their combined expertise in extraction, stripping, ion exchange, adsorption, and chemical complexing, as well as in biological waste treatmet. At present this is a developmental project worthy of considerable expansion.

Several current activities involve coal combustion, with particular regard to pollutant-formation mechanisms, behavior of particulates during combustion, and mechanisms of fluidized-bed combustion. These are complementary to other proposed LBL studies, and are themselves deserving of increased attention by virture of the capabilities of the LBL staff in this area.

A number of environmentally related LBL projects deal with fossil-energy sources and serve as an additional element of and resource to the LBL fossil-energy program. These concern pollutant emissions and partitioning in oil-shale retorting processes, as well as methods of controlling these emissions. A proposed additional project extends these studies to waters used in coal-slurry pipeline transport.

By virture of its faculty and professional-staff expertise in many facets of chemical processing and refining, LBL is also well equipped for down-the-road studies of processing, refining and catalytic upgrading of hydrocarbon products from fossil-fuel conversion processes, as well as considerations of the suitability of these products for chemicals manufacture. This is a field of wide importance and potential, which has not been much explored yet.

Coal Liquefaction

Several large pilot plants are now being constructed in this country for testing processes for direct coal liquefaction by hydrogenation. The technologies being used, however, are essentially based in pre-World War II German technology and are generally of high cost, although a number of improvements have been made. There is also operating in South Africa a plant (currently being doubled in capacity) using improved Fischer-Tropsch technology of old German design to synthesize hydrocarbons from synthesis gas derived from coal.

Relatively little is known about the underlying chemistry and physics of these processes. Only in the last 2-3 years have efforts started to gain such an understanding. If novel and more economic technologies are to be developed, much more fundamental knowledge is required.

The proposed project at LBL, titled "Chemistry and Morphology of Coal Liquefaction," deals with the mechanisms and the kinetics of coal liquefaction under mild conditions, permitting conclusions about parent structure to be drawn from them. Studies will be made of the morphological changes undergone by coal during hydrogenation by use of an electron microscope at actual liquefaction conditions.

It will investigate the role of transition metal catalysts impregnated in coal during hydrogenation. It will attempt the exchange of heteroatoms (N_1S) in coal liquids by oxygen, CO or ethylene. Model compounds will be used to study thermal and catalytic hydrogen transfer between donor solvents and coal-like molecules. Causes of corrosion by coal liquids will be investigated. In indirect liquefaction, the effect of shape selectivity of catalysts and of support-catalyst interaction in product distribution will be studied.

In the design of equipment for coal liquefaction and gasification, the properties and solubilities of gas-liquid mixtures, particularly of heavy aromatics, and their vapor-liquid equilibria are important for specification of heat exchangers and condensers. The proposed work will characterize these properties in various media.

In the gasification of coal by pyrolysis, hydrogenation or the steam-carbon reaction, the relationship between chemical and physical properties of the coal and the gas atmosphere is poorly understood. The proposed program involves the characterization of active sites on the coal and the study of changes in the coal morphology during gasification.

The Lawrence Berkeley Laboratory is in an exceptionally good position to undertake these programs, because it can bring to bear an unusually complete array of instrumentation and of diverse areas on specific, limited objectives, and in the study of the same materials.

Geological and Geochemical Impacts of Coal Mining

The 1977 Surface Mine Control and Reclamation Act requires that methods be adopted that are "consistent with known technology in order to prevent subsidence. . . to the extent technologically and economically feasible. . . except in those instances where the mining technology used requires planned subsidence in predictable and controlled manner." The objective of this proposed program is to provide basic information required for carrying out the Act, by developing an understanding of the fundamental mechanisms of the effects of coal mining on overlying strata, so as to be able to predict and control the perturbations of the surface, the disturbance to groundwater flow and the consequences of mine water drainage.

The most comprehensive studies of subsidence phenomena have been conducted in Europe, notably in Britain. These investigations are mainly in the form of extensive field measurements of surface subsidence and movements of the strata overlying mine workings. This information forms a data base from which predictions of the magnitude and extent of ground movements around future mine workings can be made. In the United States subsidence studies have concentrated largely on the development of numerical codes. Some field investigations have been carried out, but, in general, they have been coordinated poorly and there has been little atempt to correlate the data either to improve understanding of the basic mechanisms involved in subsidence or to

validate the numerical codes. In addition, until passage of the 1977 Act, the extent to which mining practices were adopted in this country to prevent subsidence or to predict and control subsidence was much less than is normal in Europe.

Although European studies of subsidence phenomena span several decades, they may not be directly applicable in the US mining situation for three reasons. First, these studies apply almost exclusively to longwall mining, a technique which accounts for only 5 percent of the nation's coal output, although gaining in popularity. Second, the depth of mining in general is substantially less in this country than in Europe. Third, the geology of the beds overlying coal seams is different from that found in Britain and West Germany. Nevertheless the Europeans have developed a method for predicting subsidence which appears to be satisfactory, and a first step in an investigation would be to determine the relevance of this work to conditions in this country.

In order to understand the mechanisms by which the overlying structure is perturbed it will be necessary to assemble a data base from measurements of the movement and subsidence of strata above US mine workings. This is required, first, to compare European and US data. Second, experimental data are required to permit verification of predictions of subsidence by numerical codes. Third, and most important, mechanisms to explain subsidence phenomena can be developed only after the behavior of the rock above the workings is well defined.

It is anticipated that these studies will reveal substantial gaps of information and that considerable effort, in the form of experimental work both in the field and in the laboratory, will be necessary to develop an adequate understanding. Several subject areas where present knowledge is inadequate for accurate subsidence prediction are: long term stability of pillars to weathering, precise nature of the caving (rubblizing) process, and the nature of strains induced in the overlying strata when subsidence occurs.

Waste stowing to minimize the effects of subsidence is a topic sufficiently extensive to warrant a separate research program. The influence and effects of stowing should be looked at in detail. Methods of emplacement of the waste, types of waste materials, hazards from spontaneous combustion are examples of areas that require attention. Again, experience in this field is more extensive in Europe than in the United States.

Groundwater hydrology is determined by the topography, permeability and porosity of the sub-surface. Since each of these factors is affected in some degree by subsidence and the mine workings constitute a new sink or aquifer, the effects of mining on the overlying strata determine in a large measure the perturbation of pristine hydrologic flow by mining. Once the mechanics of surface subsidence are understood and can be predicted, the effects of mining on the groundwater flow can be assessed. This will involve numerical modeling of these

effects and field and laboratory measurements to study these and correlate the models.

Problems arising out of the drainage of contaminated mine water are well known. However, this phenomenon is not understood sufficiently well to predict the effects of different methods of mining under various geological conditions on mine water drainage, so that they can be controlled. Once the perturbations of the hydrology by mining are understood and can be predicted, the science of geochemistry can be brought to bear as needed for adequate control of this problem.

By using the techniques described here, plus others to be developed, an understanding of the fundamental nature of the subsidence process can be gained. Empirical results will subsequently be available in a data base from which predictive studies can be made directly or computer codes developed for modeling subsidence behavior.

Total fossil fuels research requirements:

FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
$1100 K	1600	2100	2400	2600	2800

Manpower Increase:

+11	+11	+10	+6	+2	+2

DOE GUIDANCE: "The new initiative on fossil fuels research consists of several projects. Of these, only the coal liquefaction work is of interest at present. Current plans are to provide a level of support of approximately $500K in FY 1980 and to continue this level in the next few years. LBL is encouraged to define the tasks and level of effort for this directly with the program office."

IMPROVEMENTS TO PEP (FY 1984)

Apart from energy up-grading of the PEP electron-positron beams from 18 to 20 GeV and possibly to ~24 GeV (Schedule 44's have been submitted), a significant improvement would be accomplished by the addition of a superconducting proton-ring-system. This would open a completely new region for high energy exploration. The initial PEP (Proton-Electron-Positron) studies included consideration for this proton ring in order to achieve ultra-high-energy collisions of electrons with protons as well as with positrons. The current goals are aimed toward maximum energy collisions of ~25 GeV electrons with ~300 GeV protons (over 170 GeV c.o.m.).

This system would provide an extension of experimental parameters well beyond that of traditional fixed target electron machines (e.g., SLAC) in areas of inelastic scattering, photo-production, etc. In

addition, the weak interaction process could be explored uniquely with a well controlled and well understood electron probe. Details of the strength of the weak interactions at these energies would be a significant result. The energy is also interesting for the production of new particles in the vicinity of 80-100 GeV mass.

Certain special features are incorporated in the current PEP system (nearing construction completion) to make it compatible with the installation of a future proton ring with adequate shielding. Maximum field superconducting magnets are planned to achieve maximum collision energy at minimum power costs. The proton ring would be installed in the existing tunnel enclosure above and below the electron ring system. Current experimental areas are spatially adequate with structural provisions for additional shielding.

The development of high field superconducting magnets is being pursued mainly at LBL, and the development of superconducting rf cavities (important to the electron and perhaps proton rf system as well) is underway mainly by SLAC personnel.

NUCLEAR PHYSICS ACCELERATOR/STORAGE RING - VENUS (FY 1983)
(Variable Energy Nuclear Synchrotron)

Studies of a versatile facility to serve the nation's heavy ion physics needs in the 1980's and beyond have been underway at LBL for several years. Intensive discussions and workshops regarding post-Bevalac research priorities point to the need for an accelerator with the following basic capabilities:

1. Intense ion beams of all masses, from protons through uranium.

2. Low energies to 40 MeV/A, overlapping the range of the 88-inch cyclotron.

3. Intermediate energies at intensities significantly greater than those at the Bevalac.

4. Highest beam energies well above the Bevalac range, i.e., to 20 GeV/A for the heaviest ions.

5. Center of mass energies $E_{CM/}$ A = 40 GeV/2A or more with colliding beams of equal mass nuclei (i.e. the total CM energy available is 20 GeV times the number of nucleons).

