PUB- 296 c.1

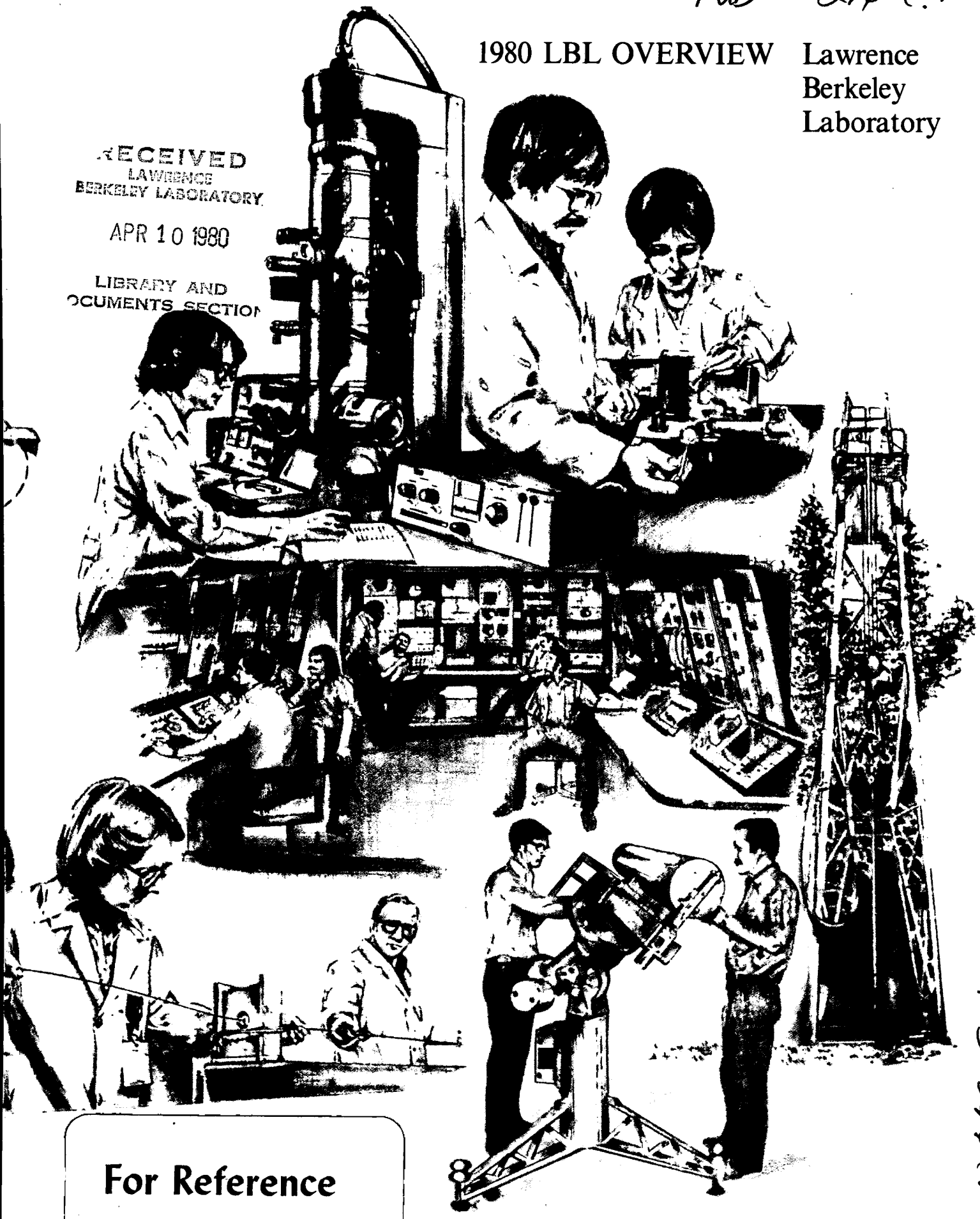
1980 LBL OVERVIEW

Lawrence
Berkeley
Laboratory

RECEIVED
LAWRENCE
BERKELEY LABORATORY

APR 10 1980

LIBRARY AND
DOCUMENTS SECTION



For Reference

Not to be taken from this room

PUB-296 c.1

ART: Jerry Miranda, Dick Gallant, Ralph Dennis

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL OVERVIEW 1980

Lawrence Berkeley Laboratory
University of California

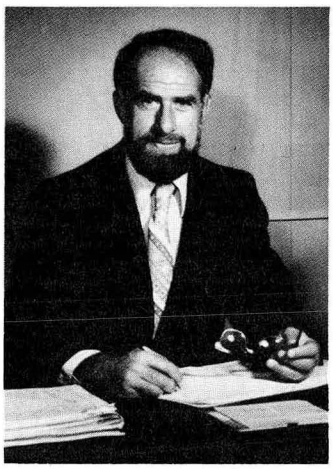
January 1980

Operated for the U.S. Department of Energy
under Contract W-7405-ENG-48

Contents

Director's Message 3
Lawrence Berkeley Laboratory 5
Divisions
- Accelerator and Fusion Research 9
- Biology and Medicine 17
- Chemical Biodynamics 25
- Earth Sciences 33
- Energy and Environment 41
- Materials and Molecular Research 49
- National Resource for Computation in Chemistry 57
- Nuclear Chemistry 63
- Physics, Computer Science and Mathematics 71
- Engineering and Technical Services 81
- Employee and Information Services 89
- Administration 95

Summary: Manpower and Financial Data 100



This Laboratory traces its origins to 1931 when Professor Ernest Orlando Lawrence started an organization called the Radiation Laboratory on the Berkeley Campus of the University California. Lawrence and his co-workers in the Radiation Laboratory designed and built cyclotrons and used the charged particle beams produced by them to make profoundly important studies of the atomic nucleus as well as to synthesize dozens of radioactive isotopes and create many new elements. The cyclotron beams and the radioactive products of the nuclear reactions were used in pioneering studies which created the field of nuclear medicine and established the usefulness of nuclear techniques in many physical and biological sciences. Not only was revolutionary new science done in Lawrence's Laboratory of the 1930s, but his style of scientific organization to do multidisciplinary science centered in big experimental facilities was a revolutionary concept destined to have profound influence on science in this and all major countries.

Since then, this Laboratory has undergone many changes as a result of the upheavals of World War II and the immediate postwar scientific and societal priorities of the nation. Today, a crisis faces our country because of our decreasing reserves of domestic petroleum and natural gas, and the steeply increasing costs and limited extent of foreign reserves. As a result, this Laboratory is now heavily involved in study of the energy problem, in research and development of new energy technologies, in research on efficient energy end-use, and in research on the environmental and medical effects of energy production and use. At the same time, LBL continues its past tradition as a center of excellence in nuclear physics, high-energy physics, fundamental biology and medicine, materials science, and atomic and molecular chemistry. This process of change is most appropriate, for an institution must continually adjust its goals and organization in order to make proper use of its traditions, its abilities, its facilities, and its staff. Only in this way can the organization remain vital and meet the challenges of the age.

Even though LBL is different in many ways from the Radiation Laboratory of the 1930s, there are some essential characteristics, derived from Ernest Lawrence's leadership, which will always shape the character and spirit of the organization which proudly bears his name. The Lawrence Berkeley Laboratory is concerned with scientific research and technological development at the frontiers of knowledge where the intellectual challenges are greatest. It knows how to organize efforts from many disciplines to attack problems, and it uses, where appropriate, large and complex experimental facilities. It is deeply concerned with utilization of fundamental scientific knowledge for solution of problems of human health and suffering and of national technological needs. It is heavily involved in the training of students and the advanced training of graduates and experts from other institutions, including those from outside the United States. Lastly, it strives to maintain an atmosphere of informality and a concern for the needs of the many creative members of the Laboratory staff. It is my intention to re-join the research staff of the Laboratory in 1980, and to pass the responsibilities of my office to my successor. It has been an honor to serve for six years as the leader of this great institution, and I return to research confident, for the reasons stated above, that the Laboratory is strong and its future well assured.

This booklet, brief as it is, is designed to provide the reader with some insight into the current organization, facilities, and activities of the Lawrence Berkeley Laboratory. I hope it succeeds in conveying the history, the tradition, the excellence, the humane spirit, and the excitement which combine to make the Laboratory one of the great scientific institutions of the World.

Andrew M. Sessler

Andrew M. Sessler
Director

Director
Andrew M. Sessler

Deputy Director
Earl K. Hyde

Associate Director at Large
Glenn T. Seaborg

Associate Director for Planning
Jack M. Hollander

Associate Directors
Hermann A. Grunder
Accelerator and Fusion Research

Edward L. Alpen
Biology and Medicine

Melvin Calvin
Chemical Biodynamics

Paul A. Witherspoon
Earth Sciences

Elton J. Cairns
Energy and Environment

David A. Shirley
Materials and Molecular Research

William A. Lester Jr.
National Resource for Computation in Chemistry

Joseph Cerny
Nuclear Science

Robert W. Birge
Physics, Computer Science and Applied Mathematics

Walter D. Hartsough
Engineering and Technical Services

Raymond K. Wakerling
Employee and Information Services

George L. Pappas
Administration

Lawrence Berkeley Laboratory and its environs. LBL covers more than 120 acres in the Berkeley Hills. In the foreground is the University of California Campus. Other points of interest include the Lawrence Hall of Science—the octagonal structure in upper center of photograph. Directly above LHS is the UC Space Sciences Laboratory.

At Lawrence Berkeley Laboratory, located in the hills above the University of California Berkeley Campus, scientists study the tiniest particles of nature, treat cancer with accelerator beams, and seek to solve the nation's energy problems by pursuing promising leads into new energy sources. These are but a few of the areas discussed in this report, *LBL Overview*—a description of how the researchers at this laboratory explore the basic nature of the universe and apply that knowledge toward solving society's problems.

Lawrence Berkeley Laboratory (LBL) is one of seven national multipurpose laboratories funded by the U. S. Department of Energy (DOE). It is operated by the University of California under contract with DOE. In addition to DOE, other federal and state agencies commission research at LBL and provide about 12% of its annual budget.

Early Development: The Laboratory is named for its founder, Ernest Orlando Lawrence, who invented the cyclotron in 1929 and subsequently attracted to his Laboratory an outstanding group of researchers who have made important contributions in many fields of science and engineering. Lawrence and his colleagues were architects of the modern way of doing science. While traditionally a scientist had worked alone in a small laboratory, at Lawrence's laboratory interdisciplinary teams, including scientists and engineers from numerous fields, combined their talents to tackle new projects. Together they built successively larger accelerators with higher energies. (Three of the basic kinds of accelerators—the cyclotron, the linear accelerator (linac) and the synchrotron — were invented and developed at Lawrence Berkeley Laboratory.)

They carried out research that produced pioneering discoveries in nuclear and elementary particle physics, nuclear chemistry, and biology and medicine. Most of the unstable elementary particles were discovered here, as were all the 14 known transuranium elements. Scientists here traced the first steps in photosynthesis and pioneered the field of nuclear medicine. Through almost five decades, researchers at this laboratory have continued to work on the frontiers of scientific exploration, gaining world renown and many awards including eight Nobel Prizes.

Current Research: Today, the Laboratory's scope has broadened to include nine research divisions: Accelerator and Fusion Research, Biology and Medicine, Chemical Biodynamics, Earth Sciences, Energy and Environment, Materials and Molecular Research, National Resource for Computation in Chemistry, Nuclear Science, and Physics, Computer Science and Applied Mathematics. Research is facilitated by the activities of three support and service divisions: Administration, Employee and Information Services, and Engineering and Technical Services. The latter, ETS Division, conducts major research projects of its own. The interdisciplinary approach instituted by Lawrence still prevails, and researchers from all divisions collaborate to carry out the Laboratory's projects.

Research directions have evolved rapidly over the years, as LBL scientists have opened entirely new areas of research and provided leadership in developing fields. In response to the nation's pressing need for new energy technologies, during the last decade the Laboratory has established a major effort in energy development and environmental research. LBL is making important contributions in these areas on a number of fronts, including fusion power, solar energy conversion, geothermal power, and the production of clean fuels from coal and cellulose. For example, researchers are developing a novel idea of breeding new kinds of plants that can be harvested for fuel and thereby provide an inexhaustible source of energy. In the Controlled Thermonuclear Research Program the neutral beam facility is being designed and developed for the Tokamak reactor under construction at the Princeton Plasma Physics Laboratory. Researchers here are also developing the materials essential to some of the proposed new energy systems.

Concerns relating to the energy tech-

nologies are subjects for investigation: The environmental pollutants produced by modern society are being examined, especially the effects of some of the nuclear and non-nuclear pollutants on living systems. The Laboratory also has a major program in energy policy analysis which provides invaluable information for making reasonable choices about the nation's energy future.

In other work, nuclear physicists and chemists explore new nuclear phenomena with LBL's three heavy-ion accelerators; scientists and engineers are collaborating with the Stanford Linear Accelerator Center to build the Positron-Electron Project, the newest high-energy accelerator to be completed; and LBL physicists are preparing to employ that device in high-energy research.

LBL Staff: More than 3000 people work at LBL's hillside site overlooking San Francisco Bay. Approximately half are scientists and engineers, and half are "support" personnel—the crafts workers, clerical employees, administrators, and many others so important to the Laboratory's day-to-day operation. Most of the nonscientific personnel are employed in the three support divisions: Administration, Employee and Information Services, and Engineering and Technical Services.

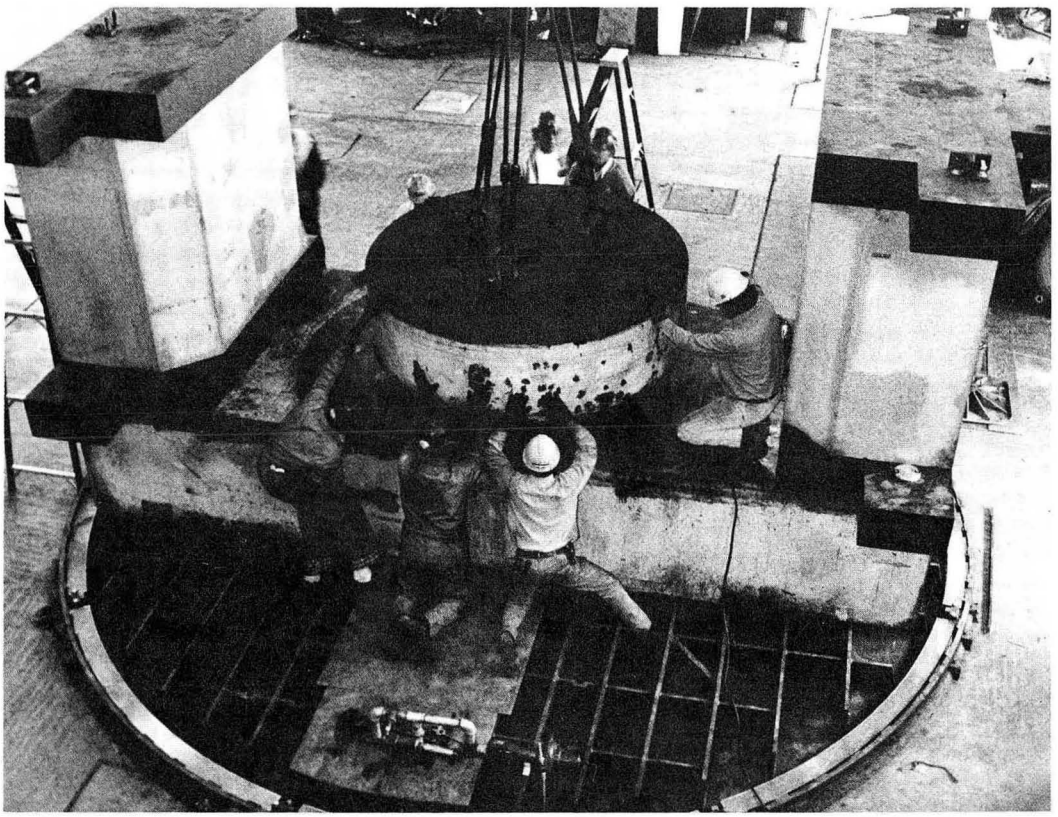
From a sentinel position at LBL, the 184-Inch Cyclotron building overlooks San Francisco Bay and the Berkeley campus of the University of California. The proximity of the Laboratory to the campus facilitates close interaction between the staffs and programs.

University Collaboration: The proximity of the Laboratory to a large university campus permits a blend of the exciting qualities of a national laboratory with the stimulating environment of academia. The close collaboration between the Laboratory and the University of California in research, education, and staff gives a special character to LBL.

Many UC faculty members in physical, biological, and engineering sciences hold key positions at LBL with responsibility for research programs and administration. These cooperative efforts with the UC Berkeley academic departments have recently been expanded to include the social sciences, since those disciplines have expertise in dealing with the economic, social, and legal matters affecting the development of new energy systems.

Approximately 450 University of California graduate students participate annually in research at LBL, and about 85 doctoral degrees and 25 master's degrees are awarded each year to students associated with the Laboratory's programs. In addition, LBL attracts outstanding postdoctoral researchers from throughout the United States and foreign countries who contribute significantly to ongoing research at LBL. The interaction of LBL staff and faculty, graduate students, and postdoctoral researchers creates a vitality that pervades the research activities at the Laboratory.

Facilities: LBL comprises 57 buildings and covers more than 120 acres. As a national laboratory, LBL designs, constructs, and operates major research facilities as national resources available to qualified scientists from around the world. Three of the accelerators—the Super-HILAC, the Bevalac, and the 88-Inch Cyclotron—form an international center



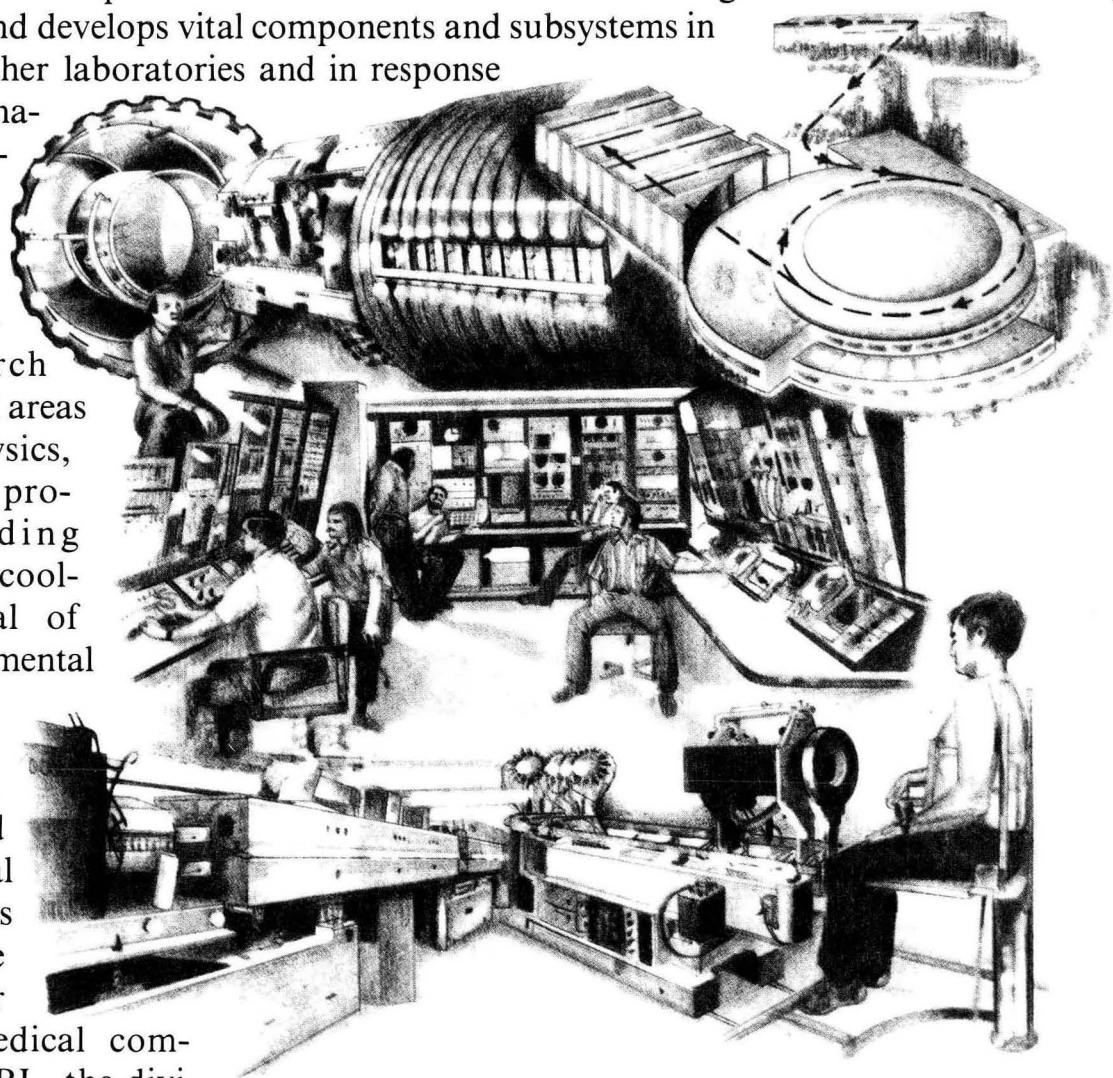
In 1980, Bevalac researchers will be able to conduct large scale experiments with relativistic heavy-ions in a new dedicated user facility. The Heavy Ion Spectrometer System (HISS) will be capable of identifying and measuring the directions and momenta of many particles from one interaction. Workmen here are positioning the 525 ton, 30 kilogauss superconducting magnet that will be the heart of HISS.

for heavy-ion research in both nuclear science and biology and medicine. A Microscope Center at the Materials and Molecular Research Division houses a variety of highly advanced electron microscopes available to outside users. The National Resource for Computation in Chemistry is opening new possibilities for theoretical chemists. Other major facilities at the Laboratory include advanced controlled-environment facilities for animal research, one of the largest user-oriented scientific computers in the country, and a fusion injector/heater test stand.

Social Benefit: All information generated by the Laboratory's research program is available to the public through regularly published reports and journal articles. There is a special emphasis on transferring this information, as well as describing new equipment and techniques developed here to the private sector where the ideas can be implemented for the benefit of society. To facilitate this process, there is a Technology Liaison Office, which makes available to industry, small businesses, and state and local governments LBL's wealth of scientific and engineering know-how for solving specific technological problems.

Basic research done in pursuit of pure knowledge, as in studies of the fundamental particles of matter, is carried out side-by-side with applied research, as in energy technology development. Such a complementary association of basic and applied research has been characteristic of this multiprogram laboratory from its early days.

The Accelerator and Fusion Research Division promotes scientific research by conducting basic studies in accelerator and beam systems, by designing, building, and operating advanced accelerator facilities; and by developing the technology for these systems and components. The common thread among the several AFRD interests is the behavior of particle ensembles in various states, ranging from those governed by single particle dynamics to the high-current collective phenomena and plasmas. In the areas of inertial and magnetic confinement fusion, AFRD researches and develops vital components and subsystems in cooperation with other laboratories and in response to the needs of the national energy program. The division originates and carries out specific theoretical and experimental research programs in selected areas of basic plasma physics, ion sources, beam propagation, colliding beams, and beam cooling, with the goal of clarifying the fundamental laws governing these systems. The SuperHILAC and Bevalac are operated by AFRD as national accelerator facilities as a service to the country's nuclear physics and biomedical communities. Within LBL, the division works closely with scientists in the nuclear science, high-energy physics, and biology and medicine programs, as well as with research groups from other institutions, to facilitate planning and development of the next generation of research tools and facilities. Technological research is carried out to advance the state-of-the-art of magnets (superconducting and conventional), cryogenics, rf systems, computer control systems, diagnostic instrumentation, and other components of particle beam systems. The variety of tasks in the AFRD requires an outstanding professional and technical staff to achieve the division's research objectives and to maintain excellent support of scientists in associated disciplines who rely on AFRD-operated facilities. In other words, our staff must anticipate future research needs and directions, preparing the necessary technology to remain scientifically competitive, without jeopardizing the current operational goals.