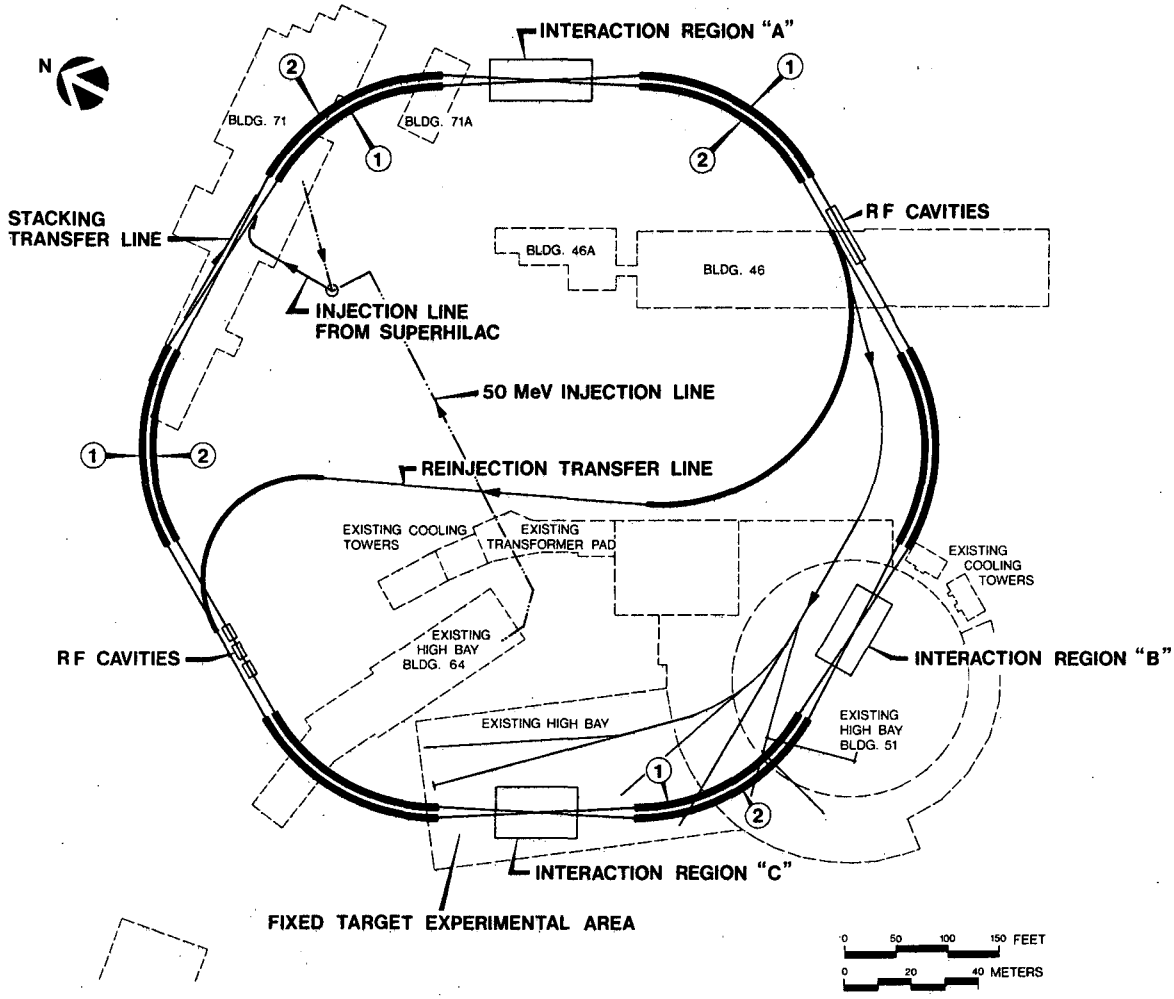
Practical considerations also dictate that both construction and operation of such a facility should be as economical as possible, with minimum power consumption and staffing requirements. Finally, the accelerator should be designed for flexibility in adaptation to future research and operating criteria.

An approach which promises to fulfill all of the above requirements is to combine an accelerator and storage ring in a single facility and do so without sacrificing the performance of either component. This scheme can be realized with two identical superconducting rings, located inside a single tunnel, with the SuperHILAC as injector. One ring would serve as SuperHILAC booster to accelerate the 8.5 MeV/A injected ions to about 1 GeV/A. At this energy they can be stripped without loss and transferred to the second ring for acceleration to a maximum of 20 GeV/A for the heaviest ions, up to 25 GeV/A for light ions and 50 GeV for protons.

An S-shaped reinjection line permits storage ring/colliding beam operation. In this mode, half the particles at the desired energy would be split from one ring, transported via the reinjection line, and injected in the opposite direction (with the magnetic field reversed) in the other ring. Two different ion beams can be sequentially stacked in one ring, and then separated for colliding beam experiments.

The ring tunnel elevation would be below that of the present Bevatron and its experimental hall. For fixed target operation this area would be reused, with experimental apparatus relocated or newly designed to suit VENUS requirements. Beam will be extracted from Ring 2 and transported up to the experimental hall at the Bevatron floor level. For colliding beam experiments, three interaction regions are envisioned.

DOE GUIDANCE: None specifically received, but DOE and NSF have in place a Nuclear Science Advisory Committee to which this proposal will be submitted in due course.



XBL 796-10101

Fig. 4-1. VENUS, A Relativistic Ion Synchrotron and Storage Ring.

SECTION V

PERSONNEL RESOURCES

The present mix of LBL professional and support personnel has evolved smoothly over several decades that encompassed periods of substantial growth. Especially during the past decade, the Laboratory has brought about a greatly increased involvement of university faculty and Laboratory staff in research related to the nation's energy problems. This interaction of Laboratory and University has produced a unique personnel blend: of the 1162 individuals on the LBL professional staff, over 150 are members of the Berkeley faculty. More than 400 graduate students from 18 campus departments are doing research toward advanced degrees at the Laboratory. A large population of postdoctoral appointees from United States and foreign universities are part of this mix. About 200 PhD scientists from 50 countries participate in LBL research.

As the nation's energy problem reaches serious proportions and the future of the United States energy system appears increasingly uncertain, the role of high-quality research becomes even more critical. Lawrence Berkeley Laboratory can continue to make outstanding contributions to this research. During periods of overall expansion, this contribution can be assured by manpower growth with maintenance of worthy ongoing research. Today, however, we are entering a period of near steady-state operation, and the Laboratory's ability to respond to new research needs and opportunities will increasingly depend on the judicious use and development of the existing personnel resources. It is important that flexibility in the application of manpower guidelines and ceilings be maintained, especially in regard to the need for short-term fluctuations required for the development of new initiatives. In the coming years, especially, it is essential that the vitality of the Laboratory's programs and staff be maintained, that new ideas and programs be encouraged and that productive scholarship be rewarded. LBL will devote great effort to this end.

SECTION VI

SITE AND FACILITIES DEVELOPMENT

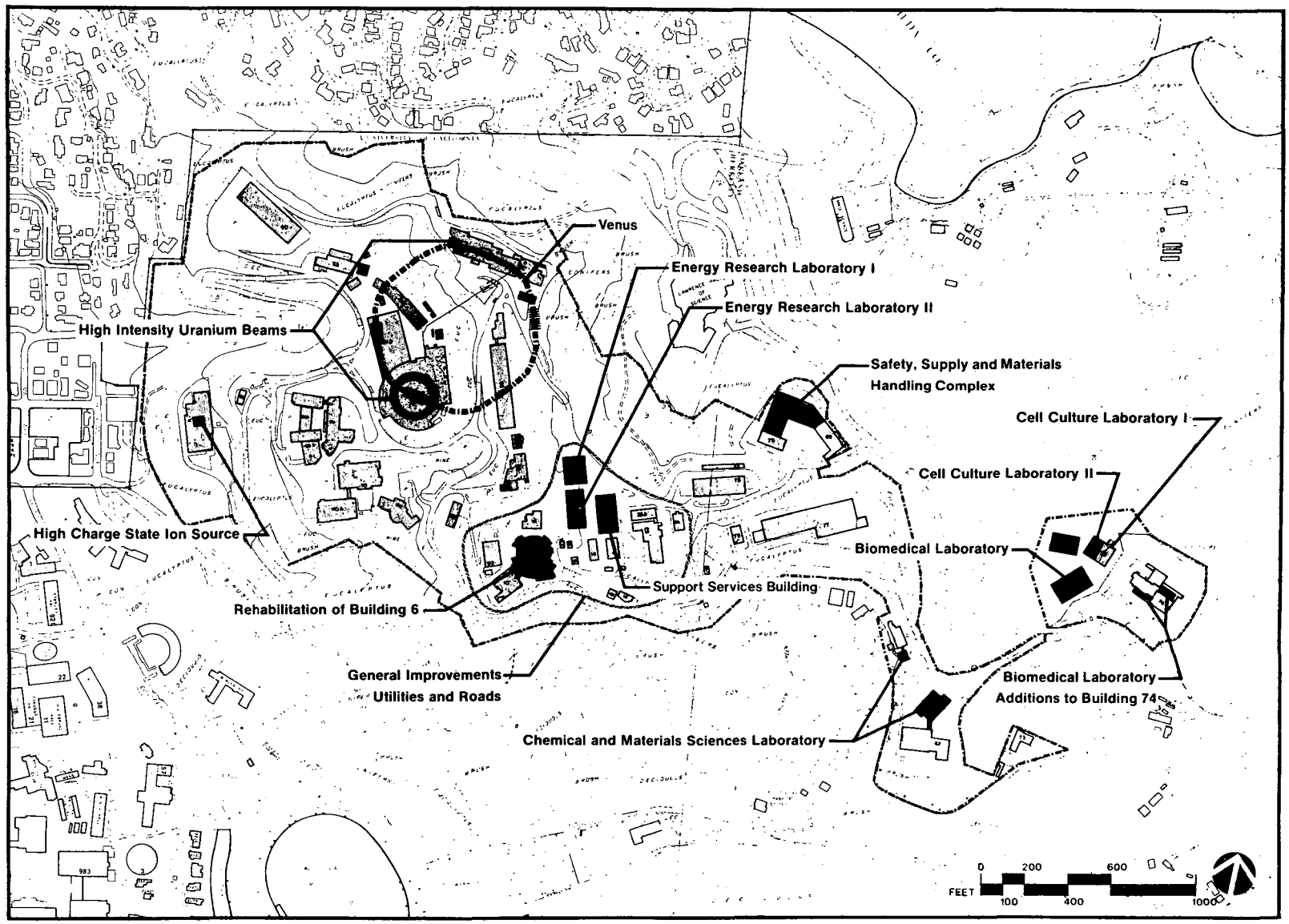
LABORATORY SITE DEVELOPMENT

In order for the Laboratory to accomplish the program goals set forth in this document new facilities need to be provided in addition to adequate manpower support. One of the largest single impediments to implementing program plans is the lack of necessary physical facilities. Many of the present facilities are less than adequate for present and planned tasks. In order to efficiently pursue the research programs to which the laboratory is committed, properly equipped laboratories and specialized facilities are needed to support the investment of experienced scientific and engineering personnel who will carry out the relevant research. Figure 6-1 is a map of LBL's major planned construction projects. Site development studies are now underway in three areas (184-Inch Cyclotron, Building 62-72 area, and Building 74 area) to determine the most practical use of the limited building sites available.

Existing programs have necessitated off-site relocations of many office and support personnel to accommodate research projects on site. Approximately 69,000 square feet of on-site trailer and modular buildings, including those planned, are needed to relieve the present problem of crowding. The space crisis emphasizes the Laboratory's primary problem: lack of laboratory facilities for optimization of ongoing programs.

Because of the effects of inflation, the present dollar limits on use of General Plant funds are too low to provide for major renovation, modifications, and equipping of present facilities. Therefore, some mechanism for agency sponsorship of general purpose facilities which simultaneously serves several DOE offices should be devised.

Proposed construction projects are briefly described below and are tabulated by DOE program in Appendix B.



XBL 797-10640

Fig. 6-1. Lawrence Berkeley Laboratory - Major Construction Projects for FY 1979-1985.

CONSTRUCTION

Program Special Facilities

High Intensity Uranium Beam (ER HK 03)

This project, presently in progress, entails modifications to the SuperHILAC and the Bevalac to permit acceleration of intense beams of all ions, including uranium, at both of these national facilities. At the SuperHILAC, a new high-mass injector will be added, while at the Bevatron, a new ultra high vacuum chamber will be inserted within the main ring. The last two magnets in the transfer line between the two machines will also be replaced.

High Charge State Ion Source (ER HK 03)

The Acclerator and Fusion Research Division and the Nuclear Science Division of LBL are planning the construction of an advanced high charge-state heavy-ion source for installation on the 88-Inch cyclotron. The purpose of this source is to double the energy available from the cyclotron for ions heavier than carbon.

Nuclear Science Accelerator (VENUS) (ER HK 03)

Studies of a versatile heavy ion facility for the 1980's and beyond have been underway at LBL for several years. The Laboratory's new initiative proposal for the VENUS acelerator is described on p. 4-9.

Improvements to PEP (ER HK 02)

The Laboratory's new initiative for the addition of a superconducting proton-ring system to the PEP electron-positron accelerator is described on p. 4-8.

Program Justified GPF

Cell Culture Laboratory I (In progress) (EV HK 01)

This project, scheduled to be complete in August, 1979 is a single story structure of about 6000 gross square feet. It contains laboratory work area, seminar room and offices. The containment area consists of a number of small laboratory rooms grouped around a general laboratory, and accessible only through air showers. The structure is situated on a hilly slope near Building 74 at the east end of the Laboratory. Research on effects of environmental contaminants at the cellular level will be done in this facility.

Chemical and Materials Sciences Laboratory (ER AK 01)

This addition to Building 62 will provide 46,000 gross square feet of floor area allocated to two-plus floors of laboratories and offices, a conference-seminar room located between Building 62 and the new

addition, partial basement with mechanical room/loading dock, and the Atomic Resolution Microscope high-bay building located adjacent to the High Voltage Electron Microscope facility at Building 72.

Biomedical Laboratory Building 74 Addition (EV HK 01)

This proposal is for the modification of the existing LBL Biomedical Laboratory to provide additional space for the programs of the Biology and Medicine Division. The modification will provide for staff and animal colony needs related to new programs, and will permit the relocation of some existing programs from older buildings not designed for biomedical research.

Biomedical Laboratory (EV HK 01)

This building, of about 40,000 gross square feet, is required to eliminate overcrowding in facilities presently occupied by the Biology and Medicine Division, particularly for ongoing space-intensive research. These programs include studies on carcinogenesis, inhalation toxicology, ionizing radiation research and radiotherapy. It will also permit geographic consolidation of programs now widely dispersed.

Cell Culture Laboratory II (EV HK 01)

This project is a structure of about 50,000 gross square feet for enlargement of the Laboratory's cell culture facilities. It will provide general laboratory facilities similar to those presently in the Chemical Biodynamics Laboratory on the Berkeley campus. It will facilitate interaction between biomedical and cell culture research, with common areas such as a library, glass blowing shop, and other support facilities.

General Purpose Facilities

Computerized Energy Management System

This system will provide continuous surveillance and control of LBL's energy consumption and plant operations. A central processor and control console will monitor and supervise remote data collecting and multiplexing panels or microprocessors, and will provide overall automatic and/or manual adjustments to plant operations as needed to maximize utilization, and minimize costs and energy consumption.

Energy Research Laboratory I

LBL's research in energy technology has developed considerably in recent years, necessitating staff additions and calling on a wide variety of physical resources. The new programs have brought together scientists and engineers from many places, including different divisions within the Laboratory, the Berkeley campus of the University of California, and from a variety of outside organizations.

Because of the lack of adequate central facilities a staff member transferring to one of the new energy-related programs has generally had to maintain his former location for lack of any space in which to co-locate with his new co-workers. This scattering of personnel has made it difficult to provide cohesiveness of program direction, and has limited the daily contact among persons of different backgrounds that is essential to success in this type of interdisciplinary research.

The staff and equipment for these programs are now dispersed through eighteen buildings at the laboratory, in many leased trailers and other temporary facilities, and at scattered places on the Berkeley campus. In addition, 40,000 square feet of off-site office space was leased for other Laboratory units displaced for these activities, thereby increasing inefficiency and operational costs.

The actions taken to date to provide for the new programs are only a temporary expedient and will not satisfy the need for adequate laboratory space for long-term productive research. The proposed Energy Research Laboratory will collect most of the elements of the energy technology programs now scattered throughout the Laboratory. The building will house energy technology research involving the Energy and Environment, Earth Sciences and Accelerator Fusion Divisions.

The proposed Energy Research Laboratory will contain about 68,000 square feet gross (45,000 square feet net), and will house about 200 people. It will be located in the central area of the Lawrence Berkeley Laboratory, a part of the Laboratory ultimately planned for redevelopment. The building will include wet and dry laboratories, shops, offices for researchers, dark rooms, constant temperature areas, space for special facilities, computer terminals, etc. A portion of the roof area will be designed to permit installation of equipment for environmental measurement and data collection.

Safety, Supply and Materials Handling Complex

This area would house supply administration, purchasing, central stores, reclamation and salvage, bulk stock, records and mailroom. Also included is a Safety Services Addition to Building 75 consisting of an office/laboratory structure to house department administration, industrial safety, equipment development and safety coordination.

Building 6 (184-Inch Cyclotron) Rehabilitation

This project involves removing accelerator equipment, which will probably become obsolete, and rehabilitating the building for use by other high priority R&D programs.

Energy Research Laboratory II

This laboratory will be similar in concept to Energy Research Laboratory I proposed for FY 1981, and would be used for continuing and consolidating programs in energy technology research.

Support Services Building

This building would provide about 50,000 square feet of space for support facilities currently located off-site in leased space as well as for other activities now scattered throughout the LBL site in old structures which should be replaced.