Hermann A. Grunder

Hermann A. Grunder
Head, Accelerator and Fusion Research Division
Associate Director, LBL

Accelerator and Fusion Research

Hermann A. Grunder
LBL Associate Director
Head, Accelerator and
Fusion Research Division

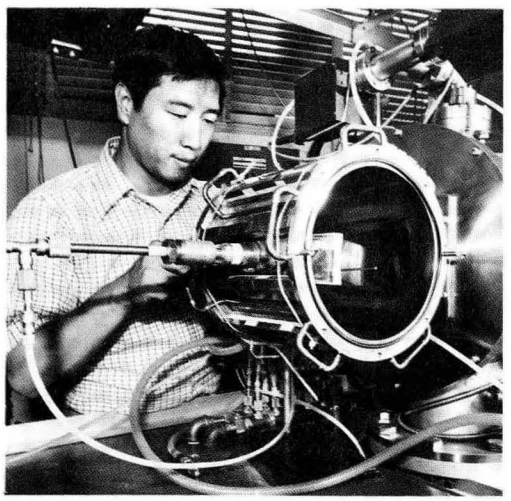
Division Administration
Tom Elioff
Kendrick J. Hebert
Ann G. Fitzgerald

Division Staff
Robert V. Aita
Jose R. Alonso
Richard L. Anderson
Douglas A. Bentsen
Klaus H. Berkner
Lee J. Besse
Barton Billiard
Joseph Bisognano
G. Stanley Boyle
James P. Brannigan
Kenneth E. Bregger
Robert W. Brokloff
Ashton H. Brown
Ian G. Brown
Charles E. Burrell
Gary M. Byer
Warren E. Byrne
James Carroll
Norris D. Cash
Virginia A. Cherniak
Warren W. Chupp
Robert C. Coates
William S. Cooper, III
Bruce B. Cork
Donald N. Cowles
Kenneth C. Crebbin
Tom L. Criswell
Elmer F. DeMartile
Martin H. Donald
Kenneth W. Ehlers
Hugh M. Ellison
Robert S. Everett
Scott Fanning
Benedict Feinberg
Robert J. Force
Alper A. Garren
Mark Gart
Basil F. Gavin
William S. Gilbert
Robert G. Gisser
‡*Jerg Glatz*
George R. Gray
Celso Grebogi
James R. Guggemos
Walter Harris
Chester W. Hatch, Jr.
Jerry Howard
John M. Johnson
Rudin M. Johnson
Orland J. Jones
Juris G. Kalnins
Leal L. Kanstein
•*Allan N. Kaufman*
Denis Keefe
Charles Kim
Hogil Kim
Kwang Je Kim
•*Wulf B. Kunkel*
Glen R. Lambertson
L. Jackson Laslett
Beat T. Leeman
Christoph W. Leeman
Ka-Ngo Leung
Morton A. Levine
Alan F. Lietzke
Robert G. Littlejohn
Edward J. Lofgren
Fred H. Lothrop
James L. MacMullen
Robert M. Main
Dexter J. Massoletti
Steven W. McDonald
Robert E. McGeary
Robert M. Miller
William S. Mirer
John K. Mooney
Ross G. Nemetz
Jack M. Palmatier

Since 1929, and the invention of the cyclotron by E. O. Lawrence, LBL has been an international leader in accelerator physics research, development and operation. The four heavy-ion accelerators operated by LBL today are an important scientific resource for researchers here and around the world. In addition, the technological expertise we gain from accelerator science is being applied extensively in the area of fusion energy research. The focus of these activities is the Accelerator and Fusion Research Division, where work is carried out in four programs: Magnetic Fusion Energy, Heavy-Ion Fusion, Advanced Accelerator Studies, and Accelerator Operations.

MAGNETIC FUSION ENERGY

In the sun's interior, nuclear fusion converts millions of tons of hydrogen into helium every second, releasing tremendous amounts of energy. Early in the next century the same process may be used by mankind to generate electricity. Because fuel for this process — deuterium — is essentially inexhaustible and the problem of radioactive waste disposal is projected to be relatively small, this applied fusion process is a particularly attractive energy system. Power is extracted from such controlled thermonuclear, or fusion, reactions in three steps: generating a dense cloud of deuterium ions called "plasma," heating the plasma to temperatures hotter than the center of the sun, and keeping the plasma together long enough for ions to collide, fuse, and release energy.



Pointing to a new direction in magnetic ion fusion, this surface conversion negative-ion source invented by Ken Ehlers and demonstrated here by K. Leung will produce beams for energies above 200 keV.

In the Magnetic-Confinement Fusion Energy (MFE) Program at LBL, we are developing improved high-power neutral beam injectors for large controlled-fusion experiments in which the plasma is held together by magnetic fields. Such injected beams are being used, for example, to produce hot plasma with temperatures higher than 100 million degrees in the mirror machines at the Lawrence Livermore Laboratory. The method has proved so successful that LBL has been asked to develop multimegawatt injector systems for TFTR, the large tokamak at Princeton, and for Doublet-III, the confinement experiment at General Atomic in La Jolla, Calif. The large-scale engineering of these latter two projects is being managed by the Engineering and Technical Services Division.

The MFE Group is also researching new concepts in magnetic confinement, fueling, heating, and diagnostics. The principal goal is to develop novel confinement systems that will lead to fusion reactors smaller and less expensive than the tokamak reactors. Our work here is being backed by theoretical studies on confinement and heating, while the neutral beam effort is accompanied by basic studies on relevant atomic processes. In this manner, the MFE project at LBL maintains solid contact with the academic world.

HEAVY-ION FUSION

An alternative approach to managing plasma compression is called "inertial confinement" fusion. This method involves the heating and compression of a tiny volume (about one cubic millimeter) of deuterium-tritium (D-T) fuel quickly enough to promote sufficient burning of the fuel (the

Staff Continued

Emery Parker
Jack M. Peterson
Philip A. Pincosy
Darrell D. Pohl
Robert E. Purvis
Robert V. Pyle
Joseph B. Rechen
Robert M. Richter
John W. Roberts
**Lawrence Ruby*
Richard C. Sah
Stephen E. Savas
Alfred S. Schlachter
Donald W. Schmeyer
Frank B. Selph
Robert S. Shaw
Joseph H. Shiloh
Leo J. Skvarla
Joseph F. Smith
Lloyd Smith
John W. Staples
Kenneth R. Stalder
John W. Stearns
William E. Steele
Robert R. Stevenson
Edward W. Stuart
Harvey K. Syversrud
John A. Tanis
Marsh M. Tekawa
Raymond K. Thatcher
Christoph A. Timossi
John E. Tommaney
Christine L. Weber
Glenn E. White
Oliver Wiggins
Malcolm D. Williams
Michael D. Wolfe
Frederick W. Yeater
Emery Zajec

*UCB faculty member
‡visiting staff

fusion reactions) before the pellet can explode and disperse. To achieve this, the D-T fuel is encapsulated in a thin shell of heavy material, which is then heated by an "igniter" or "driver." When a large amount of energy is deposited on the pellet wall, the heated shell implodes, heating and compressing the fuel, and initiating the fusion reaction. Driver systems that will instigate this reaction (lasers, or beams of electrons or light ions) have been under study for a number of years.

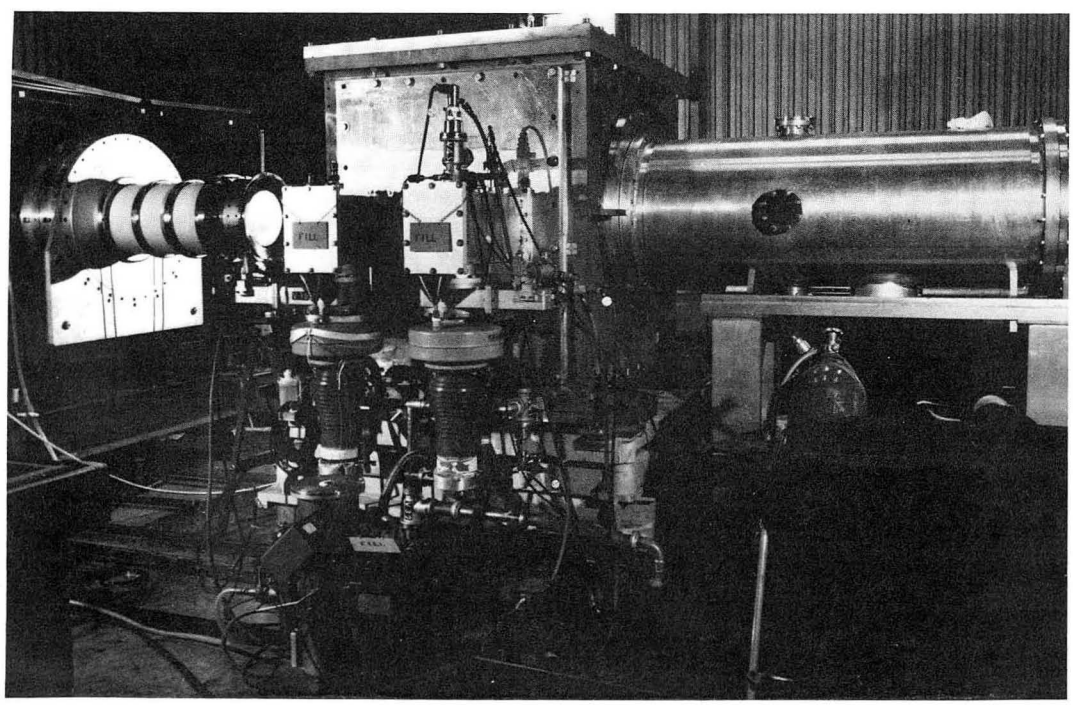
Since 1977, the division has pursued a strong and expanding program to study a system that uses heavy-ion accelerator technology for the driver system. This use of high-energy, heavy-ion beams appears to offer great advantages in being able to meet the goals of high efficiency, high repetition rate, and high availability that will be essential to a practical fusion power plant.

A heavy-ion accelerator that can be used as a driver must provide a greater beam current and much higher beam power than accelerators used for particle research. The basic specifications for the heavy-ion driver are 1 to 10 megajoules of stored energy in a beam of ions of atomic weight 200 or more, to be delivered on a focal point of about five millimeters in radius. An eventual full-scale power plant will require an accelerator that is several kilometers in length—on the scale of the Stanford Linear Accelerator.

There are two chief candidates for heavy-ion accelerator drivers: one based on the rf linac with storage rings (being explored at Argonne National Laboratory), and the other based on the induction linac, the approach we are pursuing at LBL.

The Heavy-Ion Fusion Program (HIF) at LBL is still in the beginning stages with research expected to continue for the next decade. The planned program consists of a series of five test experiments of increasing beam energy (4J, 500J, 10kJ, 1MJ, 10MJ).

In the 4J first step, now under construction at LBL, a large, 500kV, Cs^{1+} contact-ionization source has been developed and



The large 500 kV, Cs^{1+} contact ionization source (left) has given good performance in the test setup being used to develop a heavy-ion accelerator as an igniter in the fusion program.

has delivered 1.2 amperes; it is capable of a 1-Hz repetition rate with good reproducibility. Three pulsed drift tubes are 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.

The second-step 500J system is now under design as an accelerator demonstration facility. This induction linac test bed, which could be operational for accelerator and plasma physics experiments some time in 1983, would provide crucial information regarding behavior of the beam under conditions approaching those in an actual power plant.

We expect to start planning for the third step—HIDE—a device large enough for pellet experiments, in 1982, shortly before the 500J system is running.

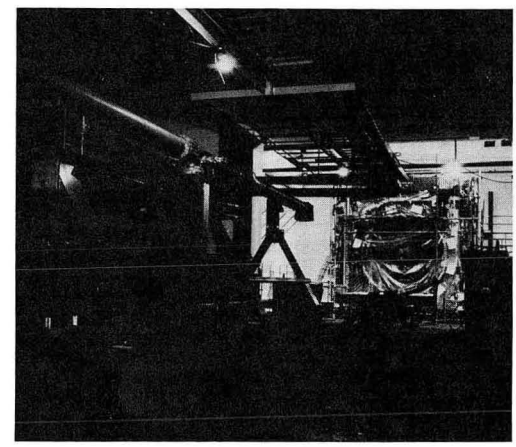
As these five experimental tests proceed, we are continuing our systems studies directed toward the use of new and less costly materials in the design and development of engineering models, components, and subsystems. Theoretical research is pursued simultaneously on new problems of transporting and bunching high-current beams, and on the final focusing of these beams on a small target area.

ADVANCED ACCELERATOR STUDIES

Positron-Electron Project

The Positron-Electron Project (PEP) is a colliding-beam, storage ring system designed and constructed jointly by LBL and the Stanford Linear Accelerator Center (SLAC) at the SLAC site. The $78 million facility was proposed in 1974, authorized in 1976, and the ground broken for the first construction on June 2, 1977.

Creating a new energy frontier for electron-positron collisions, PEP is expected to be one of the most exciting high-energy physics research facilities for the next decade. The colliding-beam technique makes it possible for us to achieve much higher interaction energies than can be obtained with a conventional accelerator; 36 billion electron volts (GeV) will be available when the electrons and positrons, each with a beam energy of 18 GeV, collide.



From the south tunnel at PEP, the colliding-beam line awaits the completion of the Mark II Detector.

The PEP storage ring will provide an energy capability more than four times greater than that of SPEAR, the colliding beam machine now operating at SLAC. SPEAR is the site of the Nobel Prize-winning experiments by LBL and SLAC scientists which led to the discovery of the new family of psi particles and later the discovery of the property known as "charm."

PEP is being constructed around the periphery of the experimental area terminating the two-mile-long linear accelerator at SLAC. The PEP storage ring is about a half mile in diameter and 1.4 miles in circumference, the beam housing tunnel being PEP's largest single structure. The cross-sectional width of the tunnel is 3.5 meters (11.6 feet) at underground depths varying from 18 to 80 feet, due to the hilly terrain. Although the interaction halls are partially underground structures, as dictated by the beam elevation, access is provided above ground.

At mid-1979, all tunnels for the beam housing and the heavy concrete structures for the experimental halls surrounding the collision points had been completed. The positron injection transport system, which carries the injected beam from the SLAC linac to the PEP ring, has been installed.

Preliminary beam tests indicate satisfactory performance for the injected beam systems.

Approximately one-half of the nearly 700 dipole, quadrupole, sextupole, and miscellaneous injection and correction magnets have been installed. Installation of utility systems, rf and power supply systems, and instrumentation and control systems is also in progress.

Eight major experiments have been approved; installation of the associated detector systems began during the summer of 1979, with expectation for first beam turn-on in the fall.

PEP's design allows for future development; by adding rf systems, beams of 25 GeV can be achieved. Provisions have also been made so that a superconducting proton ring with beam energies to 300 GeV can be added within the same tunnel enclosure to achieve high-energy collisions of electrons (or positrons) with protons.

Beam Cooling Studies

Accelerator designers have developed colliding beam facilities to achieve extremely high energies for experiments without increasing acceleration systems to an inordinate size. These systems can consist of either two concentric storage rings in which the beam trajectories cross at one or more interaction regions around the ring or a single ring where particles and anti-particles circulate in opposite directions (as in PEP). With either method, the particle beams collide head-on to produce the desired interaction.

Reaction rates between the particles in a colliding beam system depend on the intensities of the two beams; the rates are generally low, since relatively few particles can be contained in the interaction system in comparison to a solid target. To increase the utility of colliding beam facilities, the reaction rates must be increased.

In the new technology of "stochastic" beam cooling, we are attempting to maximize the efficiency of the colliding beam technique by reducing the momentum spread of the beam. This reduction has the effect of enlarging the beam area and thus increasing the reaction rate. The motions of the particles in a beam due to differences in their momenta are analogous to the thermal motions of gas molecules; thus the reduction of the momentum spread is termed "beam cooling."

To advance the theoretical and technological base for stochastic cooling designs and applications, the accelerator group is carrying out experiments with the Fermi National Laboratory on a small, 200-MeV storage ring that has recently been constructed at Fermilab. The technique, developed at CERN, involves the use of a pick-up electrode located at one point in the storage ring to detect the random (stochastic) fluctuations that occur in the particle density as the beam circulates and the faster particles overtake the slower ones. The amplified and processed signals from the pickup are delayed to correspond to the beam transit time, and applied to the beam as a corrective impulse by a down-stream kicker electrode.

The program requires the development of extremely sensitive wide-band pick-up electrodes; state-of-the-art, low-noise, wide-band preamplifiers; and wide-band, minimum-delay, power amplifiers. We are currently designing and fabricating this equipment at LBL, and will send it to Fermilab for installation in the storage ring. Beam experiments, which began in fall 1979, are expected to continue for about one year. Further applications at other facilities are anticipated as a result of these studies.

High-Field Magnets

Present superconducting magnets are in the 4 tesla range, but future accelerators and physics research will benefit from much higher fields—8 tesla or greater. To develop the high-field magnets that will be essential for the next generation of accelerators, we must explore both the limits of currently available materials and those that can be created for conductors and supporting structures. The necessary blend of expertise for this unique program has been achieved by collaboration between members of our materials research group (MMRD) and our

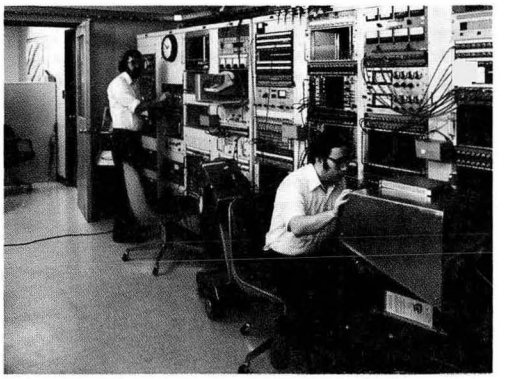
specialists in accelerator magnet design. We have built a test apparatus here at LBL so that we can measure the mechanical properties of the complex coil and support structures at liquid helium temperatures. A variety of new conductor configurations and magnet designs are being evaluated for the entire 7 to 10 tesla field range. The magnet systems we are studying have application for purposes such as adding an electron-proton capability at the PEP facility or in achieving very-high-energy proton accelerators.

Accelerator Theory

Work in accelerator theory spans 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. In our broader collaborations, we are participating in planning a p-$\bar{p}$ colliding beam system at Fermilab and have renewed studies with Brookhaven National Laboratory on the intensity limitations in high-energy accelerators.

Variable-Energy Nuclear Synchrotron VENUS

For several years we have been studying the national need for a versatile facility to serve heavy-ion physics in the 1980s and beyond. To meet these needs we have developed the VENUS concept for a dual-ring superconducting accelerator and storage ring. This concept is now being reviewed by the nuclear physics community. VENUS could be operating by 1987 to offer beams of all ions through uranium at energies from 40 MeV to 20 GeV per nucleon (and protons to 50 GeV) in the fixed target mode, with colliding beam energies from 2 on 2 GeV to 20 on 20 GeV per nucleon. The site of the 230-meter-diameter VENUS rings would circle beneath the SuperHILAC and the Bevalac, with the former serving as injector.



Counting area for outside users at the SuperHILAC.

ACCELERATOR OPERATIONS

The Bevatron/Bevalac and SuperHILAC accelerators are national user facilities for nuclear science and biomedical studies; about half of the experiments undertaken at these two machines are the work of nonLBL scientists. (The 88-Inch Cyclotron, operated by the Nuclear Science Division, is described in the Nuclear Science section of this report.) Funding comes from the Department of Energy, which also shares in the support of the fourth major LBL accelerator, the venerable 184-Inch Synchrocyclotron. This last facility is dedicated to medical treatments, and its operation is supported in part by grants from the National Cancer Institute.

LBL's three heavy-ion accelerators – SuperHILAC, Bevatron/Bevalac, and 88-Inch Cyclotron–each have a distinct energy and particle range and provide scientists with unique capabilities. LBL is the only laboratory in the world where researchers can obtain heavy-ion beams ranging from the proton (the hydrogen nucleus, not technically a heavy ion) to lead (element 82) at energies from 0.27 MeV to 2.1 GeV/nucleon.

SuperHILAC

Heavy-ion physics had its start at LBL with the 1957 christening of the HILAC (Heavy-Ion Linear Accelerator), an Alvarez-type linac capable of providing nuclei of elements as heavy as argon (element 18).

In 1971, after extensive modification, the machine was renamed the SuperHILAC because of its increased capability for accelerating heavy ions. We have continually developed new beams of ions here; the present catalog of available ions includes any element through xenon, plus holmium (element 67) and lead (element 82).

The SuperHILAC's experimental area is designed for research in three main regions: Coulomb excitation phenomena, search for new elements, interaction between heavy ions. Most of the elements heavier than uranium (element 92), including elements 104, 105, and 106, were discovered at this accelerator; and one of the current research efforts is directed at a search for "superheavy" elements, with atomic numbers in the range of 114 to 126.

Computer control of the SuperHILAC permits nearly simultaneous acceleration of two different ion species on alternate pulses. These two beams can then be "time-shared," with one ion beam delivered to one or two SuperHILAC experimental areas while the other ion beam shoots through the transfer line to the Bevalac. A complementary computer control system at the Bevalac handles all injection, acceleration, and extraction elements there.

Bevatron/Bevalac

Inaugurated as a proton synchrotron in 1954, the Bevatron is the accelerator that provided the first evidence of the antiproton in 1956. Between 1954 and 1971 this machine was a giant in revealing the properties of elementary particles.

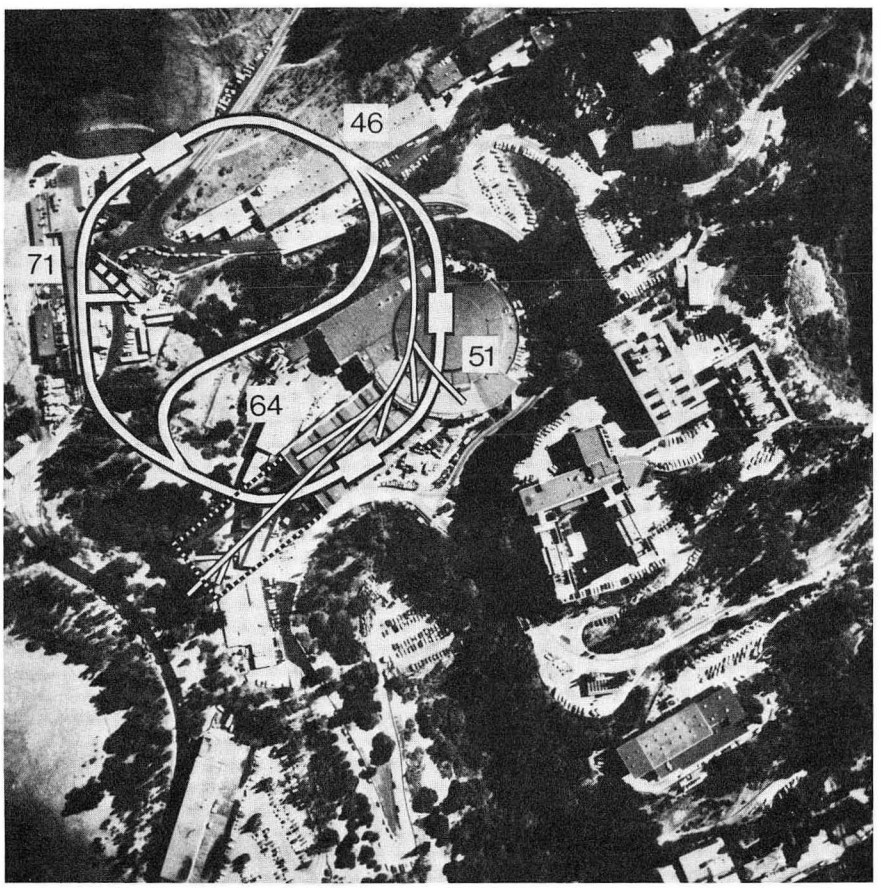
In 1971, initial tests demonstrated the Bevatron's ability to accelerate heavy ions (helium nuclei and heavier). At that time we began the first biomedical experiments to determine the feasibility of charged-particle therapy as an alternative to x-ray or neutron treatment for some human diseases.

The concept of the Bevalac followed almost immediately. In the Bevalac mode, the SuperHILAC sends particles at 8.5 MeV/nucleon through a 175-meter-long beam line to the Bevatron, where the ions are further accelerated and then delivered to experimenters. In 1974, we completed joining the Bevatron and the SuperHILAC, and high-energy, high-intensity heavy ions up to argon became available to the nuclear science community and biomedical researchers. In 1976, iron particles, especially sought by scientists studying cosmic rays, were accelerated at the Bevalac and became the heaviest ions ever accelerated in a high-energy beam in the world.

The Bevatron/Bevalac offers an extremely wide range of high-energy, high-intensity particle beams, including protons, alpha particles, carbon, nitrogen, oxygen, neon, argon, and iron. Researchers have their choice of particles at energies from 100 MeV/nucleon to 2.1 GeV/nucleon (2100 MeV/nucleon).

Subjects of current interest at the Bevatron/Bevalac include phenomena associated with central collisions of heavy-ion projectiles and targets, such as the formation of super-dense matter and shock waves. Peripheral collisions involving smaller and more localized transfer of energy, mass, charge, and monmentum are also investigated while pioneering work on heavy-ion fragmentation cross sections continues as well. These fragmentation studies are especially important to astrophysicists, as the data are used to formulate models describing the propagation of cosmic rays in space. NASA scientists also use the Bevalac's heavy-ion beams for calibrating the sensitive instruments flown in space studies. Secondary beams of every isotope lighter than the primary beam particle can be produced for experimental use from the fragmentation process.

Bevalac Biomedical Facility: In this facility the biological and physical sciences are united in a clinical program to use heavy ions for diagnostic and therapeutic radiology. The facility contains two areas, one designed for tissue, molecular, and space radiobiology, and the other for patient diagnosis and treatment of cancer. The biology area consists of an irradiation area and two preparation rooms; the patient area comprises treatment, planning, examina-



Superimposed on an aerial view of the SuperHILAC and Bevatron is a sketch of the Variable Energy Nuclear Synchrotron (VENUS), a dual-ring superconducting accelerator and storage ring planned for the 1980s.

tion, and waiting rooms. Both sections are controlled from one central control in which a PDP 11/45 monitors the detailed calculations and delivers radiation doses to a sample or patient within 1% of that desired by the researcher or physician.

Accelerator Research Coodination (ARC) Office: Researchers from around the world may submit proposals for the use of experimental beam time on the Bevatron/Bevalac and the SuperHILAC. All such proposals are reviewed by Program Advisory Committees, and our ARC Office streamlines communications with current and potential users. It also coordinates all services for experimenters at both accelerators and provides expertise in mounting nuclear science and biomedical experiments.

Uranium Capability: Because of our outstanding success with the Bevatron/Bevalac as a heavy-ion research facility, we have taken on a major project to extend that capability to accelerating ions as massive as uranium. A high-intensity source of very heavy ions is being built at the SuperHILAC, supplementing the two injectors already operating there. To accommodate these partially-stripped very-heavy-ion beams, we are installing a new ultra-high-vacuum chamber within the entire Bevatron ring to bring the pressure down to 10^{-10} torr.