ADP REQUIREMENTS

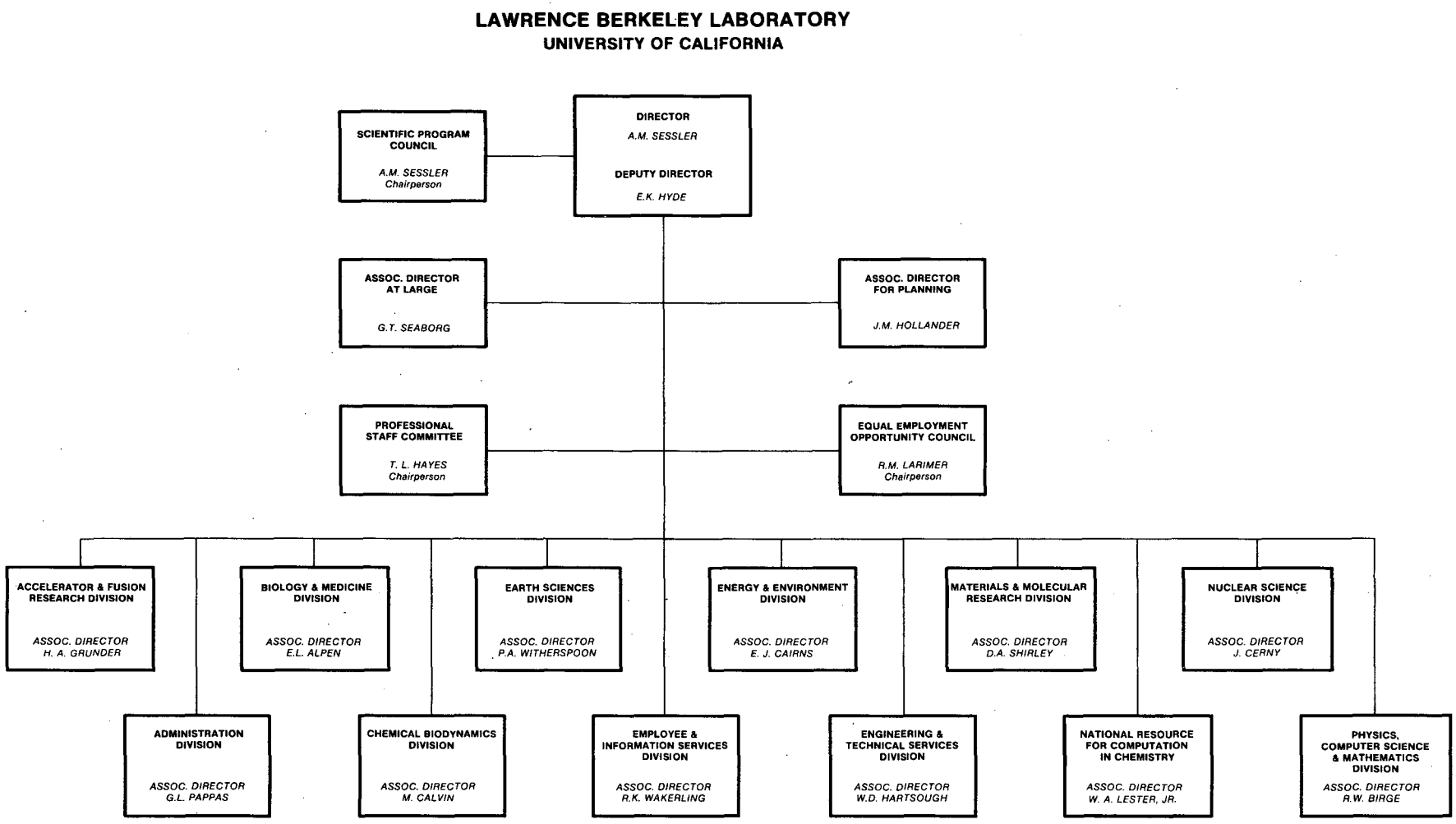
In addition to providing computational support to LBL programs, the LBL Computer Center serves as a remote computing facility for many other DOE sites and contractors, and (on a noninterference basis) for other federal agencies. Spurred by PEP, NRCC, and the new energy technology programs, LBL's demand for computing will more than double by 1984. This increase, together with only a constant level of other DOE and DOE-related work, would saturate the current configuration.

The ADP Long Range Plan for FY 1981-85 contains detailed projections of computing requirements, itemized by program, together with LBL's proposed solution to the present difficulties with interactive computing. The major elements of the ADP plan are: a) incremental replacement of the obsolescent equipment over a relatively long period (1978-1984); b) shift to a more flexible, distributed configuration than is now employed, based upon a high-speed bus (the Hyperchannel) used for intermachine communication; c) use of highly price-competitive IBM plug-compatible peripherals wherever possible; d) the replacement of two rather cumbersome front-end machines with a larger number (4-6) of smaller and more flexible front ends.

The Computer Center resource requirements include no major items of equipment, but a selection of smaller items is necessary (including mass storage, disks, front-end computers, network equipment, and miscellaneous peripherals), amounting to an aggregate of $3.5 M in General Purpose Capital Equipment/ADP money, spread over the years FY 1981-FY 1984.

The rationale behind the LBL ADP Plan is fourfold: a) to improve interactive service to an acceptable level; b) to replace inadequate and unreliable equipment (especially mass storage and disk systems); c) to facilitate intelligent distribution of computing power; and d) to lower the costs of computing.

The ADP Plan contains no major decision points: it is designed to be a flexible and evolutionary process, a series of incremental steps and decisions spread over the entire period 1978-84, looking towards the target configuration. Barring a dramatic change in the Laboratory's computing requirements (ample operating funds to do all the computing implied by TPC, for example) this mode of development is expected to persist for several years.



Date: Date: JULY 1979
Contractor: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
Contract: W-7405-ENG-48
Type of Contract: RESEARCH

Andrew M. Sessler
Director

Fig. A-1. Organization Chart.

Appendix B

Table B-1.

LAWRENCE BERKELEY LABORATORY

LABORATORY SUMMARY

($ in millions)		1979	1980	1981	1982	1983	1984	1985
FUNDING								
DOE Effort	BA	100.5	115.2	118.3	137.1	111.7	112.5	112.7
Operating	BO	100.1	110.1	115.9	132.0	116.0	112.2	112.5
Work for Others	BA	13.7	12.9	14.7	14.1	13.6	13.4	13.4
	BO	12.5	13.1	14.1	13.7	13.3	13.0	13.0
Capital Equipment	BA	11.7	13.7	13.4	14.3	13.9	14.0	13.0
Construction	BA	9.1	7.4	9.8	9.0	16.9	10.2	3.0
GPE[a] and GPP	BA	2.2	3.3	6.0	35.6	14.4	10.4	16.5
Total Laboratory Funding		137.2	152.5	162.2	210.1	173.5	160.5	158.6
PERSONNEL (In FTE Person Years)								
Direct								
DOE Effort		1,610	1,557	1,526	1,524	1,527	1,528	1,526
Work for Others		474	424	380	351	348	347	349
Total Direct		2,084	1,981	1,906	1,875	1,875	1,875	1,875
Indirect		986	985	990	995	995	995	995
Total Laboratory Personnel		3,070	2,966	2,896	2,870	2,870	2,870	2,870
New Initiatives Anticipated								
Nuclear Waste Isolation			25	35	43	51	59	65
Fossil Fuels Research			11	22	32	38	40	42
Subtotal			36	57	75	89	99	107
Total Laboratory Personnel		3,070	3,002	2,953	2,945	2,959	2,969	2,977

[a]Includes General Purpose Equipment and ADP Capital Equipment.

Table B-2.

LAWRENCE BERKELEY LABORATORY

SUMMARY BY SECRETARIAL OFFICE

(in $ million)

	FY 1979		FY 1980		FY 1981		FY 1982		FY 1983		FY 1984		FY 1985	
Secretarial Office	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO
ER: Energy Research														
Operating	40.4	40.4	45.8	44.6	50.7	49.1	52.0	51.4	53.5	53.1	54.4	54.1	54.9	54.8
Capital Equipment	7.9	7.6	8.3	8.1	6.6	6.2	7.1	6.6	6.9	6.3	6.9	6.3	6.9	6.3
Construction	6.4	.9	7.4	7.3	8.3	11.0	6.2	4.6	5.5	5.6	2.7	2.5	3.0	2.6
Total for ER	54.7	48.9	61.5	60.2	65.6	66.3	65.3	62.6	65.9	65.0	64.0	62.9	64.8	63.7
EV: Environment														
Operating	12.5	12.5	13.3	13.1	14.0	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
Capital Equipment	1.2	1.1	1.4	1.3	2.0	1.8	2.4	2.2	2.4	2.2	2.4	2.2	2.4	2.2
Construction	0.1	0.7		0.4	1.5	0.3	2.8	2.2	11.4	7.4	7.5	9.8		3.5
Total for EV	13.8	14.3	14.7	14.8	17.5	15.9	19.0	18.2	27.6	23.4	23.7	25.8	16.2	19.5
ET: Energy Technology														
Operating	22.1	22.1	23.5	22.0	21.7	21.1	21.3	20.8	18.4	18.4	18.0	18.0	17.2	17.1
Capital Equipment	0.8	0.9	1.3	1.1	1.4	1.4	1.3	1.5	1.1	1.5	1.1	1.5	1.0	1.5
Total for ET	22.9	23.0	24.8	23.1	23.1	22.5	22.6	22.3	19.5	19.9	19.1	19.5	18.2	18.6
DP: Defense Programs														
Operating	1.1	1.1	8.1	6.4	6.6	6.6	25.9	21.9	2.5	7.2	2.5	2.5	2.5	2.5
Capital Equipment	0.1	0.1	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total for DP	1.2	1.2	8.6	6.8	7.1	7.1	26.4	22.4	3.0	7.7	3.0	3.0	3.0	3.0
CS: Conservation and Solar Applications														
Operating	8.3	8.3	11.7	11.3	12.2	12.2	11.2	11.2	10.8	10.8	10.8	10.8	10.8	10.8
Capital Equipment	0.4	0.3	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.6
Total for CS	8.7	8.6	12.6	12.0	12.7	12.7	11.7	11.7	11.3	11.3	11.3	11.3	10.5	10.4
Other Miscellaneous														
Operating	2.0	2.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Work for DOE Contractors														
Reimbursable Operating	10.1	10.1	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.5	9.5	10.0	10.0
Capital Equipment	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Reimbursable	10.4	10.4	9.3	9.3	9.4	9.4	9.5	9.5	9.5	9.5	10.0	10.0	10.5	10.5
Direct Billing Operating	4.0	3.6	3.5	3.5	3.3	3.3	3.1	3.1	2.9	2.9	2.7	2.7	2.7	2.7
Construction	2.6	2.3												
Total DOE Contractors	17.0	16.3	12.8	12.8	12.7	12.7	12.6	12.6	12.4	12.4	12.7	12.7	13.2	13.2
TOTAL DOE PROGRAMS														
Operating	100.5	100.1	115.2	110.1	118.3	115.9	137.1	132.0	111.7	116.0	112.5	112.2	112.7	112.5
Capital Equipment	10.7	10.3	12.7	11.9	11.4	10.8	12.3	11.8	11.9	11.5	11.9	11.5	12.0	11.6
Construction	9.1	3.9	7.4	7.7	9.8	11.3	9.0	6.8	16.9	13.0	10.2	12.3	3.0	6.1
Work for Other than DOE														
NRC	0.1	0.1	0.1	0.1	0.1	0.1								
DOD	1.7	1.7	1.7	1.7	1.6	1.6	1.5	1.5	1.3	1.3	1.2	1.2	1.1	1.1
NSF	1.8	1.1	0.7	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
EPA	1.3	1.1	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
NASA	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
DHEW	4.8	4.5	5.3	5.0	6.5	6.0	6.6	6.2	6.7	6.4	7.0	6.6	7.3	6.9
DOL	1.3	1.3	1.3	1.3	1.2	1.2	1.0	1.0	.9	.9	.8	.8	.8	.8
Other (DOC, DOT, DOI)	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.3
Other than OFA[a]	1.3	1.3	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7
	13.7	12.5	12.9	13.1	14.7	14.1	14.1	13.7	13.6	13.3	13.4	13.0	13.4	13.0
General Purpose Equipment	1.0	1.2	1.0	0.9	2.0	1.2	2.0	2.0	2.0	2.0	2.1	2.1	1.0	1.8
General Plant Projects	2.2	3.0	2.3	3.0	2.5	1.7	3.0	2.2	3.3	2.3	3.5	2.5	3.5	2.5
General Purpose Facilities			1.0	0.3	3.5	3.5	32.6	17.7	14.1	23.0	6.9	6.6	13.0	12.0
Total LBL Funding	137.2	131.0	152.5	147.0	162.2	158.5	210.1	186.2	173.5	181.1	160.5	160.2	158.6	159.5

[a]BART, EPRI, etc.

Table B-3.

LAWRENCE BERKELEY LABORTORY

RESOURCE SUMMARY

A/S ENERGY RESEARCH (ER)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
AK 01 01 Nuclear Science:								
Operating	BA	2.1	2.2	2.5	2.6	2.7	2.8	2.8
Operating Total	BO	2.1	2.2	2.5	2.6	2.7	2.8	2.8
Direct FTE Operating		37	39	42	43	44	47	47
AK 01 02 Materials Science:								
Operating	BA	4.9	5.4	6.2	6.7	7.0	7.0	7.0
Operating Total	BO	4.9	5.3	6.0	6.5	6.9	7.0	7.0
Direct FTE Operating		108	90	98	111	120	122	122
AK 01 03 Chemical Sciences:								
Operating	BA	4.9	6.0	6.1	6.6	6.8	7.2	7.3
Operating Total	BO	4.9	5.7	6.1	6.5	6.8	7.0	7.3
Direct FTE Operating		105	98	105	110	114	118	125
AK 01 04 Engineering, Mathematics, and Geosciences:								
Operating	BA	1.6	1.7	2.0	2.1	2.3	2.3	2.3
Operating Total	BO	1.6	1.7	1.9	2.1	2.2	2.3	2.3
Direct FTE Operating		25	28	30	32	33	35	35
AK 01 06 Bio-energy Conversion:								
Operating	BA	0.6	0.6	0.7	0.8	0.8	0.8	0.8
Operating Total	BO	0.6	0.6	0.7	0.8	0.8	0.8	0.8
Direct FTE Operating		13	11	12	14	14	15	15
AK 01 Basic Energy Research:								
Operating	BA	14.1	15.9	17.5	18.8	19.6	20.1	20.2
Operating Total	BO	14.1	15.4	17.1	18.5	19.4	19.9	20.2
Capital Equipment	BA	1.2	1.3	2.6	2.6	2.6	2.6	2.6
Construction	BA		6.3	6.3				
Direct FTE Operating		288	266	287	310	325	337	344
Equipment		4	8	8	8	8	8	8
Construction			4	5				
		292	278	300	318	333	345	352
HK 02 01 Physics Research:								
Operating	BA	6.1	7.2	8.3				
Operating Total	BO	6.1	7.0	7.9				
Direct FTE Operating		115	115	115				
HK 02 03 High-Energy Physics Technology:								
Operating	BA	4.1	4.4	4.5				
Operating Total	BO	4.1	4.3	4.5				
Direct FTE Operating		85	85	85				
HK 02 High Energy Physics:								
Operating	BA	10.1	11.6	12.8	12.4	12.4	12.4	12.4
Operating Total	BO	10.1	11.3	12.4	12.4	12.4	12.4	12.4
Capital Equipment	BA	5.0	4.6	2.4	2.4	2.4	2.4	2.4
Direct FTE Operating		200	200	200	200	200	204	207
Equipment		76	70	30	15	25	35	38
		276	270	230	215	225	239	245
HK 03 01 Medium Energy Physics:								
Operating	BA	0.7	0.2	0.2	0.2	0.2	0.2	0.2
Operating Total	BO	0.7	0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE		18	5	5	5	5	5	5
HK 03 02 Heavy Ion Physics:								
Operating	BA	14.9	17.4	19.2	19.6	20.3	20.7	21.1
Operating Total	BO	14.9	17.0	18.5	19.3	20.3	20.7	21.1
Capital Equipment	BA	1.7	2.4	1.6	1.9	1.7	1.7	1.7
Direct FTE Operating		295	295	303	303	310	316	321
Equipment		22	12	15				
		317	307	318				
HK 03 03 Nuclear Theory:								
Operating	BA	0.6	0.7	1.0	1.0	1.0	1.0	1.0
Operating Total	BO	0.6	0.7	0.9	1.0	1.0	1.0	1.0
Direct FTE Operating		12	13	15	18	18	18	18
HK 03 Nuclear Physics:								
Operating	BA	16.2	18.3	20.4	20.8	21.5	21.9	22.3
Operating Total	BO	16.2	17.9	19.6	20.5	21.3	21.8	22.2
Capital Equipment	BA	1.7	2.4	1.6	2.1	1.9	1.9	1.9
Construction	BA	6.4	1.1	2.0	6.2	5.5	2.7	3.0
Direct FTE Operating		325	313	232	326	333	339	344
Equipment		22	12	15	15	20	20	20
Construction		20	70	48	20	37	17	17
		365	395	386	361	390	376	381
TOTAL: ENERGY RESEARCH (ER)								
Operating	BA	40.4	45.8	50.7	52.0	53.5	54.4	54.9
Operating Total	BO	40.4	44.6	49.1	51.4	53.1	54.1	54.8
Capital Equipment	BA	7.9	8.3	6.6	7.1	6.9	6.9	6.9
Construction	BA	6.4	7.4	8.3	6.2	5.5	2.7	3.0
Direct FTE Operating		813	779	810	836	858	880	894
Equipment		102	90	53	38	53	63	66
Construction		20	74	53	20	37	17	17
		935	943	916	894	948	960	978

Table B-4.

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

A/S ENVIRONMENT (EV)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
GK 01 01 Overview and Assessment:								
Operating	BA	1.5	1.5	1.8	1.7	1.7	1.7	1.7
Operating Total	BO	1.5	1.5	1.7	1.7	1.7	1.7	1.7
Capital Equipment	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		29	27	27	27	27	27	27
GK 01 02 Biomedical and Environmental Research:								
Operating	BA	5.0	5.7	6.0	5.9	5.9	5.9	5.9
Operating Total	BO	5.0	5.5	5.9	5.9	5.9	5.9	5.9
Capital Equipment	BA	1.0	1.1	1.3	1.4	1.4	1.4	1.4
Direct FTE Operating		94	90	90	90	90	90	90
Equipment		3	4	4	3	3	3	3
GK 01 Environmental Research and Development:								
Operating	BA	6.5	7.2	7.6	7.6	7.6	7.6	7.6
Operating Total	BO	6.5	7.0	7.6	7.6	7.6	7.6	7.6
Capital Equipment	BA	1.1	1.1	1.3	1.4	1.4	1.4	1.4
Direct FTE Operating		123	117	117	117	117	117	117
Equipment		3	4	4	3	3	3	3
		126	121	121	120	120	120	120
HK 01 01 General Life Sciences:								
Operating	BA	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Operating Total	BO	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Direct FTE Operating		27	24	23	23	23	23	23
HK 01 02 Biomedical Applications:								
Operating	BA	4.5	4.6	4.7	4.7	4.7	4.7	4.8
Operating Total	BO	4.5	4.6	4.7	4.7	4.7	4.7	4.7
Direct FTE Operating		45	42	40	40	40	40	40
HK 01 Life Sciences Research and Biomedical Applications:								
Operating	BA	6.0	6.1	6.7	6.7	6.7	6.7	6.7
Operating Total	BO	6.0	6.1	6.7	6.7	6.7	6.7	6.7
Capital Equipment	BA	0.1	0.3	0.7	1.0	1.0	1.0	1.0
Construction	BA	0.1		1.5	2.8	11.4	7.5	0.0
Direct FTE Operating		72	66	63	63	63	63	63
Equipment		1	2	3	3	3	3	3
Construction				2	6	7	8	
		73	68	68	72	73	74	66
TOTAL: ENVIRONMENT (EV)								
Operating	BA	12.5	13.3	14.0	13.8	13.8	13.8	13.8
Operating Total	BO	12.5	13.1	13.8	13.8	13.8	13.8	13.8
Capital Equipment	BA	1.2	1.4	2.0	2.4	2.4	2.4	2.4
Construction	BA	0.1		1.5	2.8	11.4	7.5	
Direct FTE Operating		195	183	180	180	180	180	180
Equipment		4	6	7	6	6	6	6
Construction				2	6	7	8	
		199	189	189	192	193	194	186

Table B-5.