184-Inch Synchrocyclotron

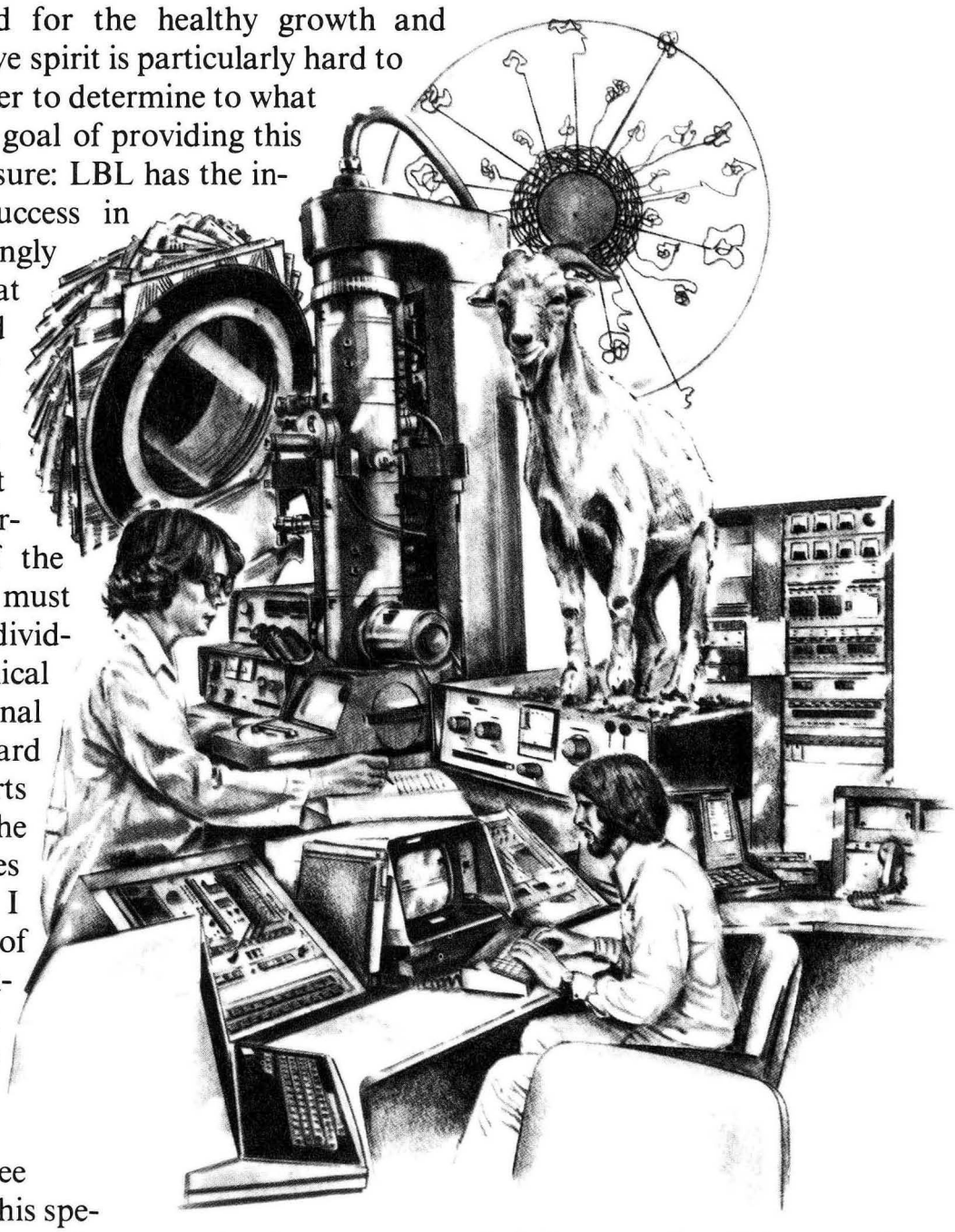
Operated as a medical accelerator for programs in LBL's Biology and Medicine Division, this reliable machine has been used during the past two decades to treat over 700 patients for acromegaly and Cushing's disease. Radiation therapy with the 184-inch accelerator's 930-MeV helium ions has become the established treatment for these pituitary diseases.

In a new program, patients are being treated with the accelerator's helium-ion beam for various kinds of cancer. This program is sponsored by the National Cancer Institute and the Department of Energy.

Accelerator Design Studies

Theoretical and practical design studies for new accelerators and their applications continue. Current efforts include design of accelerators optimized for hospital-based therapy.

The climatology required for the healthy growth and development of the creative spirit is particularly hard to define, and it is even harder to determine to what extent one achieves one's goal of providing this climate. One thing is for sure: LBL has the ingredients for creative success in abundance, and my strongly held personal belief is that the principal job assigned to me by the laboratory director is the nurture of this climate. How to accomplish this assignment is not entirely clear, but certainly some elements of the process are evident. We must identify and support individuals who have the technical skills and the special personal qualities to carry forward top-quality research efforts and provide them with the necessary tools and services to complete their tasks. I am convinced that much of the success that has distinguished this laboratory in the past arises from the special managerial and work environment that has been provided. I also see convincing evidence that this special managerial and work environment has been preserved. What are the differences that set us aside from other laboratories? I believe they mostly center about the "collegial" style of management that has been the hallmark of LBL since its founding. By this term I mean to indicate that individuals at all levels of the system have some sense of being in control of their own fate. The price one pays for such a style of management is the open expression of individuality and a certain degree of disorder. On the one hand, this expression of individuality is the very key to the creative process, while the disorder is one of the symptoms that must inevitably arise. I, for one, am pleased to pay that small price for open environment and the commitment to scientific achievement that is so important to all of us.



Edward L. Alpen

E. L. Alpen
Head, Biology and
Medicine Division
Associate Director, LBL

Edward L. Alpen
LBL Associate Director
Head, Biology and Medicine Division

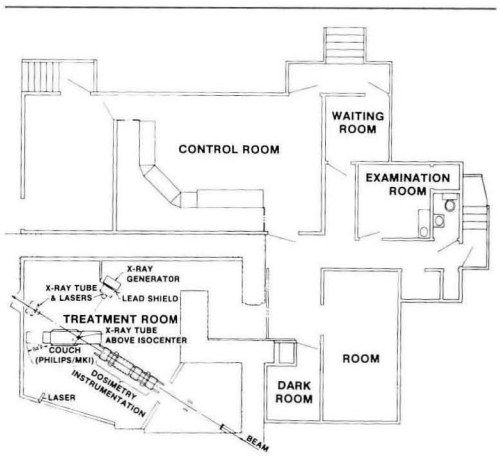
Division Administration
Janice C. DeMoor
Laurie E. Graves
Allan W. Long
Mark D. Sessler
Robert W. Springsteen
Baird Wahley
Herbert Wiener

Division Staff
E. John Ainsworth
Hal O. Anger
Mary E. Barker
John B. Bassel
Jacob S. Bastacky
Thomas E. Bauer
**Alan J. Bearden*
Eugene V. Benton
Eleanor A. Blakely
James L. Born
†George Brecher
**Thomas F. Budinger*
H. John Burki
**Joseph R. Castro*
Aloke Chatterjee
George T. Y. Chen
William T. Chu
Gisela K. Clemons
Gerald M. Connell
Stanley B. Curtis
Hunter O. Cutting
Jefferson W. Davis
Stephen E. Derenzo
Jonathan S. Dixon
Kenneth H. Downing
Patricia W. Durbin
**Shirley N. Ebbe*
†Jacob I. Fabrikant
Trudy M. Forte
Cornelius T. Gaffey
Joseph F. Garcia
**Robert M. Glaeser*
**Donald A. Glaser*
Joseph D. Goldstein
Joan W. Goodman
**Martin H. Graham*
David A. Grano
Grant T. Gullberg
Adeline J. Hackett
**Thomas L. Hayes*
Lester Hollander
William R. Holley
Junko Hosoda
Shirley Hoye
Jerry Howard
Ronald H. Huesman
Lin C. Jensen
John W. Kast
Esther H. Knudson
Ronald M. Krauss
**John H. Lawrence*
Florence Li
Frank T. Lindgren
**John A. Linfoot*
John T. Lyman
Marcos F. Maestre
John L. Magee
**Howard C. Mel*
**Robert K. Mortimer*
Frank Q. Ngo
**Alex V. Nichols*
Suzanne S. T. Pan
†Theodore L. Phillips
Julia B. Quint
†Jeanne M. Quivey
Michael S. Raybourn
Adrian Rodriguez
Ruth J. Roots
Donald J. Rosenthal
Thorton W. Sargent
Walter Schimmerling
Caroline Schooley
John C. Schooley

LBL's Biology and Medicine Division maintains a highly respected position in nuclear medicine. Since the first discovery of radioisotopes by our researchers in the 1930s, medical scientists in our Biology and Medicine Division have pioneered the treatment of diseases with artificially produced radioactive substances.

The division's facilities include the Biomedical Laboratory on the Hill, where animal studies are conducted. On the campus, Donner Laboratory, with Donner Pavilion, continues in its role as a leader of nuclear medicine. Complete treatment centers serve patients at two accelerators: The Bevalac, a combination of LBL's Super-HILAC and Bevatron accelerators, produces intense beams of heavy ions at extremely high energies and is the basis for our program here in heavy-ion radio-therapy. The 184-Inch Synchrocyclotron has been providing steady reliable service for many years for the irradiation of patients with pituitary-related problems. When further complemented by the various departments of the Berkeley and San Francisco campuses of the University of California, LBL's Biology and Medicine Division provides a comprehensive medical facility.

Our researchers in this division seek to make the techniques and tools developed in the laboratory available, through field application, to medical centers for diagnosis and treatment. Here we also explore the effects of new energy technologies on health and the environment. As a result, we are able to provide guidelines for setting biological and medical standards.



Bevalac radiotherapy facility for treating patients.

Carrying out the programs of the division are 43 LBL staff investigators and 17 faculty members from the University of California campuses at Berkeley and San Francisco, as well as 15 post-doctoral and visiting scientists. Approximately 25 graduate students participate in the research of the division as part of their graduate training.

RESEARCH MEDICINE

Medical scientists in our Research Medicine Group continue their quest for knowledge about human biochemistry in health and in disease. In addition to their findings in basic biochemistry and physiology, the tools they develop for special imaging and blood analysis are valuable for diagnostic nuclear medicine. The effects of magnetic fields on humans and the biological impact of pollutants from energy production also receive the attention of our researchers.

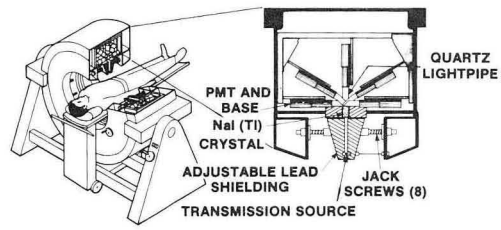
A highpoint is the completion of the 280-crystal ring detector system in July 1978 and the use of this device for animal and human studies. With its aid, our ability to visualize the blood flow and metabolism of the human beating heart has greatly increased our understanding of heart disease. These myocardial studies have proven useful to the medical profession by facilitating the early identification of the disease, clarification of the role of diet and exercise in improving the blood supply to a damaged myocardium, determination of the extent of a heart attack and the effectiveness of therapy and monitoring the blood supply to the heart muscle in people who have had bypass surgery. By learning as much as possible about the myocardium and its metabolism, we hope to uncover clues to the causes of coronary artery disease.

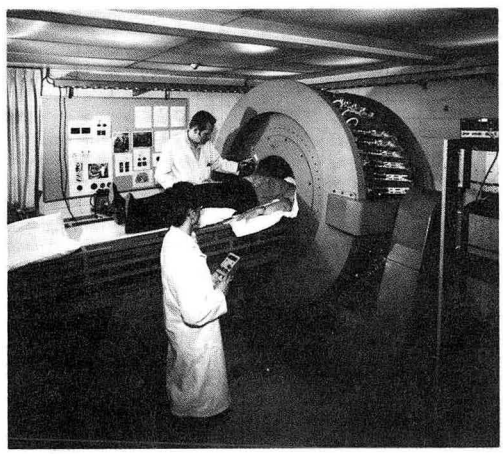
This program in research medicine is closely associated with the development of instrumentation. We are moving toward a three-ring imaging system that will provide

Staff Continued

Mason M-S, Shen
Helene S. Smith
Helen P. Shu
Alexander T. Shulgin
**Jerome R. Singer*
Lisa Snow
Henry H. Stauffer
Tirunelveli S. D. Subramanian
Pauline Sun
Tom S. Tenforde
Gregory A. Threatte
**Cornelius A. Tobias*
Robert Webber
Margaret R. White
Eckehart Wiedemann
Priscilla D. Wong
Tracy C. Ynag
Yukio Yano
Chi-Kwan Yen
Frank Zisman

*UCB faculty member
†UCSF faculty member





The Donner Positron Emission Tomograph provides high-resolution images of labeled compounds in the body. A ring of 280 gamma-ray detectors (sodium iodide and bismuth germanate crystals) completely encircles the patient and makes 14,700 simultaneous measurements of internal activity, monitored by Stephen Derenzo (front) and John Calhoun.

multi-layer views for the dynamic quantitative analysis of radionuclide distribution. Here also, new radiopharmaceuticals are developed for *in vivo* studies of the biochemistry of amino acids, fatty acids, and glucose. For example, just this past year carbon-11–labeled methionine was first used in metabolic studies of heart and brain in humans.

We are continuing our research in hematology: From studies of the megakaryocytic cell system, we learn more about the turnover of platelets and how they are regulated. This knowledge, which broadens our understanding of blood disorders, we also find valuable for assessing effects of toxic environmental pollutants. Part of the hematology program includes electron microscopy of white blood cells in our search for leukemia viruses.

DONNER PAVILION

At Donner Pavilion, our medical scientists continue to make significant contributions to our understanding of diseases of the human endocrine system associated with the pituitary gland. Currently they are investigating hormonal interactions and developing techniques for assessing the alterations of molecular structures that result from exposure to heavy-ion radiation or environmental pollutants.

For over twenty years, high-energy 910-MeV alpha particles have been used here to suppress pituitary function in patients with disorders of the pituitary gland or with diabetic retinopathy. Today, investigators are using carbon-12 ions for preliminary studies in primates. These beams of high-energy particles have additional radio-biological properties that make them desirable for treating patients with certain advanced conditions not amenable to the lower energy alpha-particle pituitary irradiation (APPI).

APPI continues to be recognized as a uniquely advantageous and essential form of therapy for many pituitary tumors. An integral part of this program is the long-term follow-up of patients who received APPI, thus providing valuable data for our investigations of the biological properties of the human pituitary. When combined with our studies on the effects of heavy ions on functioning tissues, we have a special opportunity to monitor both normal and pathological hormonal secretion. Recently we developed assay techniques for two new hypothalamic peptides, beta-lipotropin and beta-endorphin, and have been able to show that significant changes in the circulating levels of these hormones were found in patients with pituitary tumors; the increased levels were lowered after APPI. The role of these peptides, in the etiology of pituitary tumors, as well as their physiological function, is being explored through the availability of this unique patient population.

These follow-up studies also provide valuable information on the acute and long-term radiobiological and pathophysiological effects of low-level, total-body irradiation and localized, high-intensity heavy-ion

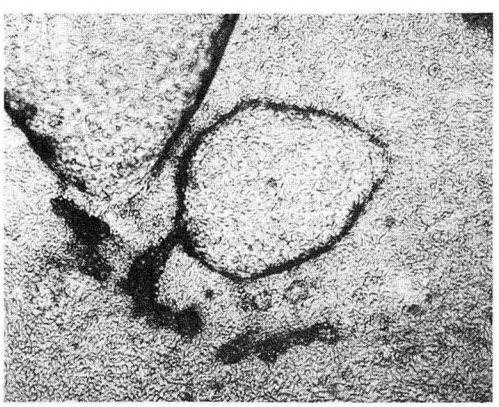
radiation exposure on the central nervous system and on normal and tumor tissues. The research potential of this program is extensive and has broad applications in cancer therapy, as well as in our understanding of basic hypothalamo-pituitary function in health and disease.

PERALTA CANCER RESEARCH INSTITUTE

The Peralta Cancer Research Institute (PCRI) was formed in May 1974 as an association of Peralta Hospital, Oakland, with the University of California, Berkeley. PCRI encourages interactions between basic researchers and clinical oncologists so that the tumor biologist gains clinical information needed to design new and perhaps more relevant model systems, while the clinician has more effective tools for making early diagnoses and for improving patient care. Since July 1977, PCRI has been affiliated with LBL's Biology and Medicine Division.

In the cell biology program here, we have spent pioneering effort in developing techniques for culturing human epithelial cells. This is particularly important since approximately 90% of human cancers are malignancies of this cell type and, until recently, no one had successfully grown most human epithelial cells in culture.

PCRI's cancer diagnosis program has been concerned with developing techniques for early diagnosis of breast cancer, the leading kind of cancer in women. In studies at the institute, medical researchers have concentrated on developing and evaluating a simple test on breast fluid samples, similar to the "pap" smear that has been so successful for early detection of cervical cancers. Plans include working with LBL biologists and physicists to evaluate the potential of heavy-ion radiation for early diagnosis in breast cancer.



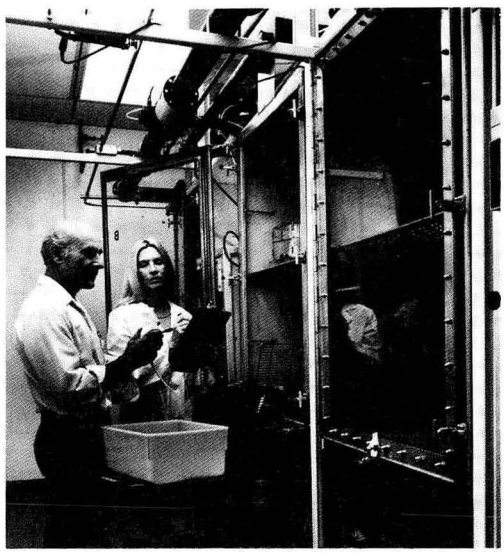
Human mammary epithelial cells in culture forming secretary domes.

Members of our cancer treatment program here are concerned with applying advances in cell biology and biochemistry to the improvement of cancer management: Cells cultured at PCRI from patients are used to test their sensitivity to chemotherapy drugs. These joint programs are another instance of how effectively LBL works with the local medical community to apply basic research advances for improved patient care.

ENVIRONMENTAL PHYSIOLOGY

A variety of programs are carried out by members of the Environmental Physiology Group, in their efforts to identify changes that occur in physiological activity when the living organism attempts to maintain homeostasis—the constant internal environment required for good health. By knowing how disease mechanisms alter homeostasis, we can begin to understand how environmental pollutants exert their effects on the body's internal environment. From our findings we hope to be able to develop tests for detecting early effects of pollutants and to provide a scientific basis for their successful treatment.

The internal metabolic processes in several body systems of rodents has received considerable study as we assess quantitatively the effects of representative types of environmental pollutants. Homeostasis in the hematopoietic (blood-forming) system is delicately regulated by a variety of feedback mechanisms mediated in some instances by circulating hormones and, in others, by cell-cell interactions. To study the effects of



Joseph Garcia and Betsy Carr examine healthy rats as they are introduced into exposure chambers for studies on the effect of environmental pollutants.

environmental pollutants on blood-forming tissues, we look at the progenitors of mature red cells and platelets to find out how environmental pollutants may alter the regulatory process; for example, we are trying to characterize the inhibition of hematopoietic cell progenitors that we have noted in the blood plasma of animals exposed to ozone.

Other of our studies concern the effects of pollutant exposure on the steroid hormone mechanism. There is a very definite male-female difference in the sensitivity of rodents to ozone exposure—female mice being significantly more tolerant. As a result, studies are in progress in which we are examining the possible role of male and/or female sex hormones in this effect.

As a result of having purified erythropoietin (a hormone that regulates the blood-forming process), we are now able to detect its presence by radioimmunological assay. We are currently using this valuable technique in a number of clinical and physiological investigations to find out how the erythropoietin concentration changes in various physiological situations and whether these changes are correlated with anemia.

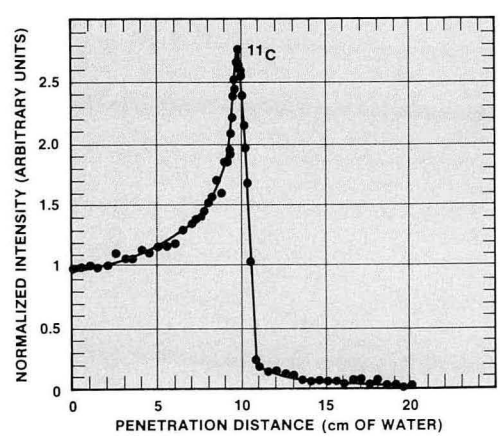
Because the lung is our biological interface to the atmospheric environment, we are seeking to understand how environmental pollutants affect growth and the differentiation of lung tissue. At this interface, pulmonary macrophages, the large cells in the lung, engulf foreign material including inhaled bacteria, viruses, and environmental particulates. We are studying changes in these cells, looking for agents that could have health consequences.

Plutonium metabolism is being studied in monkeys so that we may estimate the behavior of this heavy element in man. Our investigators are also looking for biological effects of plutonium at low exposures, such as might be encountered by individuals during the operation of nuclear power facilities. These investigations will provide information upon which to base appropriate protection standards for persons employed in the nuclear industry and for the general population.

Similar studies are being carried out with actinides and other radionuclides.

RADIATION BIOPHYSICS

Extensive radiobiological investigations are carried out at the Bevalac with high-energy beams composed of carbon, neon, or argon nuclei accelerated up to 90% of the



Bragg peak of carbon-11 radioactive beam. Such a sharp endpoint permits precise treatment of tumor volumes.

speed of light. By systematically studying the physical, chemical, and biological chalogical characteristics of these heavy-particle beams, our investigators have greatly extended our understanding of the nuclear physics of high-energy heavy ions. This knowledge has important applications in biology, medicine, and health protection, and is used, for example, in the selection of the most appropriate heavy-particle beam to achieve maximal benefit in a specific therapeutic situation.

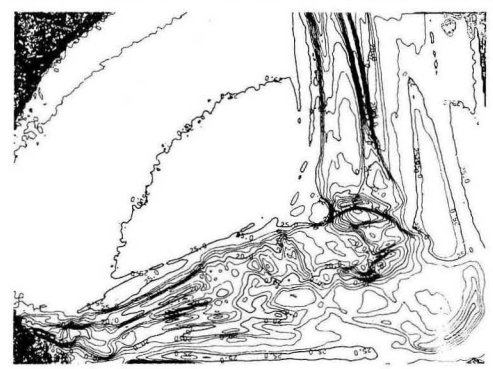
When radiation energy is absorbed in a living cell, chemical changes take place initially that are responsible for the biological effects to follow. Radiation interacts primarily with water, which composes 80% of the cellular medium, and these radiolytic products can exert damaging effects on DNA molecules. By studying these underlying chemical processes in detail, we are coming to know how radiation exerts its effect on organisms. Knowing this, we can estimate the biological damage that occurs in human cells subjected to various types and amounts of ionizing radiation—a judgment essential in radiation safety programs and in the optimal use of ionizing raidation in cancer therapy.

As a heavy-particle beam passes through tissue, nuclear interactions occur along its path, resulting in the production of lighter fragments and a consequent modification of the beam's biological effects. From studies of these nuclear interactions, we are developing calculational methods to predict their effect on dosimetry so that heavy-ion dosimetry can be precisely determined for therapeutic situations.

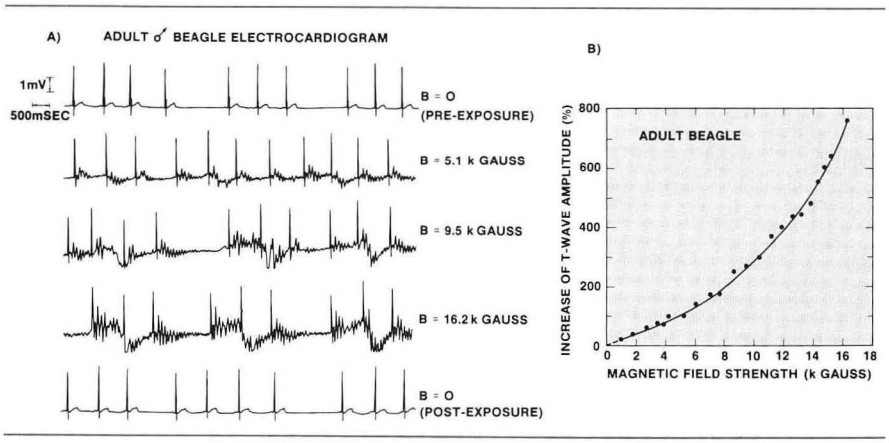
Our tracer studies with radioactive fragments of heavy-ion beams are continuing. These resultant energetic radioactive beams can be used for localizing the Bragg peak and accurately positioning the treatment beam. Studies with phantoms will soon be extended to preliminary animal studies, so that eventually Bragg-peak radiation can be used to treat precise tumor volumes, such as the pituitary gland, with great confidence. Energetic radioactive beams will also provide important biomedical tracers.

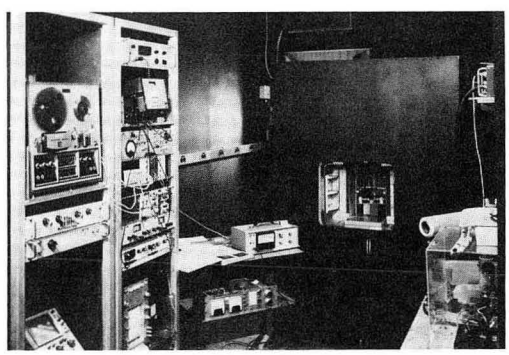
The effects of heavy-ion exposure and high-LET (linear energy transfer) on cells in culture are analyzed. Thus we reveal more of the basic mechanism involved in cell death from ionizing radiation, and so move closer to our ultimate goal of using ionizing radiation for human therapy.

The response of tumors to irradiation is studied in rats with the aid of a solid rhabdomyosarcoma tumor system. Using the high-energy heavy charged particle beam the high-energy heavy charged particle beams, from the Bevalac, we study the tumor response to single and fractionated exposures. We have found that narrow peaks of either carbon or neon ions are more useful than broad peaks; but that when deep tissue penetration is required, carbon may be the more advantageous. This comprehensive modeling of tumor response to high-energy charged particle radiation will help radiotherapists determine the optimal beam



Heavy-ion radiograph reveals detail of skin, skeletal structure, and relative density of soft tissue, surpassing that available with x-ray. Compare to contour density plot.





Experimental setup for studying effects of magnetic fields on living subjects. Electrocardiogram of dog shows effects of increasing strength of magnetic fields and prompt return to normal after cessation.

(or beams) to use for specific clinical applications.

The clinical trial, begun in 1975 to evaluate the use of heavy charged particles in radiotherapy of human cancer, continues. In cooperation with the Northern California Oncology Group (NCOG), we are treating patients with cancer of the pancreas or uterine cervix, and selected cases of esophageal cancer and ocular melanoma. At the Bevalac, patients have been treated with helium, carbon, and neon ions. In March 1979, following extensive investigations, argon ions were first used to treat cancer in a patient.

Clinical physicists work with the radiotherapists to assure precise dose localization to the specified target volume, and design ridge filters for each specific therapeutic procedure to ensure a satisfactory dose distribution.

We have found that the sharpness of the range of high-energy heavy-ion beams make them suitable for use in radiography. By this noninvasive imaging procedure we can resolve minute density differences found in soft tissues with only a low radiation dose to the patient.

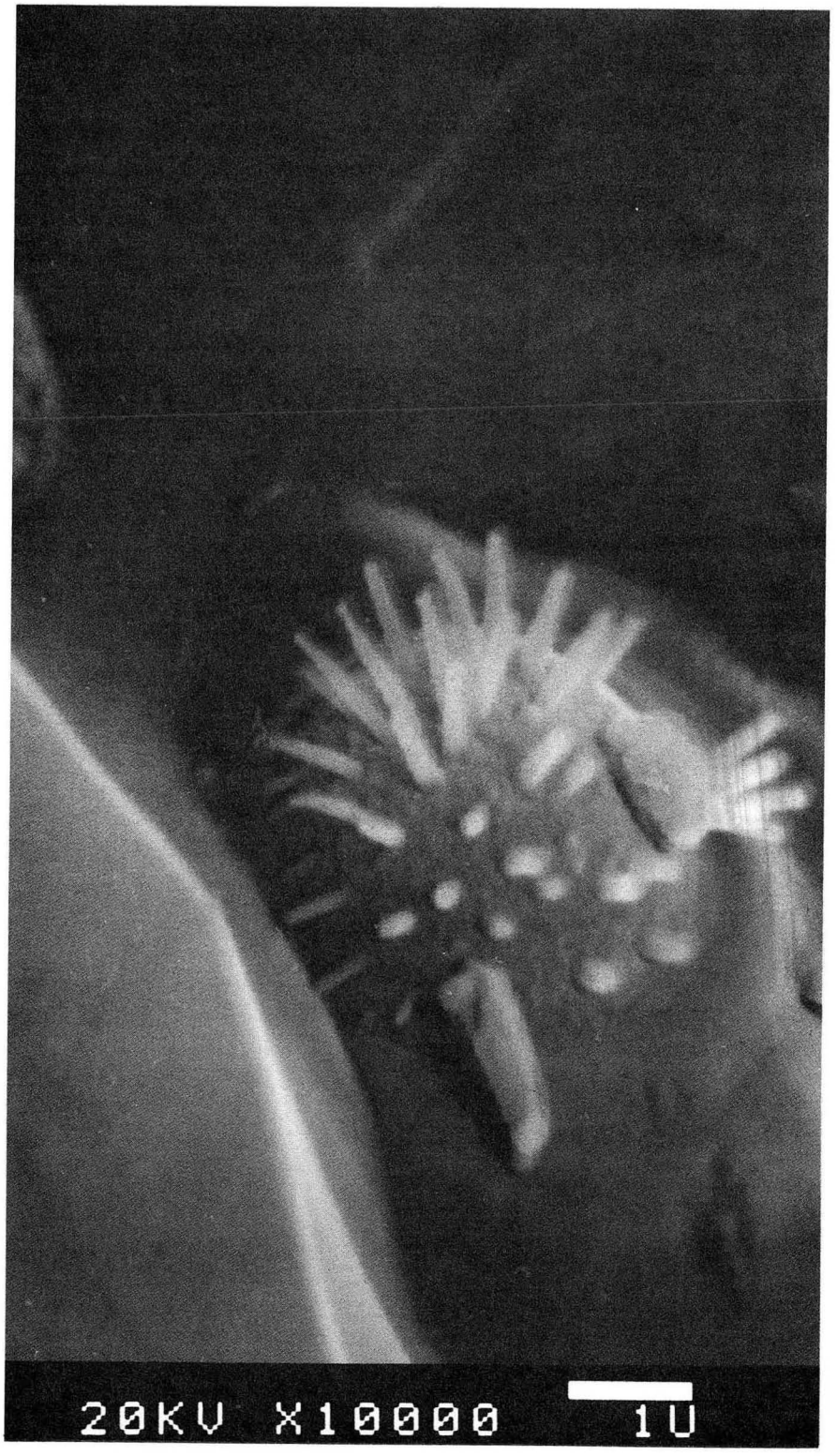
Because of the rapid development of technologies for energy production and storage in which high magnetic fields exist, including steady-state and pulsed-mode fusion reactors, magnetohydrodynamic systems, and magnetic energy storage rings, we need information concerning the biological effects of these fields. So we are undertaking detailed studies on plant and animal tissues and systems to provide quantitative baseline data for establishing human exposure guidelines.

In our studies on central nervous system (CNS) neurotoxicity, we use neural cultures in a bioassay technique to determine the effects of known toxins and potentially harmful environmental agents, as well as radiosensitizing agents used in cancer treatment.

In other studies we are examining the intrinsic differences between normal and altered red blood cells using resistive pulse spectroscopy, a rapid automated method by which we characterize various aspects of cell membrane systems.

STRUCTURAL BIOPHYSICS

Our scientists in this group use various biophysical techniques to explore the basic structure of the biological tissue system with the intent of finding out how energy is produced, and how environmental pollutants exert their effects on living systems. Work is carried out in both areas, with studies of energy transfer at the cellular level, and studies of the biological system under challenges by radiation or air pollutants. Information is gathered from many sources: electron microscopy; resonance studies; chemical biophysics, telling us about electron transfer and states of molecules; biological biophysics, which explores the genetics of cells.



Long needle-like crystals on yeast membrane are observed directly in frozen hydrated state with special scanning electron microscope.

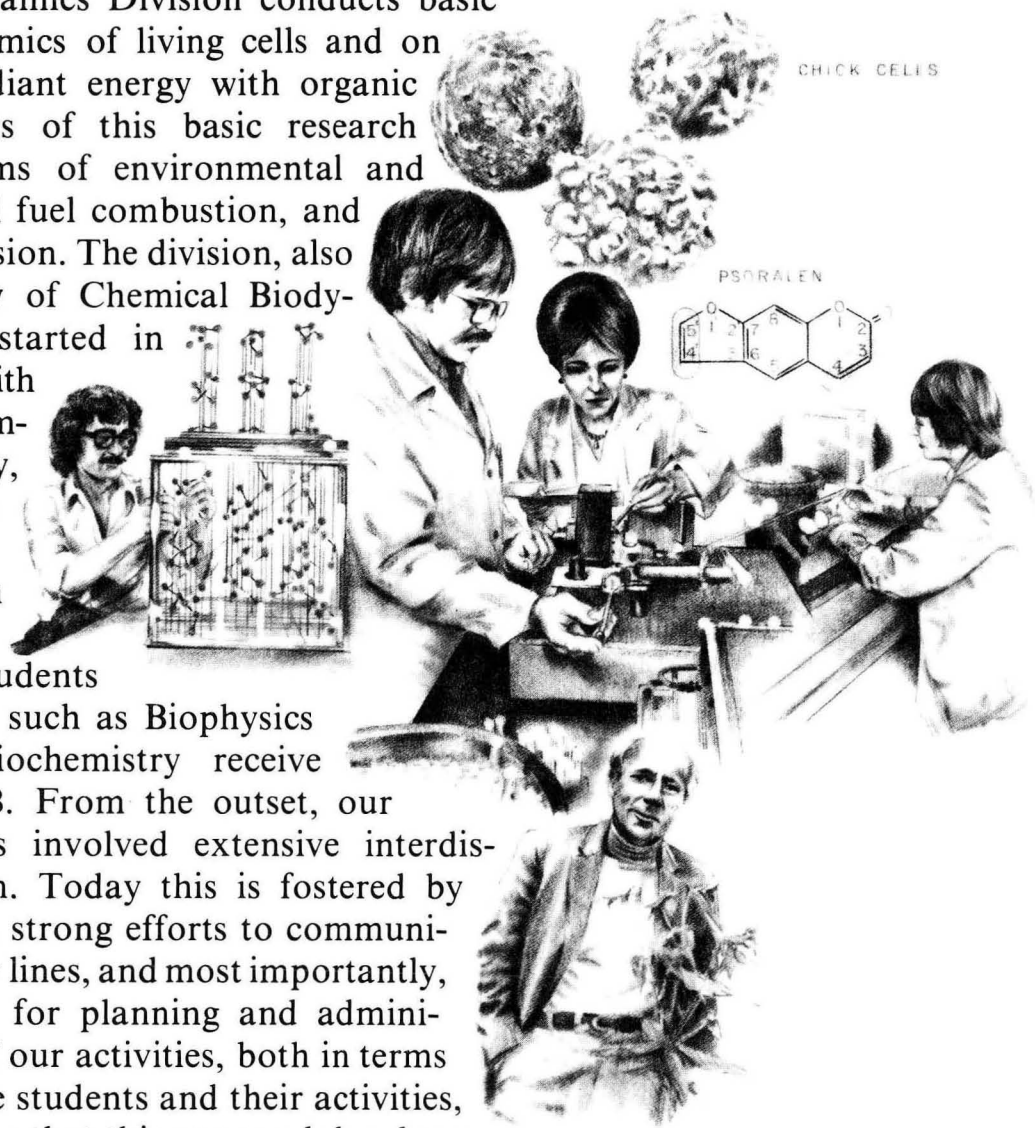
Fracture surfaces of frozen biological material, which formerly we could usually study only by replica techniques, can now be observed directly in the frozen hydrated state by using the special low-temperature scanning electron microscope facility at Donner Laboratory. With this new method, large fracture surfaces can be viewed, and the sample itself is present for x-ray analysis. We can also examine multiple fracture planes of the same specimen.

Fly ash, the particulate effluent from the smoke stacks of coal-burning power plants, contains particles ranging in size and in chemical elemental composition. When inhaled, these chemicals create biological effects at the cellular level. We have applied microanalytical scanning electron microscope techniques to determine the elemental composition and particle morphology of individual coal fly-ash particles. Using this information, we have been able to estimate the exposure of the two major types of lung epithelial cells that are subject to toxic damage.

Recent popular concern about the function of lipoproteins in the body has prompted us to develop refined techniques for their characterization. Their role in body metabolism is complex, and before the extent of their influence can be assigned, norms must be established. Our improved techniques will contribute strongly here.

The synthesis of findings from all of these various structural biophysical studies enables us to develop a knowledge of basic biological structure in its broadest sense.

The Chemical Biodynamics Division conducts basic research on the dynamics of living cells and on the interaction of radiant energy with organic matter. Many aspects of this basic research relate to the problems of environmental and health effects of fossil fuel combustion, and to solar energy conversion. The division, also called the Laboratory of Chemical Biodynamics (LCB), was started in 1946. Its interactions with the departments of chemistry, molecular biology, and physics of the University are enhanced by its location on the Berkeley campus. In addition, students from graduate groups such as Biophysics and Comparative Biochemistry receive their training at LCB. From the outset, our research at LCB has involved extensive interdisciplinary collaboration. Today this is fostered by unfettered discussions, strong efforts to communicate across disciplinary lines, and most importantly, a cooperative process for planning and administration. The record of our activities, both in terms of publications and the students and their activities, is the principle evidence that this approach has been highly successful over the years. In fact, it is this quality and characteristic of LCB that we consider to be its unique contribution to the University community – not only so in the state of California, but in the United States as a whole. There exists no other laboratory to my knowledge, that has this degree of integration of the various scientific disciplines that we have achieved here in the Laboratory of Chemical Biodynamics. Part of the success of this effort is due to our continued resistance, over the years, to all efforts to break down the unitary character of this Laboratory. If we had allowed either external or internal pressures to achieve a fragmentation of our budgetary activity, this could only have led to a similar fragmentation of our scientific activity. I hope that in the future our successors will keep this in mind and do whatever is necessary to maintain that particular quality of LCB that we feel constitutes its principle contribution to the academic community here at Berkeley, and to the scientific community of the United States.



Melvin Calvin

Melvin Calvin
Head, Chemical Biodynamics Division
Associate Director, LBL

*Melvin Calvin
LBL Associate Director
Head, Chemical
Biodynamics Division

Division Administration
James A. Bassham
Richard M. Lemmon
Paul M. Hayes
Marilyn Taylor

Division Staff
Marie S. Alberti
James C. Bartholomew
Edward L. Bennett
Mina J. Bissell
Karen L. Cornwell
Krishnakali Das
Kathleen K. Dougherty
Joanne T. Emerman
Wallace R. Erwin
Deborah A. Farson
Harry A. Frank
Benjamin E. Gordon
James L. Grant
Carroll Hatie
**John E. Hearst*
Stephen R. Holbrook
Ann M. Hughes
**Sung-Hou Kim*
Melvin P. Klein
Peder O. Larsen
Arthur Lawyer
Francis H. Martin
Hiromi Morimoto
Esther K. Nemethy
Ann E. Orme
John W. Otvos
**Roderick B. Park*
Gordon Parry
**Henry Rapoport*
**Kenneth Sauer*
Richard I. Schwarz
**Ignacio Tinoco, Jr.*
Itamar Willner
Gary P. Wiesehahn
Thomas Wydrzynski
Hisao Yokota

*UCB faculty member

The Chemical Biodynamics Division has two major objectives: to investigate fossil fuels from the standpoint of understanding the effects of their use and the mitigation of these effects, and to find ways of economically capturing solar energy, particularly by photosynthesis or synthetic processes modeled after it. Our work in this division covers a wide range of scientific disciplines from physics to psychology, but is focused around these two central themes. In the environmental theme, we are studying chemical carcinogenesis, together with the effects of environmental pollutants on plant and animal cells. In the second theme, we study the capture of solar energy by processes of photosynthesis, which is itself the subject of several studies, and we design physical devices based on our growing knowledge of photosynthesis. We also conduct research on brain mechanisms in learning, peripheral to research on environmental problems, and on chemical evolution, an outgrowth of our interest in the evolution of photosynthesis.

In addition to being a division of LBL, the Laboratory of Chemical Biodynamics is an organized research unit of the Berkeley Campus of the University of California. Approximately 90 persons work in the division's circular building, at the east end of campus. One of the most important characteristics of the division is the interaction of senior scientific staff with the technical support staff over 30 graduate students, 20 post-doctoral fellows, and visiting scholars.

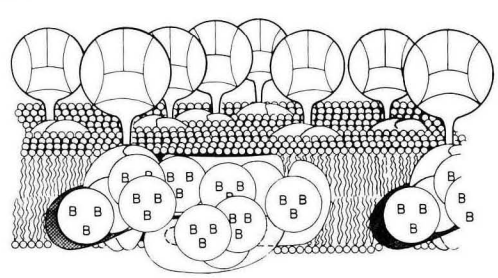
The major support for the Division's research comes from the DOE Divisions of Health and Environmental Research, Basic Solar Technology. In addition, some aspects of basic research are supported by the National Science Foundation.

LIGHT INTO CHEMICAL ENERGY

Photosynthetically active membranes consist of organized two-dimensional arrays of light-absorbing pigments, excitation trapping sites, electron transporting molecules, and coupling factors. Structural and kinetic evidence suggests that the membranes contain complex photosynthetic units that are separately competent. We have formulated a picture of this assembly as a Pebble Mosaic Model. The pebbles are the individual molecules assembled in the functioning units of photosynthetic activity, and the mosaic results from the repetition of these units in two dimensions throughout the membranes. On a somewhat larger scale the membranes close on themselves, and important differences between inside and outside surfaces are evident. The generation of transmembrane electric potentials and ion gradients serves as a source of the chemical potential needed for the formation of energy-rich compounds like adenosine triphosphate (ATP).

As we have dissected out the mosaic pebbles by using selective detergents, we have isolated a variety of chlorophyll proteins: Some are photochemically inactive and represent the components of an antenna of light-absorbing chlorophyll; others are able to initiate photoredox steps and are designated reaction center complexes. Spectroscopic studies, especially absorption and circular dichroism, show that the active complexes consist of small aggregates of chlorophylls that are imbedded in protein and have a well-defined geometric arrangement.

When light is absorbed in the photosynthetic membranes, chlorophyll is excited



Chloroplast membranes visualized by electron microscopy appear to contain particles that are often organized in regular arrays. The Pebble Mosaic Model interprets these particles as an organized collection of chlorophyll-proteins, reaction centers, and electron transport cofactors.

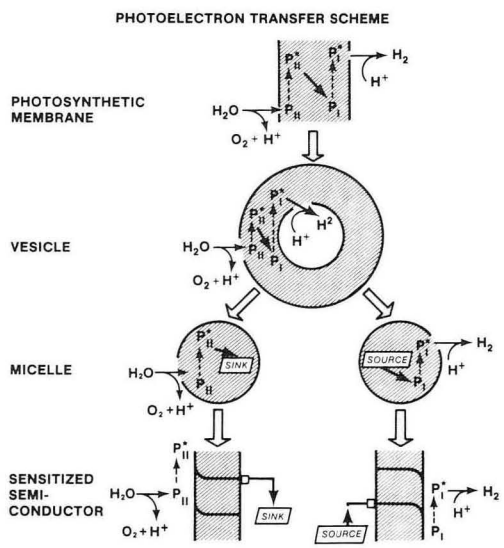
to an electronic state. We have found that this excitation energy is trapped within 10 picoseconds (10^{-11} sec)—any longer and it would be lost as useless radiation or heat.

Using laser flashes to excite photosynthetic samples and by fast detection of transient states, we have mapped a sequence of four membrane-bound acceptors associated with chloroplast reaction centers.

DIRECT CONSERVATION OF SOLAR ENERGY

We are finding model systems fruitful in understanding the nature of energy conversion. Even by studying half of the complete system using only a single interface, like a micelle or an emulsion, we are able to build our knowledge about electron transfer reactions at interfaces. We have shown that fluorescence quenching by electron transfer can be greatly enhanced in the presence of an interface where the reactants are held. In principle, such half systems can eventually be assembled and coupled onto a membrane or vesicle.

The sensitized semiconductor-electrolyte interface is another single interface that has attracted our attention. Here an exciton conversion into charge carriers occurs by electron transfer, which allows charge to move in a semiconductor. We have constructed a model for this using zinc oxide and an adsorbed layer of chlorophyll as a sensitizer.



Photoelectron transfer model by which absorbed sunlight stimulates photosynthesis to produce oxidation and reduction products.

HYDROCARBON-PRODUCING PLANTS

We suggest that certain plants rich in polyisoprenes and other hydrocarbon-like materials might be cultivated and grown as renewable sources of highly reduced photosynthetic products. We have selected two species, *Euphorbia lathyrus* and *Euphorbia tirucalli,* for trial in experimental plantations. The yields of hydrocarbon-like materials that can be extracted from *E. lathyrus* are equivalent to about 10 barrels per acre per year. This material consists of a variety of steroids, isoprenoids, and some glycerides, from which can be extracted a number of useful organic products. We have developed procedures for extracting the latex and have analyzed its chemical composition.

The yields of hydrocarbon-like materials that we have already obtained from the wild stock appear to be economically practicable in terms of either fuel or chemical raw material production. Nevertheless, genetic improvement of the plant materials is not only desirable but easily feasible by clone and seed selection (conventional plant breeding) and by plant cell culture, cell selection, and plant regeneration.

GREEN PLANT METABOLIC PATHWAYS

During the first years of this division's existence, radiocarbon and radiophosphorous were used as labeled atoms to follow the path of carbon dioxide uptake and reduction in photosynthesis (Calvin cycle).

From that early work, we developed precise quantitative methods for following the flow of tracers through metabolic paths

during constant physiological states, such as steady-state photosynthesis or glycolysis of green plants in the dark. These methods also permit us to study transient changes in the levels of labeled metabolic pools. By such studies we have discovered many ways in which metabolism is controlled in these plant cells.

And we have identified a number of sites of regulation on biosynthetic pathways leading from the basic cycle. Sucrose, formed in higher plants as a result of the Calvin Cycle, is commonly translocated to other plant tissues where it may be converted to many products of secondary biosynthesis. We are particularly interested in the resulting hydrocarbons and resins because of their potential as liquid fuels and chemical feedstocks. Bearing on this, we have been able to identify several rate-limiting enzymes that in the presence of NH_4^+ affect the synthesis of sucrose within the green cell.

Recently, we have begun work on plant cells isolated from leaves. These cells are used in metabolic studies with labeled substrates. In addition to observing the regulatory effects of externally applied NH_4^+ we have initiated studies on how plant hormones affect the pattern of carbon flow from photosynthesis into biosynthesis.

As preliminary findings, we have observed a stimulation of CO^2 incorporation, as well as glutamine synthesis, when 2,4-D is applied to leaf-free mesophyll cells.

BIOSYNTHESIS AND FUNCTION OF ALKALOIDS

Alkaloids are found in about 10% of the plant species we have investigated. Although many of these alkaloids have found useful application in medicine, their role in the plant's economy still remains obscure. We hope to clarify the formation and function of alkaloids in the opium poppy and *Nicotiana* species in a study now in progress with radioactive CO_2.

These studies have dispelled the notion that the alkaloids are merely dead-end storage products. For example, *de novo* synthesis of thebaine occurs in less than 30 minutes—nicotine in 15 minutes. The biosynthetic sequence to morphine has now been established back five steps, namely, theticuline → thebaine → neopinone → codeinone→codeine→morphine.

Our current emphasis is on aberrant alkaloid biosynthesis, metabolic fate of the alkaloids in the plant, and alkaloid biosynthesis with cell-free systems.

BIOPHYSICS

Because of the complex interdependence between structure and function in biological systems, we are examining the detailed structures and dynamics of molecules and more highly organized assemblies to gain a deeper understanding of function. For these studies we use a wide variety of spectroscopic techniques and model systems. Extensive study of the spectroscopic properties of these systems opens the way to theoretical interpretation, and we thereby increase our understanding of the complex biological systems.

Using nuclear magnetic resonance (NMR) methods, we have been able to deduce structural and dynamic information on model membrane systems. These studies are being extended to the membranes of intact cells, with the aid of double resonance methods.

Most of the world's usable nitrogen is supplied by a variety of nitrogen-fixing microorganisms that convert atmospheric N_2 to reduced forms. The enzyme system responsible, called nitrogenase, is composed of a pair of proteins; the smaller contains four non-heme iron atoms while the larger member contains two molybdenum (Mo) atoms and about thirty non-heme iron atoms. Although all known enzymes that reduce or oxidize nitrogen contain Mo, its role is unknown because the atoms of this element are generally inaccessible to observation by conventional spectroscopic methods

Similarly, the world's supply of oxygen is converted by green plant photosynthesis from water to O_2. And the manganese (Mn)

atoms, essential for photosynthetic oxygen evolution, have eluded study by conventional spectroscopies.

Our scientists at LCB have recently made significant advances in devising methods to examine these Mo and Mn atoms. The method is based on analyzing the detailed structure of the x-ray absorption spectrum of the respective elements. The measurements are carried out at the Stanford Synchrotron Radiation Laboratory, a national facility at the Stanford Linear Accelerator Center (SLAC). Measurements of this type have provided the first direct observations of the Mo atoms in the nitrogenase enzyme system and of the Mo atoms in intact nitrifying microorganisms. They suggest no change in the coordination about Mo upon binding N_2. Similarly, these experiments have yielded spectra of Mn atoms in intact leaves and in chloroplasts. There is evidence in these spectra for the presence of Mn atoms in groups of two or more.

STRUCTURES AND FUNCTIONS OF NUCLEIC ACIDS

The base sequence (primary structure) of a nucleic acid contains the information that determines its biological functions and characterizes its conformations in different environments. We want to be able to interpret a base sequence in terms of function and to be able to predict the conformations that can occur. So, we are studying how this sequence of a nucleic acid determines its secondary and tertiary structure (double-strand formation and folding). The primary, secondary, and tertiary structures in turn determine and control the biological functions.

In one approach, for example, we have found simple algorithms that allow a computer search of the 5386 bases in a virus so that we can locate the sites for termination and initiation of mRNA synthesis in this viral DNA.

In other computer analyses of base sequences, we are trying to predict likely sites for mutational events, identify active sites for frameshift mutation, locate sequences that can form cruciforms, predict folding in mRNA and transfer RNA and locate sites where processing of precursor RNAs occurs.