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

A/S ENERGY TECHNOLOGY (ET)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
AA 10 03 Coal Preparation and Analysis:								
Operating	BA	0.2	0.2	0.4	0.4	0.4	0.4	0.4
Operating Total	BO	0.2	0.2	0.3	0.4	0.4	0.4	0.4
Direct FTE Operating		3	2	3	4	4	4	4
AA 60 01 Liquefaction:								
Operating	BA	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operating Total	BO	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		2	2	2	2	2	2	2
AA 60 03 Materials and Components:								
Operating	BA	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Operating Total	BO	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Direct FTE Operating		4	3	4	4	4	4	4
AA 60 Advanced Research and Development:								
Operating	BA	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Operating Total	BO	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Direct FTE Operating		6	5	6	6	6	6	6
TOTAL AA: COAL								
Operating	BA	0.8	0.8	1.0	1.0	1.0	1.0	1.0
Operating Total	BO	0.8	0.8	0.9	1.0	1.0	1.0	1.0
Capital Equipment	BA		0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		9	7	9	10	10	10	10
AB 10 05 Environmental Studies and Other Support:								
Operating	BA	0.2	0.4	0.3	0.3	0.3	0.3	0.3
Operating Total	BO	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Direct FTE Operating		2	4	4	4	4	4	4
AB 20 01 Oil Shale Production:								
Operating	BA	0.3	0.6	0.8	0.7	0.7	0.7	0.7
Operating Total	BO	0.3	0.5	0.7	0.7	0.7	0.7	0.7
Direct FTE Operating		4	5	9	9	9	9	9
TOTAL AB: PETROLEUM								
Operating	BA	0.5	0.8	1.1	1.0	1.0	1.0	1.0
Operating Total	BO	0.5	0.7	1.0	1.0	1.0	1.0	1.0
Capital Equipment	BA		0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		6	9	13	13	13	13	13
AD 02 01 Environmental and Resource Assessment:								
Operating	BA	0.4						
Operating Total	BO	0.4						
Direct FTE Operating		4						
AD 03 01 Solar Thermal Power:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		2	2	2	2	2	2	2
AD 03 02 Photovoltaic Energy Conversion:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		2	2	2	2	2	2	2
AD 03 04 Ocean Thermal Energy Conversion:								
Operating	BA	0.9	1.0	1.3	1.2	1.2	1.2	1.2
Operating Total	BO	0.9	1.1	1.2	1.2	1.2	1.2	1.2
Direct FTE Operating		10	13	13	13	13	13	13
AD 03 Solar Electric Applications:								
Operating	BA	1.1	1.2	1.5	1.4	1.4	1.4	1.4
Operating Total	BO	1.1	1.3	1.4	1.4	1.4	1.4	1.4
Direct FTE Operating		14	17	17	17	17	17	17
TOTAL AD: SOLAR ENERGY TECHNOLOGIES								
Operating	BA	1.5	1.2	1.5	1.4	1.4	1.4	1.4
Operating Total	BO	1.5	1.3	1.4	1.4	1.4	1.4	1.4
Capital Equipment	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		18	17	17	17	17	17	17
Equipment		2						
		20						

Table B-5. (Continued)

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

A/S ENERGY TECHNOLOGY (ET)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
AE 10 01 Pacific Coast:								
Operating	BA	0.5	0.5	0.4	0.3	0.2		
Operating Total	BO	0.5	0.5	0.4	0.3	0.2		
Direct FTE Operating		7	7	5	3	2		
AE 20 01 Resource Definition:								
Operating	BA	0.1	0.1	0.1				
Operating Total	BO	0.1	0.1	0.1				
Direct FTE Operating		2	2	2				
AE 30 01 Component and Technology Development:								
Operating	BA	4.5	4.5	4.5	4.0	3.9	3.7	2.8
Procurements	BA	2.5	1.0	0.6	0.2			
Operating Total	BO	7.0	5.5	5.1	4.2	3.9	3.7	2.8
Direct FTE Operating		58	51	45	38	32	31	26
AE 30 03 Interagency Coordination and Management:								
Operating	BA	0.5	0.5	0.5	0.5	0.4	0.3	0.2
Operating Total	BO	0.5	0.5	0.5	0.5	0.4	0.3	0.2
Direct FTE Operating		1	1	1	1	1	1	1
AE 30 Geothermal Technology Development:								
Operating	BA	5.0	5.0	5.0	4.5	4.3	4.0	3.0
Procurements	BA	2.5	1.0	0.6	0.2			
Operating Total	BO	7.5	6.0	5.6	4.7	4.3	4.0	3.0
Direct FTE Operating		59	52	46	39	33	32	27
TOTAL AE: GEOTHERMAL								
Operating	BA	5.6	5.6	5.5	4.8	4.5	4.0	3.0
Procurements	BA	2.5	1.0	0.6	0.2			
Operating Total	BO	8.1	6.6	6.1	5.0	4.5	4.0	3.0
Capital Equipment	BA	0.2	0.2	0.3	0.3	0.3	0.3	0.2
Direct FTE Operating		68	61	53	42	35	32	27
Equipment		2						
		70						
AF 01 10 Tokamak Systems:								
Operating	BA	3.0						
Operating Total	BO	3.0						
Direct FTE Operating		37						
AF 02 Development and Technology:								
Operating	BA		0.2	0.2	2.9	2.2	2.2	2.2
Operating Total	BO		0.2	0.2	2.2	2.2	2.2	2.2
Direct FTE Operating			3	3	33	33	33	33
AF 03 10 Advanced Fusion Concepts:								
Operating	BA	0.6						
Operating Total	BO	0.6						
Direct FTE Operating		8						
AF 03 20 Fusion Plasma Theory:								
Operating	BA	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operating Total	BO	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		3	3	3	3	3	3	3
AF 03 30 Experimental Plasma Research:								
Operating	BA	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Operating Total	BO	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Direct FTE Operating		9	9	9	9	9	9	9
AF 03 Applied Plasma Physics:								
Operating	BA	1.2	0.7	0.7	0.7	0.7	0.7	0.7
Operating Total	BO	1.2	0.7	0.7	0.7	0.7	0.7	0.7
Direct FTE Operating		20	12	12	12	12	12	12
AF 04 01 Tokamak Fusion Test Reactor:								
Operating	BA	4.5	5.3	3.4	1.8			
Operating Total	BO	4.5	5.1	3.4	2.0			
Capital Equipment	BA	0.3	0.3	0.3	0.2			
Direct FTE Operating		80	70	49	35			
TOTAL AF: MAGNETIC FUSION								
Operating	BA	8.7	6.2	4.3	5.3	2.9	2.9	2.9
Operating Total	BO	8.7	6.0	4.3	4.9	2.9	2.9	2.9
Capital Equipment	BA	0.3	0.3	0.3	0.2			
Direct FTE Operating		137	85	64	80	45	45	45
Equipment		6						
		143						

Table B-5. (Continued)

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

A/S ENERGY TECHNOLOGY (ET)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
AG 40 10 Advanced Isotope Separation:								
Operating	BA	0.3	0.3	0.4	0.6	0.6	0.7	0.9
Operating Total	BO	0.3	0.3	0.4	0.5	0.6	0.7	0.8
Capital Equipment	BA		0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		5	6	6	6	8	9	10
AJ 01 Fuels from Biomass:								
Operating	BA	0.6	1.5	1.6	1.5	1.5	1.5	1.5
Operating Total	BO	0.6	1.3	1.5	1.5	1.5	1.5	1.5
Direct FTE Operating		16	24	22	22	22	22	22
C8 03 01 Battery Storage:								
Operating	BA	0.9	5.2	5.1	4.9	4.9	4.9	4.9
Operating Total	BO	0.9	4.2	4.9	4.9	4.9	4.9	4.9
Direct FTE		8	20	22	22	22	22	22
C8 03 03 Improved Conversion Efficiency:								
Operating	BA	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Operating Total	BO	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Direct FTE		14	15	15	15	15	15	15
C8 03 Technology Development:								
Operating	BA	1.6	5.8	5.7	5.5	5.5	5.5	5.5
Operating Total	BO	1.6	4.8	5.5	5.5	5.5	5.5	5.5
Capital Equipment	BA	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE		22	35	37	37	37	37	37
TOTAL: ENERGY TECHNOLOGY (ET)								
Operating	BA	19.6	22.5	21.1	21.1	18.4	18.0	17.2
Procurements	BA	2.5	1.0	0.6	0.2			
Operating	BO	22.1	22.0	21.1	20.8	18.4	18.0	17.1
Capital Equipment	BA	.8	1.3	1.4	1.3	1.1	1.1	1.0
Direct FTE Operating		281	244	221	227	187	185	181
Equipment		10						
		291						

Table B-6.