We have recently started to apply our knowledge of DNA structure and stability to frame shift mutagenesis. Frameshift mutations are particularly harmful because they cause the misreading of many words of the genetic message.

PHOTOCHEMISTRY AND PHOTOBIOLOGY OF THE PSORALENS

The skin-sensitizing activity of the psoralens has been known for more than three thousand years: In early Indian and Egyptian writing the use of certain tropical fruits and seeds, coupled with sunlight, was described as remedy for skin pigmentation disorders such as vitiligo. The photoactive agents in these tropical plants are derivatives of psoralen and react directly with DNA. It is our intent to clarify the mechanism of these reactions.

We believe psoralens have great potential in the treatment of cancer, in the production of vaccines, and are integral to the basic structural changes in the genetic apparatus associated with replication, transcription, and translation. We have developed an electron microscopic assay for crosslinks in DNA; and using this assay, we have discovered that not all the DNA of a cell is equally accessible to *in vivo* crosslinkage by the psoralens. The pattern of crosslinking suggests that subunits of histones, called nucleosomes, protect 200 base pair lengths of DNA from crosslinkage *in vivo*. Thus we find a pattern in the isolated DNA that relates to the pattern of protein interaction with the DNA *in vivo*.

Psoralen crosslinkage is also being used to freeze the secondary structure of DNA and RNA single strands where we hope to show that these regions of secondary structure are related to biological function.

MOLECULAR BIOLOGY OF NERVE CELL FUNCTION

The bases of long-term memory formation remain as one of the most challenging areas of scientific investigation. We need to know the fundamental properties of the mammalian nervous system in order to evaluate contemporary hypotheses concerning the biochemical and anatomical changes in the nervous system that may account for long-term memory traces. Experiments indicate that protein synthesis and anatomical changes may be major factors here. Our four projects concerned with the mammalian brain and its response to environmental stimuli are studies of (1) receptors for neurotransmitters with selected snake toxins as probes, (2) influence of drugs on brain chemistry with emphasis on clarifying the neurochemical steps involved in the formation of long-term memory, (3) brain plasticity associated with environmental stimulation and training, and (4) recovery of function after brain damage.

CHEMICAL EVOLUTION

From our research on chemical evolution, we increase our understanding of the chemical events that took place on the prebiotic earth, about 3 to 5 billion years ago when the first living cells emerged. Most scientists regard the appearance of life as an inevitable result of the intrinsic physical and chemical properties of matter. In recent laboratory experiments we have simulated presumed prebiotic earth conditions, and begin to comprehend the ways by which biological compounds (such as proteins and nucleic acids) may have been assembled on our planet's surface. This enhanced knowledge of "pre-Darwinian" evolution is also giving us a better understanding of contemporary biological processes.

At the autoanalyzer, Diane Gunson (left) and Jill Hatié measure the concentration of protein in cell suspensions.

GENE EXPRESSION AND TRANSFORMATION

Our LCB scientists are seeking to understand how the cell interacts with its environment. In the regulation of this two way process lie the answers to whether cells are normal or diseased, how they become malignant, and how they age. To understand how cells become abnormal, it is important for us to study the regulation of tissue-specific functions in *normal* cells under defined conditions. Cell culture is the obvious system of choice. However, when eukaryotic cells (cells with internal membranous structures) are removed from the host and placed in culture, they rapidly lose their ability to remain differentiated, and their metabolism becomes increasingly glycolytic as the cells adapt to culture conditions. How this altered metabolism relates

to loss of specific functions is poorly understood and until now has not yet been systematically investigated.

Despite the fact that intermediary metabolism is common to all cells, it is well established that *in vivo* the regulation of such metabolism is unique for each cell type and organ. In culture, tissue-specific differences can also be easily demonstrated initially. However, as time goes on, all cells in culture tend to become similar metabolically.

Our working hypothesis is that the metabolic state of a cell may indeed regulate gene expression. The similarity in metabolic state may explain why most cells in culture are more alike than different, regardless of the tissues of origin. Because of this laboratory's extensive experience with regulating intermediary metabolism in both plants and animals, we have an ideal setting to test the above hypothesis. So, we are establishing metabolic patterns and defining conditions for optimal gene expression in three cell systems: embryonic avian tendon, rat liver, and human (and mouse) mammary epithelial cells. Development of meaningful cell systems and conditions for expression of tissue-specific functions should enable us, as well as other investigators, to study the mechanism of gene regulation in molecular terms with more relevance to the *in vivo* situation.

CARCINOGENESIS AND CELL PHYSIOLOGY

In our current program we are investigating how the physiological state of the cell, in particular its position in the cell cycle, may be regulating carcinogenesis.

For these studies we have been using certain carcinogenic chemicals that can be divided into two broad groups: The direct-acting carcinogens, such as certain alkylating agents, react directly with DNA plus many other molecules in the cell, whereas the second group of compounds, like the polycyclic aromatic hydrocarbons, require prior activation by metabolizing enzymes.

James Bartholomew with Krishnakali Das at the flow cytometer.

The sensitivity of cells to malignant transformation by this second class of carcinogens depends at least in part on the ability of the cells to metabolize the compound.

Once the carcinogen is in the cell in an activated form, its binding to the DNA may depend on the condensation state of the DNA. DNA in the cell is complexed with nuclear proteins to give chromatin. The association of these proteins, in particular the histones, condenses the DNA into chromatin and chromosomes. The condensation state of the DNA changes as its functional state changes. For example, when DNA is serving as a template for RNA synthesis, it is more accessible to enzymes that digest DNA. These alterations in chromatin state appear to be cell-cycle related, in that dyes that intercalate into DNA have altered affinities to the DNA in different parts of the cell cycle. These observations suggest that carcinogen bind-

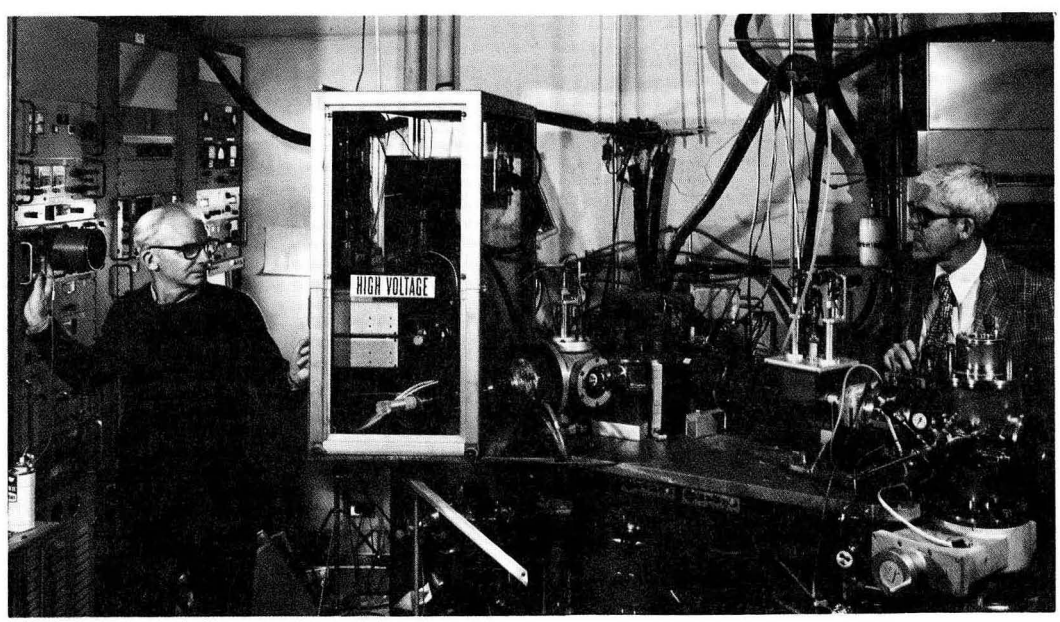
ing may be affected by chromatin state and therefore may be cell-cycle dependent.

We have been examining this pathway to carcinogen-induced alterations in DNA and DNA functions through studies on the diet-induced alterations in carcinogen metabolism, the effect of chromatin structure on carcinogen binding to DNA, the repair of DNA damaged by benzo[a]pyrene in human and mouse cells growing in culture, and the effects of chemical carcinogens on DNA synthesis.

HIGH-ENERGY CARBON AND HYDROGEN CHEMISTRY

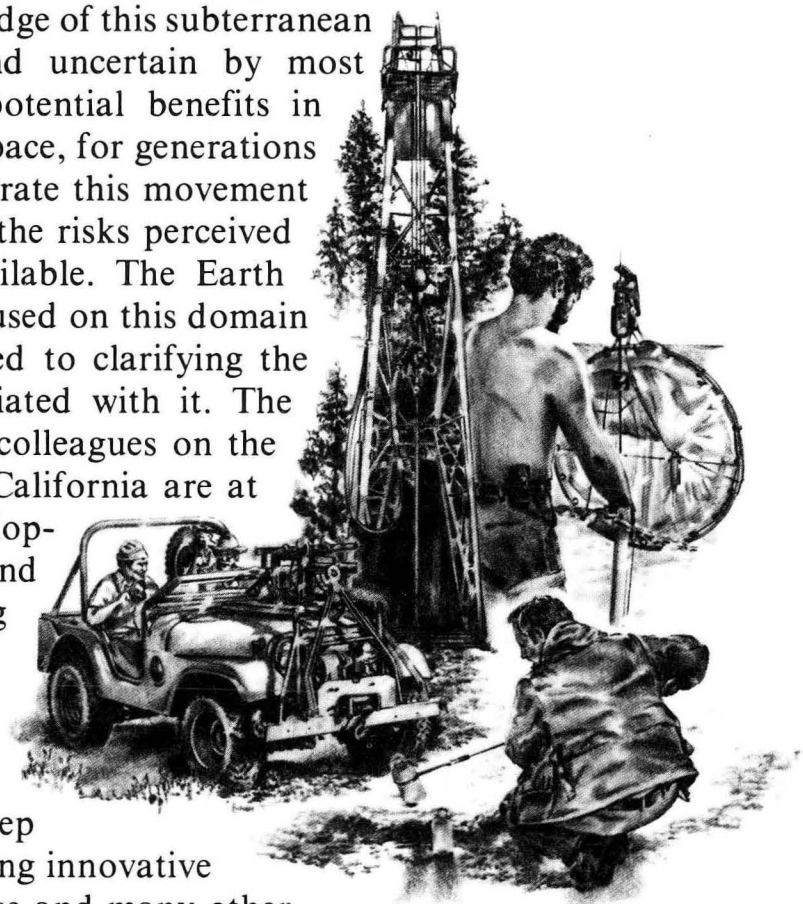
At LCB we have a carbon-ion accelerator for the study of carbon at kinetic energies beyond those attainable by thermal means. This instrument is capable of directing carbon ions and atoms and other accelerated species such as CH^+, CH^+_2, and CH^+_3 onto targets, at any chosen kinetic energy, ranging from several keV down. With this instrument we have studied the chemical and physical details of the interactions of these ions with solid benzene (and other targets) in the energy range of 5 keV to 2 eV. Carbon-14-labeled products from benzene have been identified as toluene, cycloheptatriene, phenylacetylene, biphenyl, diphenylmethane, and phenylcycloheptatriene.

We are studying high-energy hydrogen chemistry as a route to increase the usefulness of tritium as a label in biochemical and biological research. The equipment for such labeling has been built in our laboratory, and we are working to apply the new system, which employs T atoms (tritons) generated from T_2 in a radiofrequency field. Various products have been determined as a result of the microwave-generated tritons reacting with model compounds.



The carbon-ion accelerator, used to study high-energy carbon reactions, such as may occur in interstellar space, is used by Wallace Irwin (left) and Richard M. Lemmon.

Following World War II, geological sciences entered a technological frontier during which research work in all aspects of the earth sciences was actively promoted. The post-war growth in world-wide industry and population necessitated greater knowledge of those geological processes connected with mineral exploitation, energy, groundwater extraction, urban construction, petroleum exploration, and erection of large structures on the continental shelves. Man extended his interest and large-scale activity as deep as 10 kilometers into the crustal zone and in so doing raised significant challenges to our scientific and engineering capabilities. Knowledge of this subterranean region is very fragmented and uncertain by most scientific standards. Yet the potential benefits in natural resources and useable space, for generations to come, will continue to accelerate this movement to greater depths, regardless of the risks perceived or the state of technology available. The Earth Sciences Division at LBL is focused on this domain of "middle earth" and dedicated to clarifying the unknowns and problems associated with it. The research staff at LBL and our colleagues on the campuses of the University of California are at the forefront of scientific developments in defining the physical and chemical properties of deep-lying rocks and rock-fluid systems, in examining the thermodynamics of deep crustal regimes, in improving geophysical methodologies to assess and evaluate deep geological systems, and in creating innovative techniques for well testing. These and many other advances in our research programs have been accomplished through a multidisciplinary team of leading research scientists from LBL and UC with experience specifically related to the geological regimes at significant depths. Projects range from fundamental studies to complex R&D efforts, but all research activities capitalize on the unique laboratory instrumentation-engineering-computational support available at LBL. In this way, the creativity of Earth Sciences' researchers is nurtured with excellent equipment, knowledgeable technical support, and the immediate interplay between research results and engineering applications. The Earth Sciences Division will continue to emphasize the fundamental research complemented by projects in applied technology. Our goal is to improve man's knowledge of the deep crustal regime to assure its efficient and safe utilization. Due to the enormous size and complexity of geological systems, legitimate knowledge can only be obtained through the coordinated efforts of geoscientists supported by the engineering capability to mount comprehensive laboratory, field, and computational programs.



Paul A. Witherspoon

Paul Witherspoon
Head, Earth Sciences Division
Associate Director, LBL

*Paul Witherspoon
LBL Associate Director
Head, Earth Sciences Division

Division Administration
Karl Olson
Milford Bookman
Monique Adam

Division Staff
Jack Angevine
John Apps
Lois Armetta
Vinod Agrawal
Mohammed Ayatollahi
George Badger
Larry Beaulaurier
Larry Benson
Sally Benson
Eugene Binnall
‡Gunnar Bodvarsson
Harry R. Bowman
Daniel J. Bradley
Choate Brown
Wendy Brubaker
*M. Bukowinski
Annette L. Bunge
Thomas Buscheck
Timothy Buscheck
Pat Butler
Hans Carlsson
*Ian S. E. Carmichael
Chalon L. Carnahan
Joseph Chan
Tin Chan
Eric Cheney
Jerry Chin
Clement K. Chou
Jeri Chu
*John Clarke
‡Lewis Cohen
*Neville G. W. Cook
Donald J. Corrigan
R. Curnier
Jim Davey
Robert Davis (Mech. Tech.)
E. F. de Zabala
Thomas Doe
Ben Doty
Sandra Doty
Christine Doughty
Padrai Doyle
Alan Dubin
Andrew DuBois
Laurel Egenberger
Paul Elias
J. Elliot
Eugene Eno
Dan Estrella
J. W. Evans
Steve Flexser
Douglas Frink
Connie J. Frisch
Mauro Foglia
Philip Fong
Ted Fujita
Robert Fulton
Robert Galbraith
‡John Gale
Thomas Gamble
Anoushiravan Ghaffari
Orah Goldman
Norman Goldstein
Colin Goranson
Sudhanshu Goshal
Wolfgang Goubau
Keshav Goyal
Al Graf
Joyce Graves
Thomas Green
Roy F. S. Greenwald
Joe Haney
Leif Hansen (Mech. Eng.)
H. Harty
Ramsey John Haught
Mary Hege

The Earth Sciences Division is devoted principally to research in fundamental geosciences, underground storage of high-level nuclear wastes, geothermal energy development, and ocean thermal energy conversion.

Our basic program here is supported by three principal factors: first, the availability of outstanding staff and faculty, working together in fields requiring strong interdisciplinary exchange; second, the availability of LBL's extensive instrument, computer, and shop facilities for the support of such research; and, third, the intellectual resources of the University of California. No other laboratory or university possesses this advantageous combination for research in the fundamental geosciences.

GEOSCIENCES

Our Geosciences program ranges broadly over research projects covering fundamental and applied problems relating to energy technologies. Although most of our research supports the development of geothermal energy, the isolation of radioactive wastes, and the increased recovery of oil, our results are frequently of sufficiently broad scope to have application in other technologies, such as energy storage and pollution control, or metals resource characterization and metals recovery.

Fundamental Studies

In research on reservoir dynamics, our earth scientists use analytical and numerical methods to study heat and fluid flow through porous and fractured geological formations. Within the scope of this project, we are studying the effects of temperature, multiphase flow (e.g., liquid, water, and steam), multicomponent chemical transport and land subsidence or uplift due to groundwater movement, while from studies on fluid flow in fractures and chemical transport, we are gaining insight into regional groundwater effects on the geological storage of nuclear waste.

The underlying physical and chemical processes associated with the underground storage of hot or chilled water are also being considered. Our findings from such studies will help in the development of energy storage methods, which are important in the growth of solar and total energy systems. In the meantime we are pursuing our investigations on problems associated with reinjection and ground subsidence resulting from geothermal energy exploitation.

Investigators concerned with the properties and behavior of rock-fluid systems at elevated temperatures and pressures are attempting to measure the bulk physical properties of the greatest number of different rock types saturated with fluid. The data obtained will be used for testing models of rock behavior so that by knowing simple characteristics of the rock and its contained fluids, we can predict values of various properties at a given reference state. We will then extend the models to make predictions of those properties at other conditions of pressure, temperature, and fluid saturation. The properties in question include sonic velocities, pore and bulk compressibilities, permeability, electrical resistivity, and such thermal properties as conductivity, diffusivity, and thermal expansion. Most of these properties will be measured simultaneously in a new apparatus currently under design. Our test results will then be correlated and used in model development. Such models will be useful to us in analyzing subsurface reservoirs and interpreting borehole logging measurements and subsurface reservoir parameters. This research has specific application to waste isolation, geothermal reservoir development, and oil recovery.

From theoretical and experimental studies on the thermodynamics of strong mixed electrolytes, we hope to be able to predict the thermodynamic properties of dissolved constituents in groundwaters. Currently our emphasis is on the properties of fluids at elevated pressures, including the dielectric constant of water, for which we have developed a new equation that gives much greater accuracy with fewer empirical parameters than do previous equations. General equations for aqueous sodium chloride and

Staff Continued

Harold Helgeson
‡Kunio Higashi
Deborah Hopkins
*Alex Horne
John H. Howard
*Michael Hood
Richard Hsu
Charles Hyde
Jeffrey Irvine
D. Jamison
Alan Jassby
Julie Jeffrey
Athony Jones
Sirisak Juprasert
‡Valdimar Jonsson
Marlene Kam
Brian Kanehiro
Allen J. Kearns
William R. Keyes
Tjiep Kho
Stanley M. Klainer
S. Kramer
Brent Kohrt
James S. Kuo
Pavel Kurfurst
Raymond T. Lee
Wayne Lee
Donald Lippert
Marcelo Lippman
Nicholas Littlestone
Jane Long
Steve Lundgren
Ernest Majer
Donald Mangold
D. McCarthy
Don McEdwards
*Tom McEvilly
Maury McEvoy
Ellen McKeon
Janet McQuillan
Maynard C. Michel
Connie Miller
Susan Miller
J. K. Mitchell
Sofia Mitina
Ken Mirk
Milt Moebus
(Mech. Tech.)
Alison Monroe
Leuren Moret
*H. Frank Morrison
Catharine Mouton
T. N. Narasimhan
John M. Neil
Phil Nelson
S. A. Nelson
Harry Ng
Helen Nicholas
John Noble
Duane Norgren
Maura O'Brien
Irmgard Orzech
Valeria Parker
Walter Palen
Bjorn Paulsson
Susan Payne
Christopher J. Peiper
Louise Pellerin
Scott Peterson
Ron Philips (Mech. Tech.)
S. L. Phillips
*Thomas Pigford
Howard Pines
*Kenneth S. Pitzer
Bill Pope
Karsten Pruess
*Clayton G. Radke
William Ralph
(Mech. Tech.)
Pascal Rapier
Ruthie Redic
Janet Remer
Carlos Riveros
M. Roach (Elec. Tech.)
G. Rochlin
Pamela Z. Rogers
Don Rondeau
Theresa Ruiz

potassium chloride are also being developed that yield important thermodynamic properties up to 300° C.

Equations for other geochemically important solutes, such as magnesium chloride and sodium sulphate, are being developed, and we are making density measurements for aqueous sodium chloride ranging up to 300° C and 600 bars, with an accuracy to thirty parts per million. For measuring the heat capacity of these brines, we are having to develop special experimental equipment. The results of this research will have important applications, not only in geothermal energy development, but throughout industry in many processes.

The solubility of albite, chlorite, tremolite, and epidote—four common rock-forming minerals—are being measured at temperatures between 100° and 400° C, as a way of determining the reactions between rock-forming minerals and groundwater. We can then express the solubility measurements in terms of the conditions for thermodynamic equilibrium and the kinetics of the dissolution process. From these findings we can then begin to interpret the ways in which both porous and fractured rocks are altered and chemical components are transported in groundwaters. By identifying the conditions under which rocks in geological systems dissolve in aqueous fluids at high temperatures, we hope to gain an understanding of the mechanisms of rock alteration, so that the chemical evolution of groundwaters might be predicted.

Connie Frisch uses the petrographic microscope to analyze rock specimens in studies on basalt, water and nuclear waste interaction.

Physical and chemical interactions occur between solutes and solid phases during solute transport in natural flow systems. In our study of the transport of chemicals in these systems, we are attempting to clarify these interactions and to incorporate them in a conceptual framework that explicitly recognizes the thermodynamic irreversibility of transport phenomena. Of particular interest to us is the sorption and secondary phase precipitation resulting from competitive interactions among the variety of solutes usually present in natural groundwaters. We are investigating the effects of reversibility on the kinds and quantities of precipitated secondary phases with particular reference to possible differences between steady-state conditions and the state predicted under the assumption of chemical equilibrium. Eventually, we will translate our conceptual model of transport interactions into a computational code that can be coupled to existing hydrodynamic codes simulating groundwater transport.

This research has many applications in the area of radionuclide transport, toxic metal transport, pollution problems associated with the mining of fossil fuels, and improved methods of recovering residual oil from subsurface reservoirs.

In a new project we are studying the suitability of Nuclear Quadrupole Reso-

Staff Continued

Jackie Runnels
Sharad Sarvate
M. Schauer
Bruce Schechter
Rolly Schilling
Ron Schroeder
Werner J. Schwarz
Lisa K. Shomura
Robert J. Silva
Lenard Silvester
Terry Simkin
Ray Solbau (Mech. Tech.)
**Wilbur H. Somerton*
Harold Sonenklar
Hwaili Soo
Barbara Srulovitz
Mitchell Stark
Bill Stromdahl
Rebecca Sterbentz
Robert Stolzman
Beverly Strisower
Dho Jeen Su
H. Su
Nina Taylor
Jerome Thomsa
Richard Thorpe
Marc Trujillo
Chin Fu Tsang
Leon Tsao
Badawi W. Tleimat
W. C. B. Villet
Stephen Vonder Haar
David Watkins
Cherie Walker
Oliver Wan
Joseph Wang
Chris Weaver
Virginia Weaver
Oleh Weres
Jerry West
R. Whiteman (Elec. Tech.)
Charles Wilson
Michael Wilt
L. C. Wong
William Wong
Harold Wollenberg
F. Wong
Lester C. Wong
Andrew Yee
Mike Zerzan

*UCB faculty member
‡visiting staff

nance (NQR) spectroscopy for characterizing mineral hosts for element isolation. Four aspects are being addressed simultaneously: 1) an in-depth study of plagioclases (common rock-forming minerals), with the aluminum-27 isotope as a probe nucleus, 2) initial experimentation to determine the extent to which NQR can be used to characterize actinide compounds, 3) an assessment of whether NQR information can be used for determining *in situ* strain, and 4) modification of current instrumentation to improve sensitivity and optimize measurement capability. NQR spectroscopy as a technique has many potential and powerful applications in the earth science field, particularly in connection with problems of waste isolation.

From our study of the thermodynamic and transport properties of naturally occurring silicate melts (i.e., magmas) we expect to be able to predict their properties over a wide range of temperatures, pressures, and elemental compositions. We are also investigating the thermodynamic properties of the mineral phases that crystallize from naturally occurring magmas. Because of the high temperatures involved in this study, specialized equipment is being fabricated to operate under sustained exposure to liquid silicate melts at temperatures as high as 1600°C. The information we obtain here will have an important bearing on the general understanding of the deforming, flow, and transport properties of magma bodies at depth in the earth's crust. This research has long-range applications to the use of geothermal energy, although our primary concern is to identify the natural processes that are incompletely or imperfectly understood.

Enhanced Oil Recovery

We are currently engaged in two projects that relate to enhancing the recovery of oil from subsurface reservoirs.

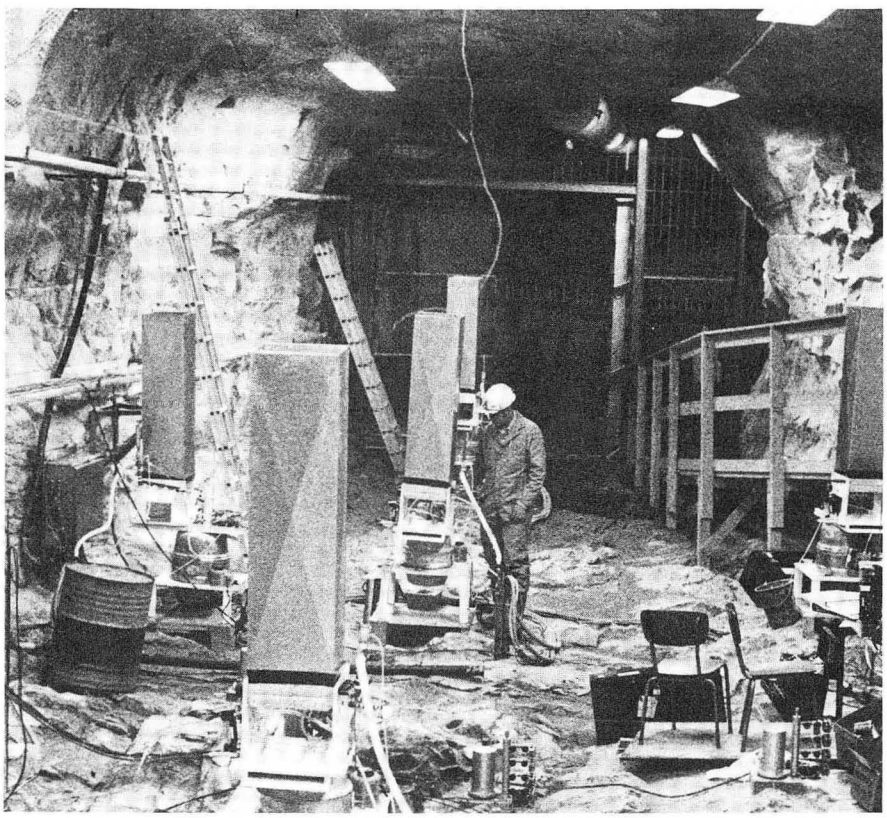
The first concerns the *in situ* formation of surfactants. An unusually high concentration of oil remains in many California reservoirs after completion of primary and secondary recovery, due mainly to the high viscosity of the oil in the producing formations. Recovery of an additional amount of oil necessitates the injection of various types of chemical agents that will enhance the recovery process. For this purpose, we are studying the use of relatively inexpensive caustic solutions, which, upon reacting with crude oil, generate surfactants in the reservoir. In addition to improving the displacement of oil, the surfactants also form emulsions that may act as mobility control agents and lead to improved recovery efficiencies. The research is being coordinated with field tests at two California oil fields.

We are also investigating the role of clays in the enhanced recovery of oil. Most California oil formations contain significant amounts of clays. These clays have a large surface area with resulting high reactivity, and so may dominate the response of the formations to various tertiary recovery processes. Thus, the success or failure of enhanced recovery methods may be directly related to the amount and type of clays in the formations. To make this assessment, we are evaluating the types and amounts of clay minerals present in California oil-producing formations, particularly with respect to their adsorption and reactions with caustic solutions, surfactants, and other chemicals that may be added to enhance oil recovery.

We are also making flooding tests on extracted and oil-bearing core samples to evaluate the magnitude of chemical loss and to determine means of minimizing these effects.

UNDERGROUND NUCLEAR WASTE ISOLATION

The numerous important geological questions that need to be answered before repositories for radioactive wastes can be built beneath the earth's surface are being addressed by our earth scientists. Such repositories must be capable of storing nuclear waste materials safely for thousands of years. Our major study is a cooperative investigation in Sweden, and in addition we have related research projects,



Deep in the Stripa mine, a Swedish technician stands beside one of the heaters installed in granitic rock. This Time Scale Experiment will simulate the thermal output of high level nuclear waste cannisters for hydrological and geomechanical studies.

which deal with the flow of water through fractured rocks, the chemistry of rock-water interactions, and the design of better ways of disposing of low-level radioactive waste.

In July 1977, the United States and Sweden agreed to a cooperative research effort in which an abandoned iron ore mine in Stripa, Sweden would be used for determining the feasibility of isolating radioactive wastes in granitic rock. This first-of-a-kind test in "hard" rock is taking place about 1000 feet below the surface, a depth approximating that mentioned for true repositories. LBL and Swedish scientists and engineers, along with cooperating university and industry scientists, have framed major questions and then designed experiments to seek the answers. The result is a highly productive international program of complementary research projects.

From Stripa experiments, our LBL researchers have determined that temperatures measured in granitic rock, under simulated conditions of storage agree with predictions, indicating that fractures in the rock have little effect on the thermal field. The thermal expansion of the rock was considerably less, however, than that predicted for an unfractured mass. Since granitic fractures also affect the flow of water around potential repositories, these fractures are as important as the rock itself. So, we are participating in an intensive study at various locations to characterize fractures and predict their behavior.

Fractures in the Stripa rock have been mapped by direct underground examination and by making boreholes; thus the permeability of the rock near the underground workings has been determined, as a basis for predicting water flow. At Stripa we have also developed a method for measuring extremely slight water flow into a large working, based on the change in the humidity of the air entering and leaving the working. At LBL, we are investigating theoretical and practical questions about flow of fluids in fractures by using a core testing machine that accommodates cores up to 3 feet in diameter and 6 feet long.

Our designs for experiments in heating and permeability, as well as some of the instrumentation developed here at LBL, are being adapted by other workers both in the U.S. and abroad in their own underground tests.

A possible advantage to storing nuclear waste underground is that any escaping material may react with the rocks and thus not move to the surface. Rock-water-waste actions must therefore be carefully evaluated to examine the various aspects of this migration barrier. Our studies include aqueous actinide chemistry, analytical modeling of radionuclide migration, laboratory measurement of radionuclide sorption on natural materials, theoretical studies of the physical-chemical interactions between solutes and solid phases during transport in natural flow systems, and

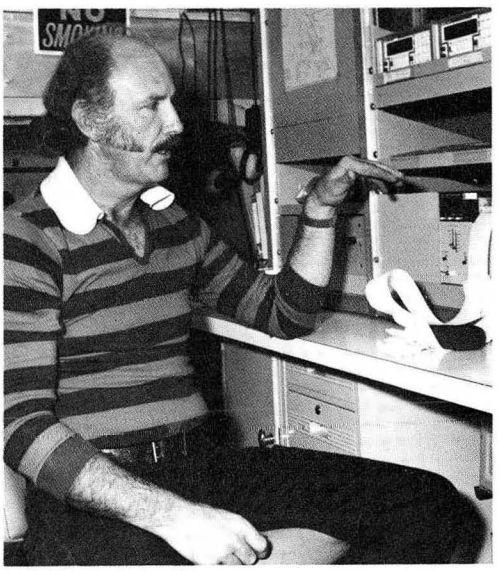
improved tracer techniques for field investigations.

Although the "high-level" waste from nuclear power plants must be handled differently from the much larger volume of short-lived "low-level" waste, the same problems of hydrology, fluid flow, and geochemical reactions apply to the problems of underground waste disposal. Consequently, the efforts of our LBL scientists to find geological alternatives to the current methods for disposing of low-level wastes have application across the continuum of the nation's radioactive waste disposal problems.

GEOTHERMAL ENERGY

For some years, LBL and UC researchers have pursued the safe and economic development of geothermal resources. Most of these research activities have involved hydrothermal (water-dominated) systems that are used in both electrical and process-heat production. Such valuable national applications are being restrained, however, because of the lack of general technologies by which we, and others, can efficiently and reliably predict the long-term performances of both the geothermal reservoir energy resource and the energy conversion/utilization systems. To rectify these deficiencies, our Reservoir Assessment and Engineering Group is conducting studies in the four general program areas of exploration technology, reservoir engineering technology, reservoir case studies, and environmental research.

Our research in exploration technology is directed toward developing better geophysical and geochemical techniques and methodologies for exploration and reservoir assessment, with a heavy emphasis on seismic and electric/electromagnetic geophysical studies. We are conducting these studies at LBL and on the Berkeley campus, and the technology developed is tested at various geothermal field sites, such as the High Cascade Mountains of Oregon, Nevada, and Cerro Prieto, Mexico.



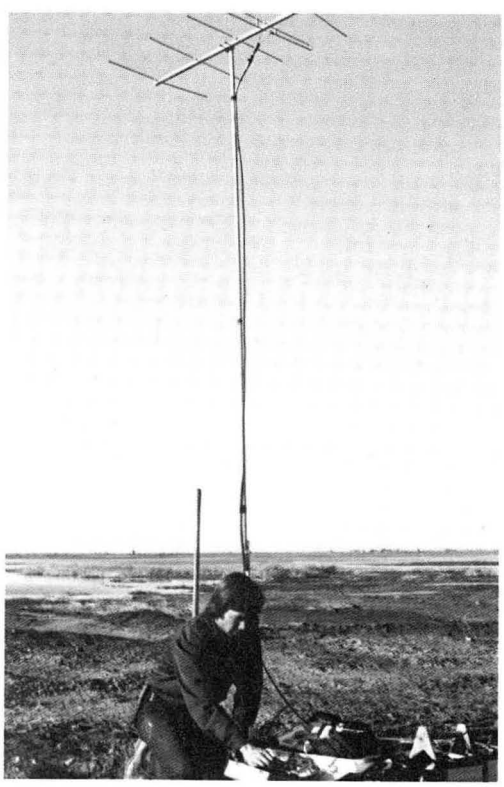
Downhole pressure data is monitored by Bob Davis during a well test at Cerro Prieto, Mexico. Data from two quartz pressure gages is recorded at LBL's mobile geothermal reservoir engineering laboratory.

In reservoir engineering technology, our scientists and engineers are developing more effective methods to determine the size, capacity, energy content, and productivity of geothermal reservoirs. This research involves testing wells and developing supportive computer modeling to help interpret the pressure-temperature, and flow-rate data. Recently we have developed computer codes to interpret pressure-temperature data under two-phase flow conditions in wells, and a new code, SHAFT78, to simulate production from any specified reservoir, even one consisting of both brine and gas phases. SHAFT78 should enable engineers to make more accurate and reliable estimates of reserves than were heretofore possible. On the strength of the group's experience in reservoir engineering, DOE selected LBL to manage the national program in geothermal reservoir engineering (GREMP). As a result, researchers from industrial and university groups, under contract to DOE through LBL, are mutually engaged in an effort to accelerate the development of geothermal power.

Geothermal reservoir case studies are being prepared on specific reservoir prob-

lems. We have completed such a study for the U.S. Bureau of Reclamation on the East Mesa reservoir, and have a continuing case study investigation of the Cerro Prieto Field with the Mexican government utility, Comision Federal de Electricidad. In addition, we are providing technical assistance on the geothermal project in Valles Caldera, New Mexico, where a 50 MW demonstration plant will be built under an agreement between Union Oil, Power of New Mexico, and DOE.

Our environmental research efforts deal with subsidence and seismicity as related to geothermal development. We are currently managing a national program in subsidence research, bringing together researchers from industry, government, and academia to study subsidence prediction, monitoring, and mitigation. In addition, we are conducting separate research in subsidence prediction based on our understanding of how and why rocks compact and deform at depth when geothermal fluids are extracted. We have begun a complementary study of induced seismicity by installing seismic monitors in shallow wells at East Mesa and Cerro Prieto.



The FM telemetry at a seismic station is adjusted by Ernie Majer. The Cerro Prieto geothermal field was monitored continuously in a month-long study of earthquake activity and wave propagation characteristics.

Problems associated with converting the energy contained in geothermal fluids to useful forms are addressed by investigators in our Utilization Technology Group, which includes staff from the LBL Mechanical Engineering Department. Although the generation of electricity is effectively and relatively easily achieved with high-temperature fluids from water-dominated geothermal resources, there are other less common techniques, which may allow lower temperature fluids, the largest fraction of the world's geothermal resource, to be converted efficiently. These other options are the subject of study in this group.

Most current projects focus on the potential "binary" processes to generate electricity. A binary process is a two-fluid system in which the working fluid in a closed system absorbs heat from the geothermal fluid, is vaporized, drives a turbine connected to a generator, is condensed, and then recycled.

In collaborative projects with the University of California, we are studying the basic heat-transfer properties of the candidate binary working fluids, while with the Electric Power Research Institute we are studying the actual performance of these fluids in full-size conventional heat exchangers at the Magma Power Co. geothermal facility. From these projects we expect to gain basic information for use in a full-size generating plant.

Such a complete pilot generating plant is being constructed by the Barber-Nichols Engineering Co., under LBL management. This plant will generate 500 kW of useful electric energy by "direct contact" heat exchange, while also supplying enough energy to operate its own subsystems. In this process the working fluid, isobutane, is

mixed with the geothermal fluid directly in a common container. This concept has been proven technically feasible in a prototype that produced 10 kW of electricity.

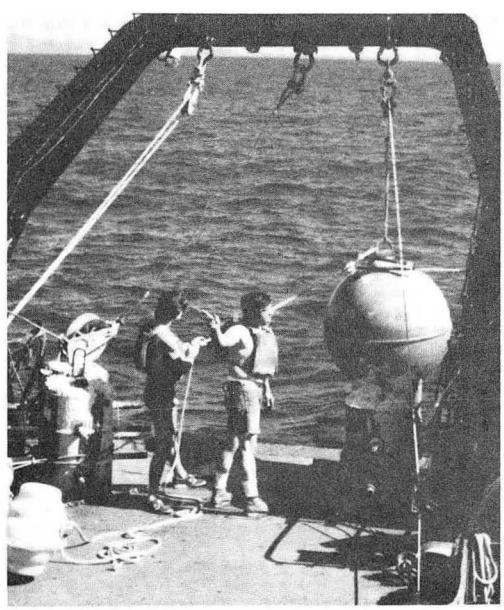
The cost of the electric energy generated by a commercial-size geothermal plant of the binary type will be evaluated as the subsystem and pilot-size development work progresses. A large-scale computer code developed by us at LBL is used to simulate possible plant variations and to study their influence on energy cost, plant cost, operating cost, thermodynamic efficiency, and other parameters of interest. These computer simulations are also used to predict and compare the cost or efficiency parameters for different processes.

Members of our Geothermal Energy Utilization Technology Development Group also participate in international cooperative efforts, the latest being the Second Latin American Seminar on Geothermal Exploration, held in El Salvador.

OCEAN THERMAL ENERGY CONVERSION

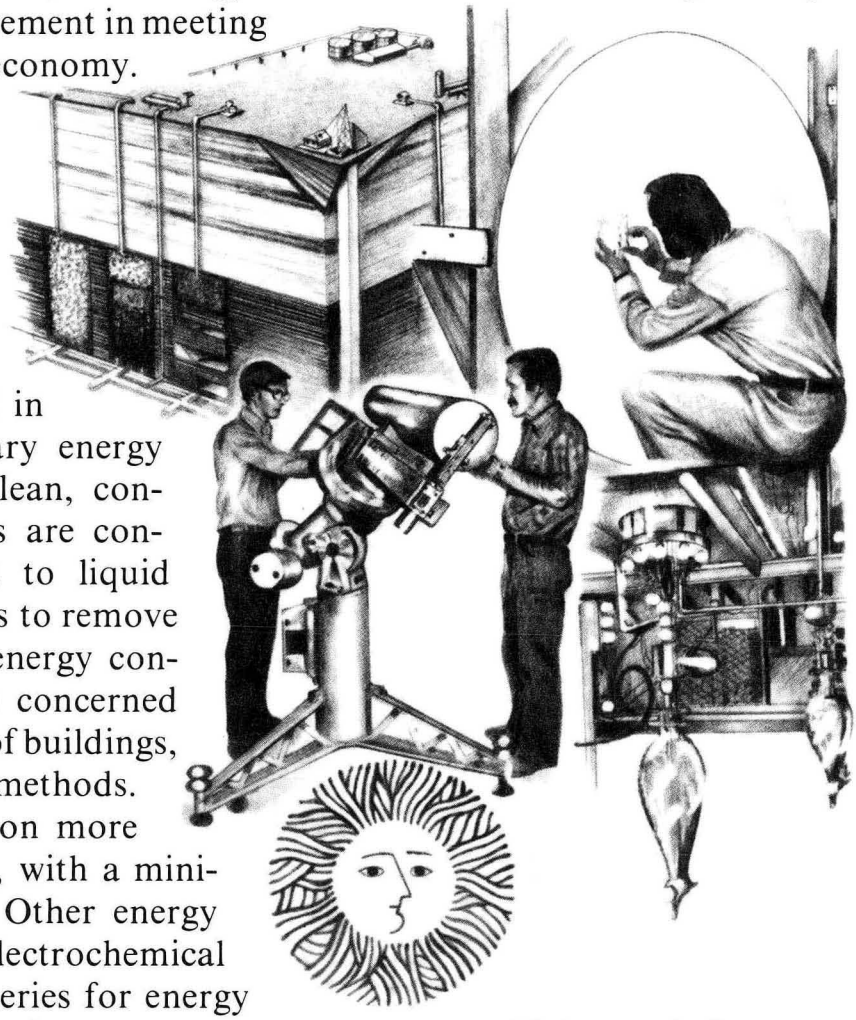
Ocean Thermal Conversion (OTEC) is a technology in which the temperature difference between warm surface and cold deep waters is used to produce electric power with a gas or steam turbine. As we propose, the OTEC system may be used to generate electricity in any of three modes: moored to the ocean bottom by a cable that also transmits the generated electricity to the power grid system; floating on a platform for manufacturing energy-intensive products from raw materials brought to the site; or land-based at the seaside. OTEC plants are proposed for areas off Hawaii and Puerto Rico, with possible future plants near Guam.

Our role is to collect and evaluate data on the proposed OTEC sites for the design and environmental impact of the OTEC plants. The data analyzed include the identification and distribution of algal and zooplankton populations; chemical variations of the ocean waters including salinity, pH, the nutrients available for plant growth, and chemicals that are potentially harmful or toxic if their concentrations increase; physical properties of the ocean waters and the ocean bottom geology.



The buoyancy spheres are being positioned to support water current meter arrays in OTEC mooring studies.

The Energy and Environment (E&E) Division, formed in 1973, has grown virgorously in responding to the need for a broad spectrum of R&D efforts to help meet the nation's energy requirements with an acceptable environmental impact. E&E researchers are involved in work on critical problems in all three major segments of the energy economy; energy supply, energy conversion, and energy demand. Each of these segments presents opportunities for major improvement in meeting the energy needs of a strong economy. The E&E Division comprises five major program areas: chemical processes, energy analysis, solar, energy efficient buildings, and environmental. In the energy supply area, the Chemical Processes Program is engaged in research on processing primary energy source materials to provide clean, convenient liquid fuels. Examples are conversion of coal and biomass to liquid fuels, and the treatment of fuels to remove pollutants such as sulfur. In energy conversion, the Solar Program is concerned with solar heating and cooling of buildings, by both active and passive methods. Combustion research focuses on more efficient combustion processes, with a minimum of pollutant formation. Other energy conversion studies include electrochemical systems such as advanced batteries for energy storage. The energy demand area is represented by the Energy Efficient Buildings Program, which is engaged in a variety of studies that have as their objective the conservation of energy used in the heating, lighting, and ventilation of buildings. Spanning all of the above areas are the Environmental Program and the Energy Analysis Program. The Environmental Program investigates a variety of aspects of atmospheric aerosol chemistry, fresh water lakes, pollution from oil shale and coal conversion processes, indoor air pollution, and the research and development of extremely sensitive instruments and techniques for the determination of extremely low levels of various pollutants. The Energy Analysis Program evaluates the impact of various energy technologies on the energy system, the environment, and the economy, providing important guidance in planning at the state, regional, and national levels. It is clear that the division's staff – about 50 University of California faculty members, 80 graduate students, and 120 LBL scientists and engineers – must span a wide range of disciplines, and must work in an interdisciplinary manner to carry out its research most effectively. Its broad interests and capabilities, its enthusiasm, and the close interaction between scientist and engineer are the division's great strength.



Elton Cairns
Head, Energy and Environment Division
Associate Director, LBL

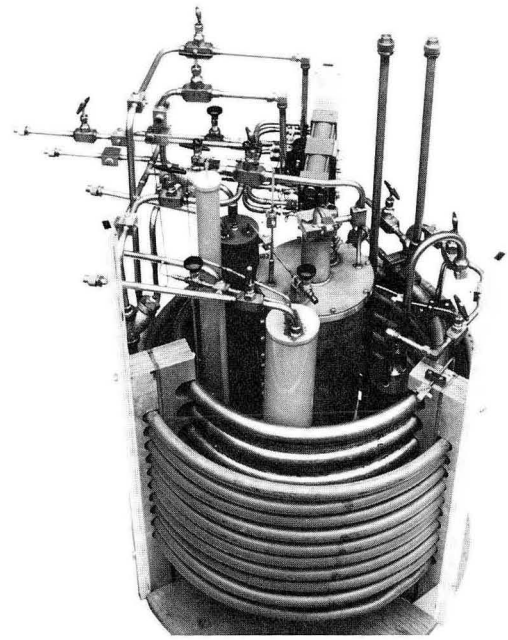
Elton J. Cairns
LBL Associate Director
Head, Energy and Environment Division

Division Administration
Roland J. Otto
Barbara B. West

Division Staff
Yogesh C. Agrawal
Hashem Akbari
Nabil M. Amer
Roy N. Anaclerio, Jr.
Brandt Andersson
Reginald D. Anson
Douglas W. Anthon
Kenneth C. Arnold
Frank Asaro
Cynthia J. Ashley
Janette M. Bacon
Kimball A. Baker
Myra J. Baker
Andrew M. Baum
Fred S. Bauman
Mark T. Bee
Linda A. Beiswinger
Peter Benenson
William H. Benner
Felicity A. Bensch
Paul H. Berdahl
James V. Berk
Samuel M. Berman
Jacquelin M. Bernier
**Harvey W. Blanch*
Eileen C. Bleeker
Ake Blomsterberg
Carl J. Blumstein
Mary L. Boegel
Pamela Bostelmann
Dorothy L. Bottini
Denise E. Boudreau
Barbara J. Boyce
Harold J. Boyer
Kathleen M. Boyer
Barbara Branstetter
**David L. Brink*
Patricia A. Bronnenberg
Daryl R. Brown
Nancy J. Brown
Stephen R. Brown
Carolyn E. Bryant
Thomas S. Buckmeyer
Robert J. Budnitz
Walter F. Buhl
Garth E. Burns
‡Chanoch Carmeli
Jade I. Carroll
Alfred M. Casarez
Charles W. Case
Minna W. Chan
Peter T. Chan
Shih-Ger Chang
Chuan-Run Chen
Robert K. Cheng
**Mark N. Christensen*
Hannah R. Clark
Robert D. Clear
Ray G. Clem
Rick Codina
Paul E. Condon
Lynn C. Conway
Jan A. Corfee
Enrique Cuellar-Ferreira
Margaret B. Curtis
**John W. Daily*
Madjid Daneshyar
Richard C. Diamond
Dennis L. Dibartolomeo
Raymond L. Dod
Elaine A. Draper
David A. Drury
Richard F. Dutcher
**Harry A. Dwyer*
Timothy S. Eitzen
Sabri Ergun
Jose H. Estrada
David B. Evans

The Energy and Environment Division carries out a broad program of applied research and development in energy supply and conservation technologies to determine ways of increasing the efficiency and reliability of energy production systems, while reducing their environmental impact. The division's existing capabilities in the fields of energy and environmental policy analysis and energy conservation provide a strong base of support for this program.

Approximately 100 scientists and engineers, 30 University of California faculty members, and 80 graduate students staff the division. Its research activities are carried out in five programs: solar energy, energy analysis, chemical analysis, chemical process R&D, environmental research, and energy-efficient buildings.



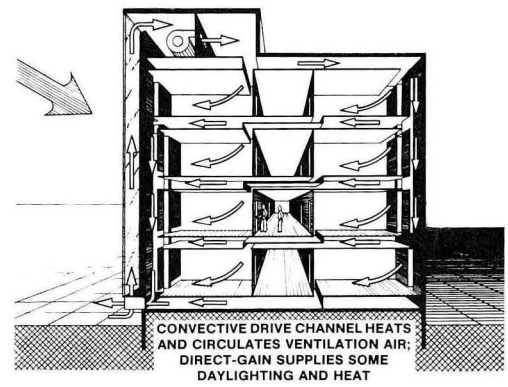
A prototype solar-driven absorption air conditioner being developed at LBL.

SOLAR ENERGY

Solar energy is a renewable resource that holds promise for providing new energy sources that are environmentally acceptable. Our scientists in this group investigate advanced approaches to solar energy conversion; they also develop analysis techniques and obtain information necessary for the future use of solar energy.

Both "active" and "passive" solar technologies for heating and cooling buildings are being investigated. In active systems, solar equipment is used in buildings of conventional design. In this area, our staff is working on new solar-powered air conditioners using innovative regenerative absorption cycles that would be more efficient than conventional cycles. An experimental heating and cooling system is being used to evaluate the use of advanced control strategies as a means of reducing the operating costs of solar heating and cooling systems.

In passive solar heating and cooling systems, the building itself is designed to take maximum advantage of natural energy flows. Methods are being developed by which we analyze the thermal performance of various passive approaches, such as the Trombe wall. As well as being used at LBL to investigate innovative passive design concepts, the method will be made available to engineers and architects in the building community. In addition, we are making an experimental investigation of the cooling of a building by radiation of heat from special roof material.



An example of a multi-story, multi-zone passive solar heating system.