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

A/S CONSERVATION AND SOLAR APPLICATIONS (CS)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
BD 01 01 Demonstration:								
Operating	BA	0.3	0.1					
Operating Total	BO	0.3	0.1					
Direct FTE Operating								
BD 01 02 Systems Development:								
Operating	BA	1.6	2.3	2.4	2.4	2.4	2.4	2.4
Operating Total	BO	1.6	2.3	2.4	2.4	2.4	2.4	2.4
Direct FTE Operating		32	32	32	32	32	32	32
BD 02 01 Commercialization and Planning:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	BA	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		1	1	1	1	1	1	1
BD Solar Energy Operating:								
Operating	BA	2.0	2.5	2.5	2.5	2.5	2.5	2.5
Operating Total	BO	2.0	2.5	2.5	2.5	2.5	2.5	
Capital Equipment	BA	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		33	33	33	33	33	33	33
C3 01 01 Residential and Commercial Buildings:								
Operating	BA	1.2	0.5					
Operating Total	BO	1.2	0.5					
Direct FTE Operating		8	4					
C3 01 02 Performance Standards:								
Operating	BA	2.9	4.7	5.2	5.2	5.2	5.2	5.2
Operating Total	BO	2.9	4.2	5.2	5.2	5.2	5.2	5.2
Direct FTE Operating		49	54	58	58	58	58	58
C3 01 04 Consumer Products and Technology:								
Operating	BA	1.7	3.6	4.1	3.1	2.7	2.7	2.7
Operating Total	BO	1.7	3.2	4.1	3.1	2.7	2.7	2.7
Capital Equipment	BA	0.2	0.8	0.3	0.3	0.3	0.3	0.5
Direct FTE Operating		20	20	20	20	20	20	20
C3 01 05 Technology Transfer, Economic Analysis and Consumer Motivation:								
Operating	BA	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operating Total	BO	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct FTE Operating		1	1	1	1	1	1	1
C3 01 Buildings and Community Systems:								
Operating	BA	6.2	9.0	9.5	8.5	8.1	8.1	8.1
Operating Total	BO	6.1	7.9	9.5	8.5	8.1	8.1	8.1
Capital Equipment	BA	0.2	0.8	0.3	0.3	0.3	0.3	0.5
Direct FTE Operating		78	79	79	79	79	79	79
C3 03 Appliance Efficiency Performance Standards:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		1	1	1	1	1	1	1
C4 20 01 High Temperature Processes:								
Operating	BA	0.1						
Operating Total	BA	0.1						
Direct FTE Operating		1						
C5 06 04 Technology Development:								
Operating	BA	0.1						
Operating Total	BA	0.1						
Direct FTE Operating		2						
C8 08 Appropriate Technology:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		4	3	3	3	3	3	3
TOTAL: CONSERVATION AND SOLAR APPLICATIONS (CS)								
Operating	BA	8.3	11.7	12.2	11.2	10.8	10.8	10.8
Operating Total	BO	8.3	11.3	12.2	11.2	10.8	10.8	10.8
Capital Equipment	BA	0.4	0.9	0.5	0.5	0.5	0.5	0.7
Direct FTE Operating		119	116	116	116	116	116	116

Table B-7.

LAWRENCE BERKELEY LABORATORY

RESOURCE SUMMARY

OTHER A/S (DP, EIA, IR)

($ in millions; personnel in FTE)

B&R Code - Subactivity		FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
Defense Programs (DP)								
JF 01 Inertial Confinement Fusion (JF 01 05 Heavy Ion Source Development)								
Operating	BA	1.1	8.1	6.6	25.9	2.5	2.5	2.5
Operating Total	BO	1.1	6.4	6.6	21.9	7.2	2.5	2.5
Capital Equipment	BA	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Direct FTE Operating		18	35	50	54	42	30	30
Equipment		3	2	2	2	2	2	2
		21	37	52	56	44	32	32
Energy Information (EIA)								
FK 01 Applied Analysis:								
Operating	BA	0.2	0.4	0.4	0.4	0.4	0.4	0.4
Operating Total	BO	0.2	0.4	0.4	0.4	0.4	0.4	0.4
Direct FTE Operating		1	5	5	5	5	5	5
FK 03 01 Data Validation:								
Operating	BA	1.4						
Operating Total	BO	1.4						
Direct FTE Operating		19						
TOTAL FK: MULTI-RESOURCE								
Operating	BA	1.6	0.4	0.4	0.4	0.4	0.4	0.4
Operating Total	BO	1.6	0.4	0.4	0.4	0.4	0.4	0.4
Direct FTE Operating		20	5	5	5	5	5	5
Intergovernmental and Institutional Relations (IR)								
KN 02 01 Technical Information Services:								
Operating	BA	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Operating Total	BO	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct FTE Operating		9	8	8	8	8	8	8
KN 02 02 Education and Training Programs:								
Operating	BA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operating Total	BO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct FTE Operating		1	2	2	2	2	2	2
TOTAL KN: TOTAL INTERGOVERNMENTAL AND INSTITUTIONAL RELATIONS (IR)								
Operating	BA	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Operating Total	BO	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Direct FTE Operating		10	10	10	10	10	10	10
TOTAL OTHER: (Does not include DP)								
Operating	BA	2.0	0.8	0.8	0.8	0.8	0.8	0.8
Operating Total	BO	2.0	0.8	0.8	0.8	0.8	0.8	0.8
Direct FTE Operating		30	15	15	15	15	15	15

Table B-8.

LAWRENCE BERKELEY LABORATORY

PERSONNEL SUMMARY

BY SECRETARIAL OFFICE

(FTE)

Secretarial Office	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
ER: Energy Research							
Operating	813	779	810	836	858	880	895
Capital Equipment	102	90	53	38	53	63	66
Construction	20	74	53	20	37	17	17
Total for ER	935	943	916	894	948	960	978
EV: Environment							
Operating	195	183	180	180	180	180	180
Capital Equipment	4	6	7	6	6	6	6
Construction			2	6	7	8	
Total For EV	199	189	189	192	193	194	186
ET: Energy Technology							
Operating	281	244	221	227	187	185	181
Capital Equipment	10						
Total for ET	291						
DP: Defense Programs							
Operating	18	35	50	54	42	30	30
Capital Equipment	3	2	2	2	2	2	2
Total for DP	21	37	52	56	44	32	32
CS: Conservation and Solar Applications							
Operating	119	116	116	116	116	116	116
Other Miscellaneous							
Operating	30	15	15	15	15	15	15
DOE Contractors							
Reimbursible Operating	121	121	107	92	92	92	94
Direct Billing Operating	110	105	95	85	80	79	79
Direct Billing Construction	44						
Total DOE Programs							
Operating	1,687	1,598	1,594	1,605	1,570	1,577	1,590
Capital Equipment	119	98	62	46	61	71	74
Construction	64	74	55	26	44	25	17
Work for Other than DOE							
NRC							
DOD	28	25	17	14	14	14	14
NSF	10	10	10	10	10	10	10
EPA	21	19	14	12	12	12	10
NASA	6	6	3	3	3	3	3
DHEW	85	93	98	105	109	113	115
DOL	22	20	16	16	15	15	15
Other OFA	9	7	3	3	3	3	3
State/Local Government	14	16	12	7	6	3	3
Other	6	5	5	4	4	3	3
Total	201	201	178	174	176	176	176
General Purpose Equipment	0	0	0	0	0	0	0
General Plant Projects	13	10	12	12	12	12	12
General Purpose Facilities			5	12	12	14	6
Total Direct Personnel	2,084	1,981	1,906	1,875	1,875	1,875	1,875
Total Indirect Personnel	986	985	990	995	995	995	995
Total LBL Personnel	3,070	2,966	2,896	2,870	2,870	2,870	2,870

Table B-9.

LAWRENCE BERKELEY LABORATORY

MAJOR CONSTRUCTION PROJECTS

CONSTRUCTION ALLOWANCE SUMMARY

($ in millions--BA)

	TEC	FY 1979		FY 1980		FY 1981		FY 1982		FY 1983		FY 1984		FY 1985	
	BA	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO	BA	BO
FUNDED PROJECTS															
Program Special Facilities															
High Intensity Uranium Beam (ER)	6.6	6.0	0.7	0.6	4.8		1.1								
Program Justified GPF															
Cell Culture Lab I (EV)	0.1[a]	0.1	0.7												
BUDGETED PROJECTS															
Accelerator Improvements (ER)	0.9	0.4	0.2	0.5	0.5										
Program Justified GPF															
Chemical & Materials Science Lab (ER)	12.6			6.3	2.0	6.3	8.0		2.6						
General Purpose Facilities															
Computerized Energy Management System	1.0			1.0	0.3		0.7								
Total Funded and Budgeted Construction	21.0	6.5	1.6	8.4	7.6	6.3	9.8		2.6						
PROPOSED PROJECTS															
Program Special Facilities															
High Charge State Ion Source (ER)	4.0							4.0	0.7	3.0	3.3				
Nuclear Science Accelerator (VENUS) (ER)	b									b					
PEP Improvements (ER)	c											c			
Accelerator Improvements (ER)						2.0	1.2	2.2	2.0	2.5	2.3	2.7	2.5	3.0	2.6
Program Justified GPF															
Biomedical Lab 74 Addition (EV)	1.5					1.5	0.3		1.2						
Biomedical Lab (EV)	9.8							2.8	1.0	7.0	6.0		2.8		
Cell Culture Lab II (EV)	11.9									4.4	1.4	7.5	7.0		3.5
General Purpose Facilities															
Energy Research Lab I	21.0					3.5	2.8	17.5	13.2	0.0	5.0				
Safety Service Material Handling Complex	12.2							6.1	2.0	6.1	8.0		2.2		
Building 6 Rehabilitation	4.0							4.0	1.0	3.0	3.0				
Support Services Building	10.0							5.0	1.5	5.0	7.0		1.5		
Energy Research Lab II	19.9											6.9	2.9	13.0	12.0
Total Proposed Projects	94.3					7.0	4.3	41.6	22.6	31.0	36.0	17.1	18.9	16.0	18.1

[a]TEC is $1.2 M; $1.1 M funded in FYs 77/78.