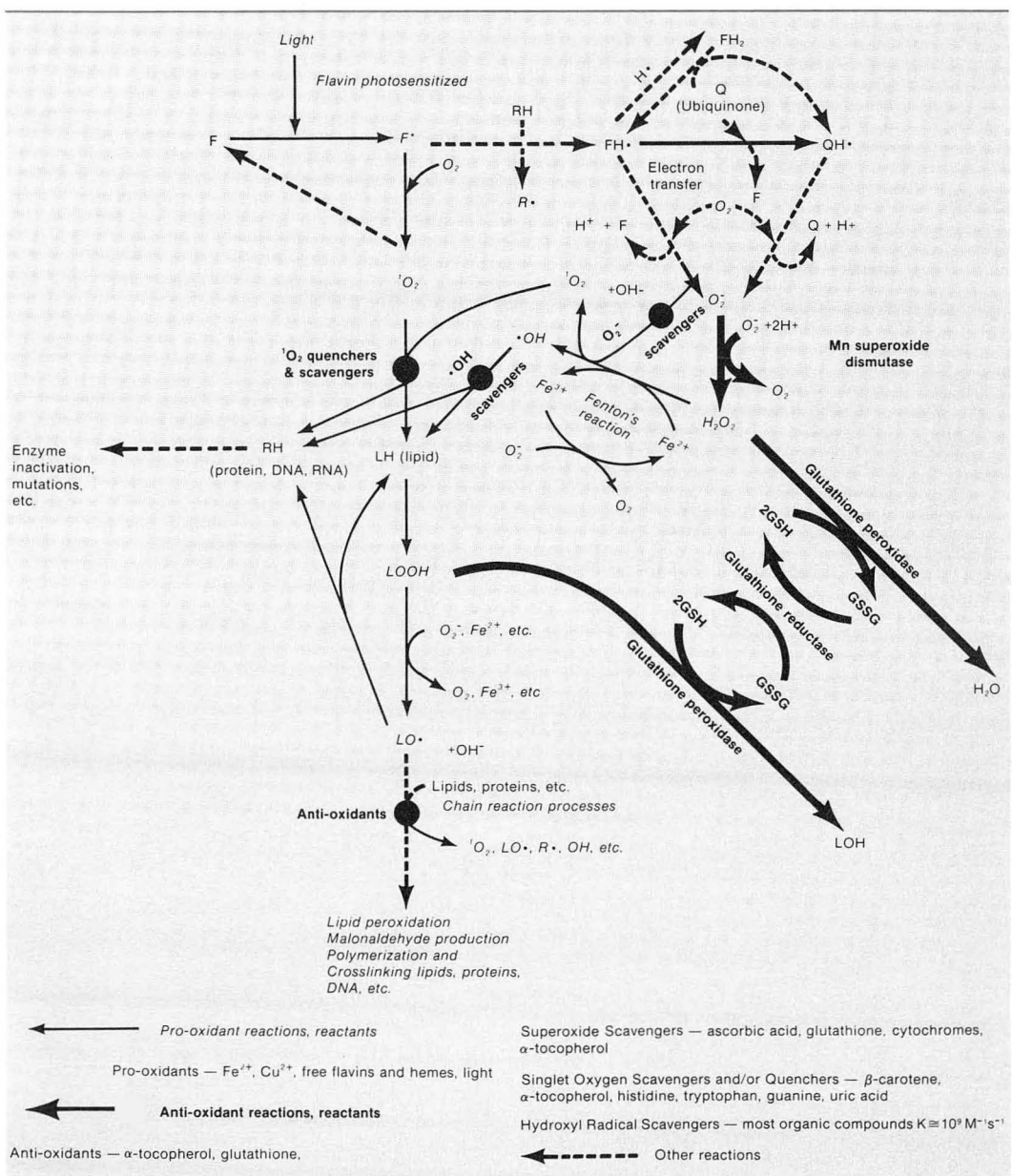
Members of our group have helped DOE and the Solar Energy Research Institute develop the National Passive Solar Program plan. We also provide technical assistance to DOE on solar heating and cooling, includ-

Staff Continued

*Arnold M. Falick
Maryleah Z. Fanning
Carlos Figueroa
Richard H. Fish
Sharon G. Forsberg
*Alan S. Foss
Phyllis Fox
Raymond P. Freitas
R. C. Frensley
Mary S. Friedline
Peter D. Fuller
Roberta B. Garrett
Steven D. Gates
Robert W. Gerlach
Robert D. Giauque
Donald C. Girvin
Lilly Y. Goda
David B. Goldstein
Thelma C. Gonick
Daniel S. Greenhouse
*Ralph Greif
*Edward A. Grens
Donald F. Grether
David T. Grimsrud
Lara A. Gundel
Anthony D. Hansen
*Donald N. Hanson
Mary L. Hart
John Harte
Kendall F. Haven
Kathryn R. Hendricks
Mark A. Henriquez
Tonya L. Hill
Phyllis A. Hillis
Sally K. Hinds
James J. Hirsch
Niloufer I. Hirschmann
Alfred T. Hodgson
Craig D. Hollowell
Kenneth Hom
Peter Hornick
Mark W. Horovitz
Kathleen Hudson
*Joseph A. Humphrey
Arlon J. Hunt
Mary S. Hunt
*Franklin C. Hurlbut
John G. Ingersoll
Daniel E. Jackson
Linda A. Jacobs-Curletto
Stephen P. Jaeger
Richard L. Johnson
Edward P. Kahn
Ronald C. Kammerud
Stephen G. Kanzler
Cihan Karatas
Mahmut N. Karayel
Ira B. Katz
Jeffrey D. Kessel
Dharma K. Khalsa
*C. Judson King III
Mathilde J. Kland
Joseph H. Klems
Stanley E. Kohn
James F. Koonce, Jr.
Elizabeth Krieg
David L. Krinkel
*Alan D. Laird
Ralph G. Langenborg
*Brian E. Launder
J. Dennis Lawrence
Michael D. Lee
Fred K. Lenherr
Susan R. Lepman
Mark D. Levine
Alfred L. Levinson
Donald J. Levy
Chin-I Lin
Joyce E. Littlejohn
Richard A. Lockhart
Billy L. Long
Andrea J. Longpre
Stephen P. Lubic
Frank B. Lucarelli
Toya L. Luna
*Scott Lynn
John J. Maguire
*Samuel S. Markowitz

ing reviewing proposals and monitoring work at other institutions. Likewise, technical support is provided to DOE in developing small-scale energy technologies through the DOE Appropriate Energy Technology Program. This work involves reviewing proposed projects for their technical merit, monitoring the progress of the funded projects, and summarizing the results.

The circumsolar telescope and the nitinol engine have been developed by members of our group. The circumsolar telescope measures the amount of sunlight available to solar energy systems that use lenses or mirrors to concentrate the light. The nitinol engine exploits the ability of nitinol (a nickel-titanium alloy) when warmed, to snap back forcefully to a preimplanted shape. The machine is being developed to



The process of photochemical conversion.

Staff Continued

Ruth B. Marsh
Marlo R. Martin
Gary E. Mason
Ashwani K. Mathur
Elizabeth L. Mawson
Bruce E. Mayer
Deborah McClain
Scott T. McCreary
Frank R. McLarnon
James E. McMahon
Rolf J. Mehlhorn
Douglas R. Merritt
Helen V. Michel
Robert R. Miksch
Harry Miller
Sandra S. Mocco
Hani A. Mohamed
Don L. Murphy
Phiroze J. Nagarvala
Anthony V. Nero, Jr.
Amos S. Newton
John C. Nides
Tihomir Novakov
Christoph Nyberg
**Antoni K. Oppenheim*
Donna L. Osgood
Maria T. Ossa
**William J. Oswald*
Huseyin Ozbek
**Lester Packer*
Monica L. Padilla
**Patrick J. Pagni*
Rebecca C. Palmer
Peter Persoff
**Eugene E. Petersen*
Susan S. Petersen
Janet L. Phillips
Sidney L. Phillips
J. Wayne Place
Richard I. Pollack
Gordon R. Porter
†Thomas M. Powell
Alexandre T. Quintanilha
John T. Rees
Robert W. Richardson
Oliver H. Richter
**Robert W. Risebrough*
Ronald L. Ritschard
Alan W. Robb
Franklin A. Robben
Nancy C. Rodgers
Sandra P. Rose
Gary D. Roseme
Hal J. Rosen
Steven L. Rosenberg
Charles S. Rosenblatt
**Arthur H. Rosenfeld*
Michael D. Rubin
Francis M. Rubinstein
Henry Ruderman
William J. Ryan
Ellen I. Saegebarth
Richard H. Sakaji
Laurie H. Sampietro
Jayant A. Sathaye
**Robert F. Sawyer*
Larry L. Schaleger
Robert W. Schefer
Steven R. Schiller
Leon J. Schipper
Emily L. Schmidt
Richard C. Schmidt
Nancy E. Schorn
Linda J. Schuck
Volker M. Schuler-Will
Aldo F. Sciamanna
Stephen E. Selkowitz
**Robert E. Selleck*
**Steve Selvin*
Manu Seth
Richard G. Sextro
Brenda C. Sharp
Mary J. Shenkin
John E. Shively
Ellen M. Shurtleff
Harrison W. Sigworth, Jr.
Melvin K. Simmons
William E. Siri

obtain mechanical energy from low-temperature heat, such as would be available from solar-heated water, from a fossil fuel plant's waste heat, or from ocean thermal gradients.

Photochemical conversion is being investigated in terms of the light energy conversion of bacteriorphodopsin, which is a stable protein pigment derived from the purple membranes of *Halobacteria* (a genus of bacteria that lives in highly saline water). This research is directed toward developing an energy cell based on the ability of the bacteria to generate an electrical current from incident sunlight.

ENERGY ANALYSIS

Advances in energy technology do not ensure a quick and untroubled transition from our heavy dependence on oil to alternative and it is to be hoped, indigenous sources of energy. The wide-spread adoption of unconventional technologies, new resources, and even conservation affects the whole fabric of society, which in turn constrains their implementation.

The Energy Analysis Program encompasses interrelated studies, through which we assess societal and environmental impacts and their constraints on energy policy, developing technologies, and regional energy supply systems. The object of these studies is to provide DOE and other decision makers with sound, analytical bases for policy formation, legislative initiatives, and DOE research, design, and development programs.

In one major subprogram we are assessing the national economic, environmental, institutional, and health impacts of energy policy for the states of California, Hawaii, Nevada, and Arizona, i.e., Federal Region 9. Similar integrated assessments of energy technologies are being undertaken to determine their economic and environmental characteristics and to provide insights on constraints for their deployment. To date, in these studies, we have explored the implications of accelerated use of coal technologies, geothermal development in the Geysers area of California, several uses of solar energy, and technological conservation measures.

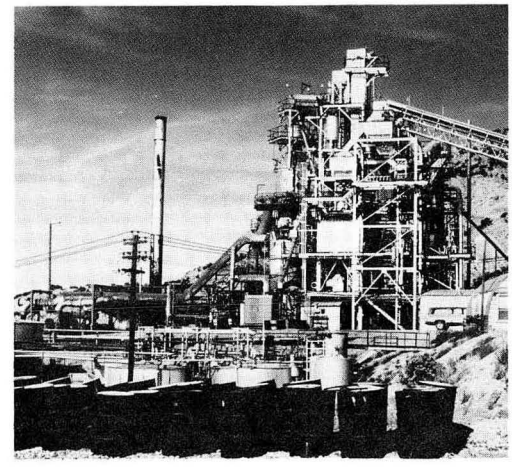
We are also making major data acquisitions and analyses: the validation of DOE energy information reporting systems; collection and statistical analysis of energy, environmental, economic, and technology data.

Other current studies include

- Energy self-sufficiency alternatives for Hawaii,
- Residential building and appliance efficiency,
- Energy and economic model development,
- National economic analysis of DOE energy plans,
- Integrated environmental analyses,
- Energy conservation measures and plans, and
- Domestic and foreign issues in geothermal development.

CHEMICAL PROCESSES

In the Chemical Processes Program we are conducting research on techniques for biomass conversion to fuel, coal conversion, oil-shale retorting, coal cleaning,



The Paraho retort is one of several surface oil shale retorts that is nearing commercialization. This facility near Anvil Points, Colorado, recently produced 100,000 barrels of oil in a production run for the U.S. Navy.

Staff Continued

Brian V. Smith
Stanton R. Smith
Angela P. Smothers
Robert C. Sonderegger
Elia M. Sterling
Benjamin D. Stitt
Carol A. Stoker
Vincent O. Storti
Philip C. Strong
Carola B. Sullam
•Lawrence Talbot
S. K. Tangnu
Seyed M. Tavana
David I. Temianka
•Jerome F. Thomas
Launey J. Thomas III
Benjamin E. Thurston
•Chang-Lin Tien
Laura J. Tom
Louise A. Tom
Reza Toossi
Ahmet A. Toprak
Gregory W. Traynor
Fred Tripp
Norman L. Trondsen
Isaac Turiel
•Robert H. Twiss, Jr.
Rudolph R. Verderber
•Theodore Vermeulen
Enis Veryeri
Michael A. Wahlig
Ezzat I. Wali
Linda L. Walls
Mashuri L. Warren
Pamela J. Weber
Maureen V. Westmoreland
Lawrence A. Wiebe
•Charles R. Wilke
•Robert B. Williamson
•Wellford W. Wilms
Frederick C. Winkelmann
•Warren Winkelstein
Joseph K. Winsen
Cheryl A. Woodard
Mary L. Worth
James A. Wrathall
Linda M. Wroth
Linda L. Wurdeman
Nasser Yaghoubzadeh
Zafer A. Yasa
Winifred W. Yen
Carl M. York
Rodger A. Young
Geordie H. Zapalac
Sharran A. Zeleke

•UCB faculty member
†UCSF faculty member
‡visiting staff

and chemical storage of thermal energy.

From bioconversion studies we hope to develop economical methods of producing energy from agricultural and forest cellulose wastes. A fungus enzyme is used to convert cellulose to glucose, which ferments to form ethanol—being considered as a possible alternative to, or diluent for, gasoline. Such low-cost glucose could also provide a source for acetone and other chemicals now made from petroleum products.

We also issue technical operating directives for, and monitor the wood-to-oil pilot plant at Albany, Oregon, where a barrel of oil was produced recently by using a prehydrolysis technique, followed by thermochemical liquefaction. This technique produced the first purely wood-derived oil at this Department of Energy pilot plant.

In coal-related research, we have projects dealing with removing sulfur from coal for cleaner combustion. Different methods are being compared, and in accompanying studies, the structure, accessibility, and reactivity of sulfur in coal are being explored. In concurrent catalytic liquefaction studies, we are developing catalysts that are effective under conditions of low severity and thus preserve as much of the fuel value of coal as possible.

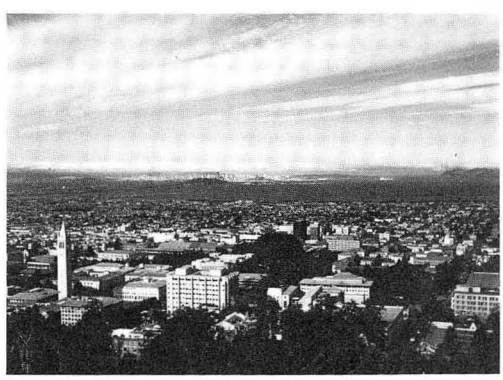
Methods for processing condensate waters from coal conversion and shale retorting are being studied. These involve innovative approaches to ammonia stripping and the novel use of solvents for extracting phenolics and acids.

ENVIRONMENTAL RESEARCH

Instrumentation is being developed for studying a broad range of environmental problems: the mechanisms of air pollution, the environmental consequences of oil-shale development, and the effects of pollutants and combustion processes on natural ecosystems.

The production and use of energy releases potentially harmful contaminants into the environment. Consequently, we need accurate and sensitive detection methods to determine the nature of these pollutants and appropriate control measures. We are developing instrumentation methodology, based on modern physical techniques, to detect such trace contaminants. This approach is highly accurate, speedy, and requires minimal preparation of the sample. Among the methods being developed are laser photoacoustic spectroscopy and detection, high-resolution laser spectroscopy, liquid-crystal applications, Zeeman atomic absorption spectroscopy. In addition, routine chemical analysis by such techniques as x-ray fluorescence spectroscopy, anodic stripping voltammetry, gas chromatography/mass spectroscopy, and neutron activation analysis is being done.

We are initiating new research on the optical and phototransport properties of hydrogenated amorphous silicon. Photovoltaic devices using this amorphous matter offer the first real promise for an economical solar cell.



Clean air over Berkeley and San Francisco viewed from LBL.

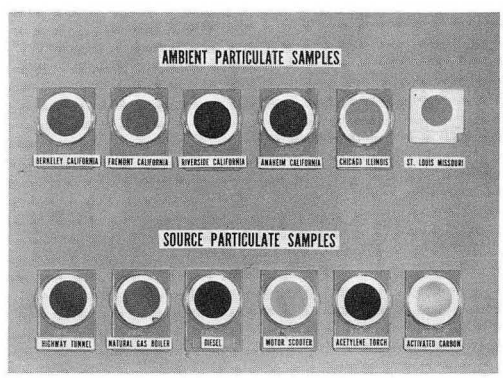
A different day.

The Atmospheric Aerosol Research Group has played a leading role in the science of airborne particles. Our scientists here are engaged in a national program to establish the origin as well as the chemical and physical effects of aerosols produced from fossil fuel combustion. Pioneering work by these experimenters has shown that soot particles are not only a major constituent in urban air, but also can have an import antcatalytic role in transforming gases like SO_2, NO_x, and hydrocarbons to particulate species.

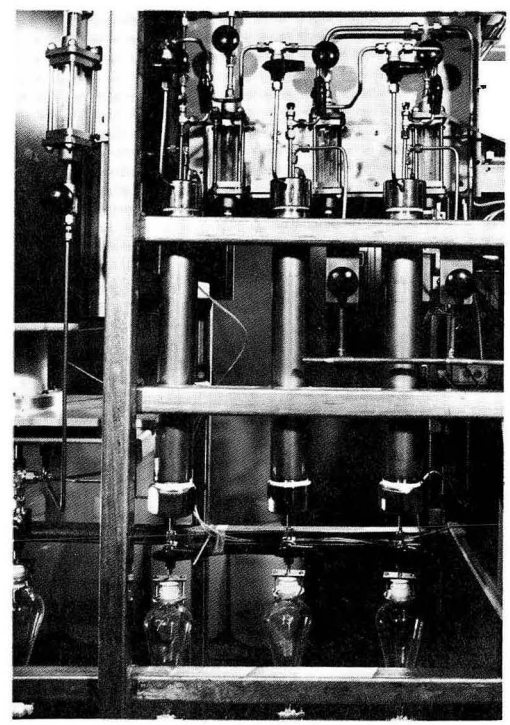
Investigators in the Oil Shale Program are examining the environmental impacts and control technology for the emerging oil shale industry by using hydraulic, heat flow, and chemical transport modeling techniques, as well as state-of-the-art instrumentation. This group plays a leading role in defining and identifying candidate solutions to such environmental problems as underground leaching of processed residuals, process water treatment and disposal, and the emission and control of toxic trace elements. Areas of investigation include aquatic toxicology, geochemical trace element distribution, the transport and fate of aqueous contaminants, the toxicological aspects of organometallics, and the procedures for *in situ* retort abandonment. A number of instrumental, analytical, and engineering techniques have been developed in conjunction with this work, including a novel purification process for highly contaminated waters; a gas monitor capable of continuous, in-place measurements of toxic trace elements; and a continuous-flow bioassay technique.

We are also developing laboratory-sized freshwater lakes (microcosms) and analyzing their use for environmental impact assessment: both intrinsic limitations on their use, and design modifications to enhance the similarity of these microcosms to natural lakes are being studied. Applications of aquatic microcosms to analysis of the potential effects of acid precipitation in California, and of the effects of toxic substances on decomposition processes are in progress.

Society's increasing reliance on heavier fossil and alternative fuels to supply future energy requirements presents a series of challenges to the combustion scientist. The



Particulate samples collected from various urban atmospheres and combustion sources appear gray or black. Energy and Environment Division researchers have identified this absorbing material as "graphitic" carbon which plays an important role in atmospheric chemistry and visibility degradation, and may lead to climate modification.



Zeeman atomic absorption spectroscopy, developed at LBL by Tet Hadeishi, has been used for the first time to measure mercury in real time in a highly contaminated gas stream from an oil shale retort.

optimal use of these fuels requires that efficient combustion systems which simultaneously reduce pollutant emissions, be developed. To this end, in our current combustion research we are concerned with: 1) improving our understanding of combustion chemistry and fluid mechanics; 2) developing and characterizing pollution control methodology; 3) developing advanced combustion systems, and 4) solving combustion-related safety problems.

Unimolecular reactions are an important class of chemical reactions that occur during combustion. The theoretical calculation of rate coefficients of unimolecular reactions, is being extended, thus providing kinetic data essential to combustion modeling studies. Most practical combustion systems operate with turbulent flow of air and fuel, which profoundly affects both efficiency and pollutant generation. Accurate prediction of the performance of turbulent combustion systems, by both engineering tests and numerical modeling, is essential in order to meet efficiency and pollution standards. A substantial program of numerical analysis and computation is underway, which complements several ongoing experimental laser-diagnostic studies of idealized turbulent combustion. The overall goal is to increase the understanding of turbulent combustion, and to develop improved numerical modeling capabilities which have been tested against detailed experimental results from idealized turbulent combustion configurations.

One of the most serious problems associated with combustion of heavier fossil and alternative fuels is pollution formation. Air quality is seriously threatened by these pollutants since they contain nitrogen and sulfur chemically bound to the hydrocarbon fuel molecules. Consequently, we are developing diagnostic procedures and establishing criteria for measuring pollutant species that occur in both combustion products and under ambient conditions. These include innovative separation techniques using gas chromatography, mass spectrometry, and *in situ* laser and differential absorption spectrometry. With these diagnostic aids we plan to assess the mechanisms of pollution formation and destruction in several combustion systems. Techniques for controlling pollution are also being investigated.

Advanced combustion concepts being investigated include catalytic and fuel-lean combustion. Lean combustion results in lowered flame temperatures and reduced thermal NO_X formation. Combustion aided by surface catalysis promotes stable combustion under lean conditions, which cannot be achieved by conventional means. We have investigated some of the fundamentals of the combinations of surface and gas phase combustion reactions, which will aid in the conceptual applications and design of catalytic combustion systems. The potential application of catalysis concepts to alternative fuel combustion is also being investigated. In the internal combustion engine program we are trying to understand some of the processes necessary for a significant improvement in lean engine operation. With a square-piston, single-pulse, compression-expansion machine, four aspects of combustion under conditions simulating the operation of a spark ignition engine are being studied: ignition processes, flame propagation phenomena, wall-quenching processes, and heat transfer processes. Considerable progress has been made, and an improved one-cycle compression-expansion machine, driven mechanically by a fast-acting clutch and brake, has been constructed for extension of the work. A separate study aimed at developing and understanding new technique for ignition of lean mixtures has achieved considerable success. High-speed photography has shown that a plasma jet igniter is capable of multi-point ignition, throughout the combustion volume, of lean mixtures which cannot be ignited by a normal spark.

Our Energy and Environment Division scientists are making significant contributions to the field of fire research. Materials are being evaluated for their fire endurance in both small and large-scale experiments, and these results are used as a basis for

models of flame spread and fire growth. The dominant heat transfer mechanism in most large-scale fires is flame radiation. Since small soot particles are largely responsible for the radiation, the mechanisms of soot formation and the characterizations of the soot radiation field are being investigated.

ENERGY-EFFICIENT BUILDINGS

To meet our energy needs, it is essential that we reduce waste and increase the efficiency of existing energy systems. One-third of U.S. annual energy consumption is used in buildings, and the Department of Energy has funded the Energy Efficient Buildings (EEB) Program to establish ways to improve energy conservation in residential, institutional, and commercial buildings.

Energy savings can be achieved by changing the thermal properties of buildings and by reducing the natural and mechanical ventilation rates. In the LBL Building Envelopes Program we are investigating energy-efficient ways of "tightening" building structures and reducing thermal losses through walls, windows, fireplaces, and other envelope penetrations. The LBL Building Ventilation Program includes field monitoring of indoor air quality, laboratory analyses of indoor air pollutants and their sources, and research and development of energy-efficient ventilation systems. With this program we intend to establish a scientific basis for determining energy-efficient ventilation standards and systems designs that do not compromise the health, safety, or comfort of the building occupants.

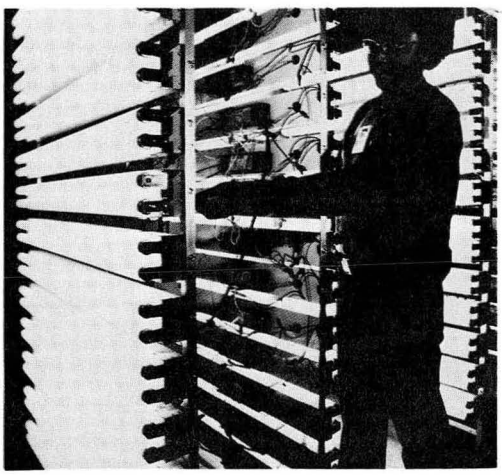
Educational facilities and hospitals account for 30 percent of institutional building energy used. For them, we are focusing special attention on developing energy- and health-efficient ventilation standards and/or retrofits for such buildings, and are evaluating the effects and effectiveness of energy conservation measures.

In another major project, LBL is participating with Los Alamos Scientific Laboratory, also a national laboratory, in developing an easy-to-use public domain computer program, DOE-2, for analyzing energy use in buildings.

Windows are commonly thought to be the source of greatest energy waste in buildings. However, if winter solar heat gain is considered, and year-round provision of natural lighting is accounted for, window systems can be shown to provide net energy benefits, rather than losses. Energy and Environment researchers are developing analytical tools and experimental techniques to better understand both the thermal and daylighting performance of windows. Their goals in this program are to develop improved building design methodologies, and to assist in commercializing improved window systems and components. ("Commercialization" includes research and development activities culminating in hardware prototypes, as well as market studies and projects designed to remove barriers to market acceptance.)