[b]Project planning indicates approximate cost of 100.0 M$.

[c]Project planning does not include cost estimate at this time.

Table B-10.

LAWRENCE BERKELEY LABORATORY

GENERAL PLANT PROJECTS

($ in millions - BA)

Description	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
Total GPP Requirements*	2.2	2.3	2.5	3.0	3.3	3.5	3.5

*Escalation figured at 12% a year

Table B-11.

LAWRENCE BERKELEY LABAORATORY

GENERAL PURPOSE EQUIPMENT

($ in millions - BA)

Description	FY 1979	FY 1980*	FY 1981*	FY 1982	FY 1983	FY 1984	FY 1985
General Purpose Equipment	1.0	.7	1.2	1.1	1.1	1.1	1.6
ADP Equipment	—	.3	.8	.9	.9	1.0	.4
Total General Purpose Equipment	1.0	1.0	2.0	2.0	2.0	2.1	2.0

*Escalation figured at 12% per year

Appendix C

Table C-1.

LAWRENCE BERKELEY LABORATORY

PHASES OF R&D ANALYSIS

($ in millions - BO)

Secretarial Office	FY 1979	FY 1980	FY 1981
Director, Energy Research (ER)			
Basic Research	37.9	41.3	46.2
Applied Research	1.8	1.9	2.0
Exploratory Development	0.7	0.8	0.9
Total for DER	40.4	44.0	49.1
A/S Environment (EV)			
Basic Research	7.1	7.4	7.8
Applied Research	4.1	4.3	4.6
Exploratory Development	0.9	1.0	1.0
Technology Development	0.4	0.4	0.4
Total for ASEV	12.5	13.1	13.8
A/S Energy Technology (ET)			
Basic Research	0.7	0.7	0.7
Applied Research	6.0	6.0	6.0
Exploratory Development	2.5	2.0	1.5
Technology Development	4.7	7.0	7.5
Engineering Development	8.2	6.3	5.4
Total for ASET	22.3	22.1	21.1
A/S Conservation and Solar Applications (CS)			
Applied Research	6.9	8.2	8.5
Exploratory Development	0.7	0.8	0.8
Technology Development	0.7	2.7	2.9
Total for ASCS	8.3	11.7	12.2
A/S Defense Programs (DP)			
Basic Research	0.6	0.6	0.6
Applied Research	0.2	0.4	0.4
Exploratory Development	0.2	2.7	2.8
Technology Development	0.1	2.7	2.8
Total for ASDP	1.1	6.4	6.6
Other DOE (EIA, IR)			
Basic Research	0.6	0.6	0.5
Exploratory Development	1.4	0.2	0.3
Total Other	2.0	0.8	0.8
Laboratory Total			
Basic Research	46.7	50.5	55.8
Applied Research	19.0	20.8	21.5
Exploratory Development	6.4	7.5	7.3
Technology Development	5.9	12.8	13.6
Engineering Development	8.4	6.4	5.4
Total for LBL	86.4	98.0	103.6

Appendix D

Table D-1.

LAWRENCE BERKELEY LABORATORY

WPAS CROSS REFERENCES

A/S B&R Code	HQ Number	Title	Preparation Date
ER A/S Energy Research			
HK 02 01	41XX*, 4580*	Physics Research	4-79 (all)
HK 02 02	41XX*	Accelerator and Facility Operations	
HK 02 03	45XX*, 42XX*	High Energy Physics Technology	
HK 03 01	4250*, 4643*	Medium Energy Nuclear Physics	
HK 03 02	4501*, 4602*, 4610*, 4611*, 4614*, 4616*, 4617*, 4618*, 4619*, 4622*, 4630*, 4633*, 4635*, 4640*, 4643*, 4644*, 4646*, 4648*, 4649*, plus 4 new	Heavy Ion Nuclear Physics	
HK 03 03	4605*	Nuclear Theory	
EV A/S Environment			
GK 01 01	1535, 2691, 3211, 3212, 3241, 800353, 800354, 800363, 44XX*, plus 1 new	Environmental Research and Development	
GK 01 02	111, 226, 305, 308, 314, 475, 705, 708, 1307, 1308, 1447, 1598, 1599, 1849, 1851, 1852, 1860, 1866, 2189, 2419, 2524, 2688, 2692, 2693, 2701, 2776, 2935, 3082, 3088, 3091, 3097, 3250, 4030, 4033, 4034, 4037, eight 44XX*	Biomedical and Environmental Research	
HK 01 01	112, 114, 116, 815, 1305, 3228, 3274, 44XX*	General Life Sciences	
HK 01 02	328, 329, 330, 331, 332, 333, 706, 742, 2417, 2418, 2420, 3106	Biomedical Applications	
ET A/S Energy Technology			
AA 10 03	4772*	Coal Preparation and Analysis	
AA 60 01	7129	Advanced R&D - Processes	
AA 60 03	7132	Advanced R&D - Materials and Components	
AA 60 04	New	Advanced R&D - Program Development and Coordination	
AB 10 05	7240	Environmental Studies and Other Support	
AB 20 01	7301	Oil Shale Production	
AD 02 01	4686*	Environmental Resource Assessment	
AD 03 01	4751*	Solar Thermal Power	
AD 03 04	4686*	Ocean Thermal Energy Conversion	
AE 10 01	4662*, 4663*, 4667*, 4669*	Pacific Coast	
AE 20 01	New	Gulf Coast	
AE 30 01	4660*, 4664*, 4665*, 4666*, 4668*, 4670*, New	Component and Technology Development	
AE 30 03	4707*, 4980*	Interagency Coordination and Management	
AF 01 10	4958*	Tokamak Systems Experiments	
AF 01 20	4570*	Magnetic Mirror Systems Experiments	
AF 03 10	4572*	Advanced Fusion Concepts	
AF 03 20	4570*	Fusion Plasma Theory	
AF 03 30	4571*	Experimental Plasma Research	
AF 04 01	4959*	Tokamak Fusion Test Reactor	
AG 40 10	4041*, 4042*	Advanced Isotope Separation	

*LBL account number. HQ number not available.

Table D-1. (Continued)

LAWRENCE BERKELEY LABORATORY

WPAS CROSS REFERENCES

A/S B&R Code	HQ Number	Title	Preparation Date
ET (continued)			
AJ 01	4480*, 4754*, 4775*, New	Fuels From Biomass	4-79 (all)
AK 01 01	4610*, 4611*, 4615*, 4619*, 4620*, 4630*, 4646*, 4648*, 4649*	Nuclear Sciences	
AK 01 02	4051*, 4052*, 4053*, 4054*, 4055*, 4056*, 4057*, 4058*, 4059*, 4060*, 4061*, 4063*, 4064*, 4066*, 4067*, 4068*, 4069*, 4070*, 4072*, 4073*, 4074*, 4075*, 4076*, 4077*, 4078*, 4079*, 4080*, 4081*, plus 3 new	Materials Sciences	
AK 01 03	4001*, 4002*, 4004*, 4005*, 4008*, 4009*, 4010*, 4012*, 4014*, 4015*, 4016*, 4017*, 4018*, 4019*, 4021*, 4022*, 4023*, 4024*, 4025*, 4027*, 4028*, 4495*, 4761*, 4763*, 4765*, 4767*, 4768*, 4769*, 4991*, plus 4 new	Chemical Sciences	
AK 01 04	4291*, 4683*, 4684*, 4762*, 4980*	Engineering, Math, and Geosciences	
AK 01 06	113, 115, 229	Bioenergy Conversion	
C8 03	4039*, 4723*, 4756*, plus 1 new	Technology Development	
DP A/S Defense Programs			
JF 01 05	4560*	Heavy Ion Fusion	
CS A/S Conservation and Solar Applications			
BD 01 01	4950*	Solar - Demonstration	
BD 01 02	4751*, 4752*, 4753*, 4757*, 4758*	Solar - Systems Development	
BD 02 01	4771*	Solar - Commercialization Planning	
C3 01 01	4728*	Residential and Commercial Buildings	
C3 01 02	4726*, 4728*	Performance Standards	
C3 01 04	4725*	Consumer Products and Technology	
C3 01 05	4728*	Technology Transfer, Economic Analysis and Consumer Motivation	
C5 06 04	4970*	Transport - Technology Development	
C8 08	4727*	Appropriate Technology	
EIA A/S Energy Information Administration			
FK 03 01	4708*	Data Validation Program	
IR A/S Intergovernmental and Institutional Relations			
KN 02 01	4981*	Technical Information Services	
KN 02 02	4773*	Institutional Relations	

*LBL account number. HQ number not available.