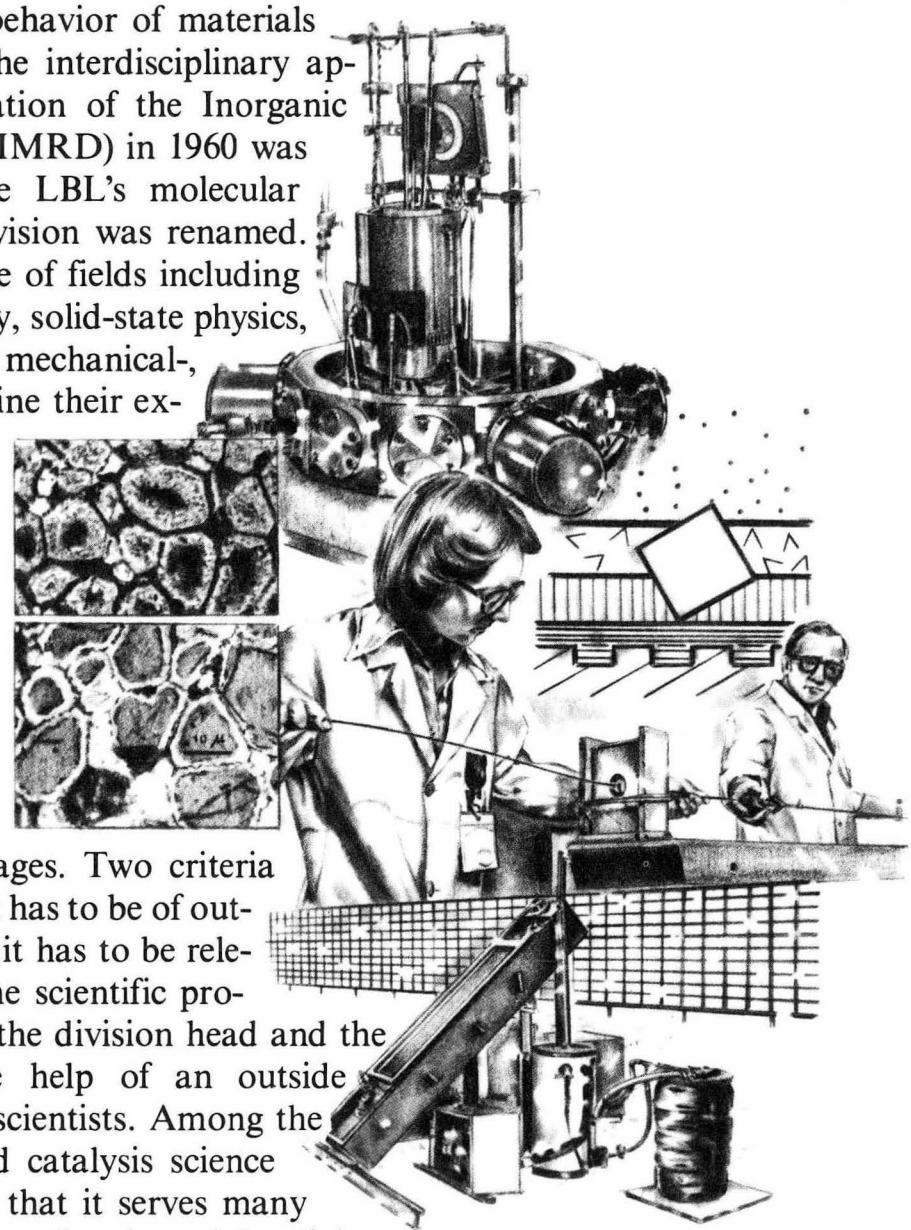
By using daylight in buildings, we can reduce energy consumption and peak power demands. In addition, many technical options currently exist for improving the energy efficiency of lighting systems in both the residential and commercial building sectors. Our lighting program is aimed at commercializing more efficient lamps, ballasts, fixtures, and lighting controls.

The EEB Mobile Laboratory monitored energy utilization and indoor air quality at Iowa State University's Energy Research House in February 1979.



Mack Morgan checks the lamp life test facility rack. Tests on lamps driven by electronic ballasts will determine effects of high frequency excitation on phosphor and cathode life.

The Materials and Molecular Research Division (MMRD) conducts research on the physical and chemical aspects of the behavior of materials and of chemical processes. The interdisciplinary approach that marked the creation of the Inorganic Materials Research Division (IMRD) in 1960 was expanded in 1975 to include LBL's molecular science programs, and the division was renamed. Researchers from a wide range of fields including chemistry, ceramics, metallurgy, solid-state physics, atomic physics, and chemical-, mechanical-, and nuclear engineering combine their expertise to explore basic factors that determine the behavior of materials under conditions encountered in advanced energy technologies and the molecular processes that are involved in the production and use of fuels. The diverse activities within the division can be grouped as shown on the following pages. Two criteria must be met by every project: it has to be of outstanding scientific quality and it has to be relevant to energy technology. The scientific program is reviewed annually by the division head and the laboratory director with the help of an outside review committee of eminent scientists. Among the project groupings, surface and catalysis science occupies a special position in that it serves many technologies and involves a large fraction of the divisional activities including many of the project groups listed separately. On a national scale, MMRD emerges as a formidable center for surface and catalysis research. Similarly, the division's capabilities in electron microscopy contribute to many research areas and are of national importance. Research in MMRD provides a unique environment for instruction at the graduate level and is tightly coupled to the Berkeley campus. A hallmark of the work conducted in the division is its high quality; year after year MMRD scientists are recognized by honors and awards; of the investigators, 48 are faculty members, 17 of them are members of the National Academies of Sciences and Engineering; 314 graduate students currently receive training in MMRD laboratories.



David A. Shirley
Head, Materials and
Molecular Research Division
Associate Director, LBL

Materials and Molecular Research

*David A. Shirley
LBL Associate Director
Head, Materials and Molecular Research Division

Division Administration
Rolf H. Muller
Margie Janzen
Kent McArthur
Conway Petersen
Ethel Skrydlinski

Division Staff
**Neil Bartlett*
**Alexis Bell*
**Robert Bergman*
**Robert H. Bragg*
**Leo Brewer*
‡William D. Brewer
**Steven Brown*
**John Clarke*
**Marvin L. Cohen*
**Eugene D. Commins*
**Robert E. Connick*
John G. Conway
**Lutgard De Jonghe*
Norman Edelstein
**Anthony Evans*
**James Evans*
**Leopoldo Falicov*
**Iain Finnie*
Ronald Gronsky
**Charles B. Harris*
**Dennis Hess*
**Craig Hill*
**Carson Jefferies*
**Harold Johnston*
**William Jolly*
**Yuan Lee*
Alan Levy
**Bruce Mahan*
**Richard Marrus*
**William Miller*
**Bradley Moore*
**John W. Morris, Jr.*
**Erwin Muetterties*
**John Newman*
**Donald Olander*
**Joseph Pask*
**Norman Phillips*
**Alexander Pines*
**Kenneth Pitzer*
**John Prausnitz*
**Kenneth Raymond*
**Paul Richards*
‡Moshe Rosen
Philip Ross
**Henry F. Schaefer, III*
**Glenn T. Seaborg*
**Alan Searcy*
**Mitchel Shen*
**Yuen-Ron Shen*
**Howard Shugart*
**Gabor Somorjai*
**David Templeton*
**Gareth Thomas*
**Charles Tobias*
**K. Peter Vollhardt*
**Jack Washburn*
Kenneth Westmacott
David Whittle
**John Winn*
Allan Zalkin

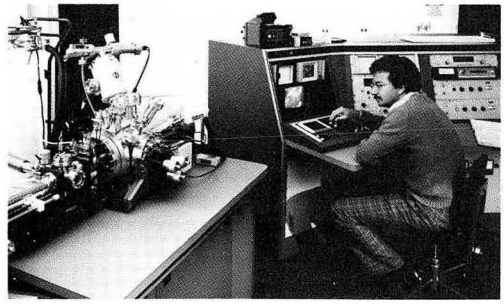
*UCB faculty member
‡visiting staff

CATALYSIS AND SURFACE SCIENCE

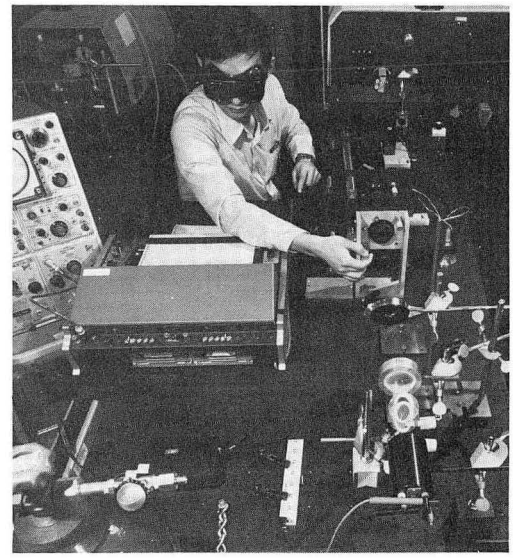
Over one hundred scientists of our Materials and Molecular Sciences Division participate in a major program of research in the fields of surface and catalysis science. Surfaces provide the first material defense to contain the hostile environment of energy and fuel conversion processes. On certain surfaces, specific catalytic reactions that do not occur elsewhere can take place at high rates. In these investigations the focus is on the atomic and electronic structure of surfaces and adsorbed molecules, the catalysis of surface reactions, and the grain structure and interface structure of solids. The first two areas involve research at the solid-gas and solid-liquid interfaces and relate to the chemical and electronic properties of surfaces, while in the third area we are investigating the properties of the solid-solid interface, which relate mostly to the mechanical properties of solids. From these investigations, our scientists at MMRD hope to provide the scientific understanding for what makes surfaces reactive or nonreactive —a matter of importance in many areas of energy sciences and technologies such as synthetic fuel production, coal conversion, energy storage in batteries, solar energy conversion, and energy transmission.

CHEMICAL PHYSICS

Staff members of the Chemical Physics Group make direct and wide-ranging contributions to society, while continuing to develop the basic technology of the future. Highly specialized spectroscopic techniques are under constant development and are used, in addition to more conventional procedures such as nuclear magnetic resonance spectroscopy, for specific application to a variety of practical and energy-related problems, not the least of which is the analysis and characterization of coal. Several laser isotope separation methods are being explored for their applicability in selectively exciting molecules undergoing chemical reactions, in multiphoton excitation, and in selective condensation of molecules.



Philip Ross uses the Scanning Auger Microscope to analyze the surface of a steel for the presence of embrittling elements at the grain boundaries exposed by in situ fracture.



Graduate student Hai-hung Dai focuses infrared photons into a photolysis cell with ethyl chloride gas. The absorption of photons causes the molecules to dissociate in an isotropic process. This knowledge can be applied to isotope separation, synthesis of new molecules, and nuclear waste management.

Reaction chemistry in all its complexity, especially as it occurs in combustion, is being examined by our scientists who study the reaction of oxygen atoms and radicals in crossed molecular beams. By using both atmospheric modeling calculations and by experimentally measuring important rate constants, we are also actively investigating the chemistry of the lower and upper atmosphere and the dynamic equilibrium

that maintains the concentration of ozone.

The strength of our Chemical Physics Group lies in its fundamental research efforts: investigating the physical properties of matter and studying chemical dynamics. From our studies here of the thermodynamics of low- and high-temperature systems, and of phase transformations and critical phenomena, we continue to gain information by which we can advance the field. By combining a strong theoretical attack on the question of molecular processes with experimental studies of chemical reactions and using laser photochemistry and the molecular beams technique, we are pushing forward the frontiers of chemistry.

SYNTHETIC CHEMISTRY

We are developing new materials, new oxidation states of elements, and novel synthetic methods for application in the efficient production, clean use, and storage of energy. Highly conducting graphite compunds, when prepared with superoxidizing agents, show promise for use as electrode materials in electrochemical syntheses and in storage batteries. Related materials may be semiconductors or photoconductors. Sophisticated spectroscopic examination of inorganic materials provides us with a clearer understanding of the factors that determine bond stability and electronic characteristics of such systems. We are also measuring rates of reaction and product formation in the removal of sulfur dioxide, a pollutant in stack gases of power plants.

PHYSICAL METALLURGY

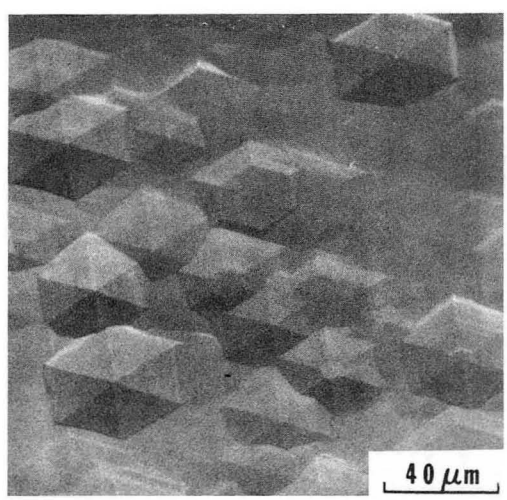
In our research in physical metallurgy, we are concerned with the relation of microstructure to physical and mechanical properties of metals and alloys, and with the development and preparation of inorganic materials that have technological significance. We use a variety of analytical tools, including electron microscopy, x-ray diffraction and spectroscopy, and Auger and Mössbauer techniques to characterize the chemical and microstructural features of metals, alloys, and ceramics. A number of testing techniques are used to characterize physical properties. Supportive theoretical work includes both analytic and computer simulation studies of phase transformations and mechanical behavior. From our results we are able to clarify fundamental principles and to provide guidelines for the design of new engineering alloys having improved properties. Programs here include research on magnetic and superconducting materials as well as on structural steels and composites.

Specialty Steels

We strive to improve the strength and toughness of technologically important ferrous alloys such as cryogenic steels, and steels for mining, transportation, and geothermal applications, through the control and manipulation of alloy microstructures by the design of composition and heat treatment.

Erosion-Corrosion

Basic and applied research programs are conducted on the behavior of metal and



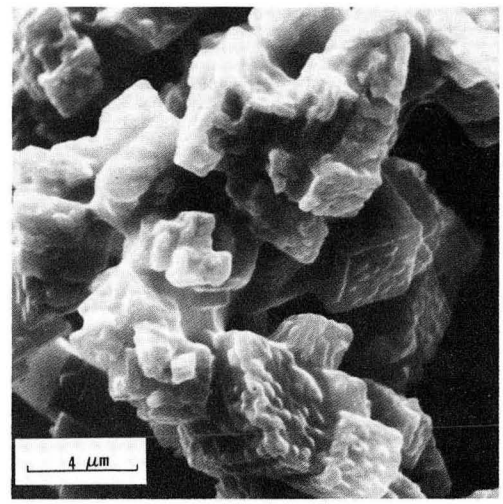
Scanning electron micrograph of the top surface of a single crystal cadmium sulfide film grown on a (lll) gallium arsenide substrate. These studies are leading to improved semiconductor materials.

ceramic surfaces exposed to particle-laden fluids at an elevated temperature. Such conditions cause erosion and corrosion in systems for coal conversion and *in-situ* oil shale retorting.

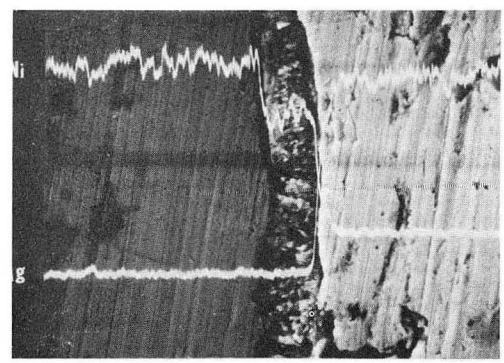
Electronic Materials

We are characterizing defects in semiconductor materials that result from ion implantation and subsequent annealing. These defects occur in silicon and gallium arsenide; and from analyses of single-crystal CdS-Cu_2S solar cells we find that by replacing some of the cadmium with zinc we can obtain a higher open-circuit voltage.

From our studies of structure-property relationships in magnetic materials such as ferrites, garnets, iron base, and rare-earth alloys, we are able to fabricate varistors and ferroelectric materials based on an understanding of magnetic behavior. Thus we are able to improve material properties through control of phase transitions and lattice defects.



The scanning electron micrograph shows previously angular particles of calcium oxide starting to pucker at 650° C. This is evidence that diffusion of the particles occurs approximately 500° cooler than expected.



The scanning electron micrograph reveals bonding characteristics of silver and nickel. The dark center band is a layer of nickel oxide which forms when the nickel is heated in air, preventing good bonding. The problem is solved by heating in a helium atmosphere.

CERAMIC SCIENCE

Ceramic studies in MMRD are directed toward improving our understanding of the chemical reactions by which useful inorganic solids can be obtained; of the processes by which these solids can be formed into shapes of desired physical and chemical properties; of the relations between the chemical bonding; and of the structures of these solids on the atomic and near atomic level to their mechanical, chemical, and electrical behavior.

As part of this program, the kinetics of several representative examples of industrially important chemical reactions – the decomposition of carbonates and sulfates, and the reduction of iron oxides – are being studied by techniques designed to clarify both the mechanism of the chemical reactions and the influence of reaction conditions on the physical and chemical properties of the solid reaction products.

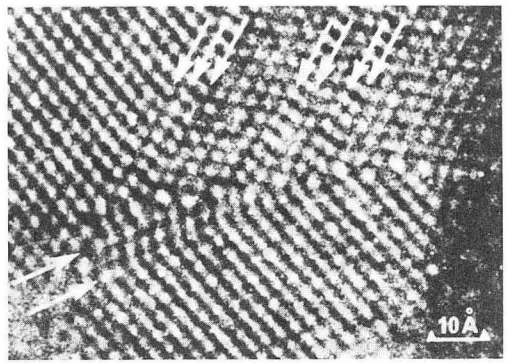
We are also investigating the influence of small concentrations of additives on the rates and mechanisms of the sintering of oxide powders into compacts and the nature of the chemical interactions between oxides of different compositions. From these studies we hope to learn how to control processing variables in ways that will reduce the cost of production and will increase the reliability and usefulness of the products.

Our studies of the relationship between structure and properties of ceramics are designed to take advantage of their great strength at high temperature, impressive resistance to abrasion and chemical attack, and sometimes uniquely valuable electrical

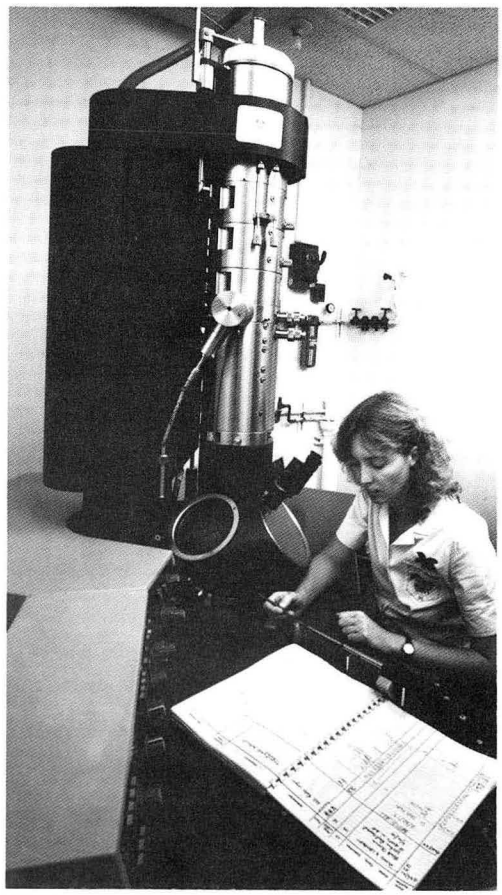
or magnetic properties, while minimizing their inherent defects — notably brittleness, and often irreproducible behavior. From recent progress in brittle fracture theory we have hope that the construction of turbines from ceramics may be possible for higher temperature operation, thus permitting greater energy efficiency than can be realized with metals.

ELECTRON MICROSCOPY

Transmission electron microscopy provides detailed insight into crystal defects, interfacing structures, fine-scale precipitate morphologies, and other microstructural and microchemical features that are responsible for the behavior of materials. This information is then made available for use in the design of new metallic and ceramic alloys including steels for the mining and transportation industries, and electronic devices and refractory nitrides for turbine applications. In response to increasing national needs in this field, we have developed new programs at MMRD in (1) high-voltage electron microscopy, including a 1.5-MeV machine (the highest accelerating potential of any microscope in the United States) for examination of "bulk" specimens with environmental control; and (2) atomic resolution microscopy, bringing to LBL a unique microscope of such advanced design that it will be capable of imaging individual atoms.



The first direct experimental observation of an atomic arrangement. The dark areas are the grain boundaries of germanium seen atom by atom. Light areas between atoms are about 3Å. Magnification is greater than 10,000x.



With the 100 kV Philips 301 transmission electron microscope, Carolyn Gosnell will study the microstructure of cadmium sulfide. Electrical properties of the compound can then be altered to improve its efficiency as a semiconductor for solar cells.

SOLID-STATE PHYSICS

In our Solid-State Physics Group, members work on the fundamental physical properties of materials and on applications of new solid-state devices and measurement techniques. Using infrared spectroscopy to probe absorbed molecules on surfaces, these researchers seek a good theoretical understanding of the electronic properties of various types of surfaces. Others of the group are able to explain and predict properties of bulk solids from theoretical calculations. Properties of materials are

Felix Schwager adjusts the galvanometer amplifier on the automatic ellipsometer used for in situ investigation of electrochemical surface layers.

also being effectively studied by using lasers in a new linear and nonlinear optical techniques. And from investigations on superconductivity and excited quantum fluid in solids, group members are developing superconducting devices as sensitive detectors for geothermal and astronomical studies.

ELECTROCHEMISTRY

Electrochemical processes are not limited to the Carnot cycle as are thermal processes, and are therefore inherently energy-efficient. They can also be specific, theoretically resulting in high purity materials with few undesirable by-products. In reality, however, before these advantages can be put into practice, fundamental research is needed to extend the range of electrochemical transformations.

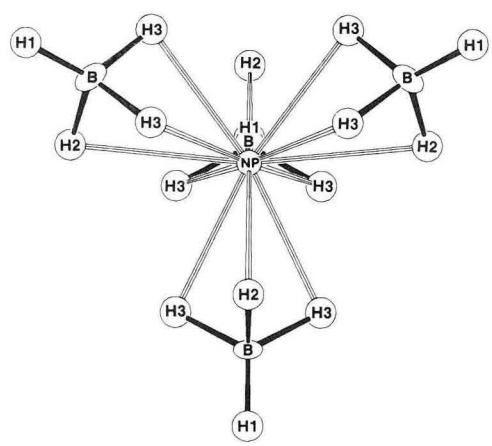
Our researchers have designed projects by which they plan to expand the scientific foundations of electrochemical processes. These projects include studies of transport phenomena in electrochemical cells, electrolytic gas evolution, high-rate metal deposition and dissolution, reactions in non-aqueous solvents, formation of electrochemical surface layers, modeling of electrochemical systems, and electrocatalytic processes. We expect that benefits from this work will be seen in the recovery of basic metals, the preparation of inorganic and organic chemicals, the shaping and surface treatment of materials for advanced energy technologies, and the conversion and storage of energy in fuel cells and batteries.

Among the advanced experimental techniques being developed are the automatic ellipsometry of electrochemical surface layers and the interferometry of mass-transport boundary layers. The electrochemical research effort at LBL is based on the first electrochemical engineering program in the U.S., initiated here in 1959. It is the only major continuing research program of this kind in the country.

ACTINIDE CHEMISTRY

MMRD researchers are studying the chemistry of the actinide elements to develop a base of knowledge necessary for the safe and economical use of actinides. The program is based on LBL's prestigious history of producing, isolating, and characterizing all the transuranium elements. Our present actinide project extends from fundamental research (such as the complexing of plutonium) to clinical trials in cooperation with LBL's biomedical facilities. This program includes synthetic work in organo-actinide chemistry, coordination chemistry, and actinide inorganic chemistry.

Responding to problems posed by nuclear power, one part of the program addresses the design of sequestering agents for actinide ions capable of engulfing the ion and generating neutral or charged complexes. These agents will have a high specificity for individual actinide ions, as well as large absolute formation constants with these ions. Such compounds could have use in treating actinide poisoning by allowing removal of plutonium from body tissue, and for selective separation of americium, plutonium, and curium in new processing schemes for nuclear waste.



The molecular structure of a newly synthesized neptunium complex — $Np(BH_4)$. This compound is a liquid at room temperature and is the most volatile tetravalent neptunium complex known to date.

At MMRD, our scientists in actinide chemistry are identifying and characterizing synthesized compounds by x-ray diffraction, optical and vibrational spectroscopy, magnetic resonance and magnetic susceptibility techniques, and titration studies that analyze bonding strength.

ATOMIC PHYSICS

Three programs are being carried out by our scientists in the atomic physics group:

Spectroscopy of simple atomic systems at high atomic number is being carried out with the facilities of the SuperHILAC. Our current research there includes the measurement of the n = 2 fine structure in helium-like iron, the study of wavelengths and oscillator strengths in lithium-like rhodium, and the study of electron capture into the continuum by fast, fully ionized projectiles in a gas. These measurements test fundamental atomic theories and provide us with useful information for the diagnostics of thermonuclear plasmas.

Traps capable of storing ions for times of the order of minutes are being used to measure lifetimes of lithium ions. We have developed techniques using lasers to probe plasma densities in such traps.

Using state-of-the-art lasers developed in our laboratories, we have detected a small parity-violating effect in neutral thallium. This result confirms theoretical predictions. Further work is under way to improve the accuracy of the results.

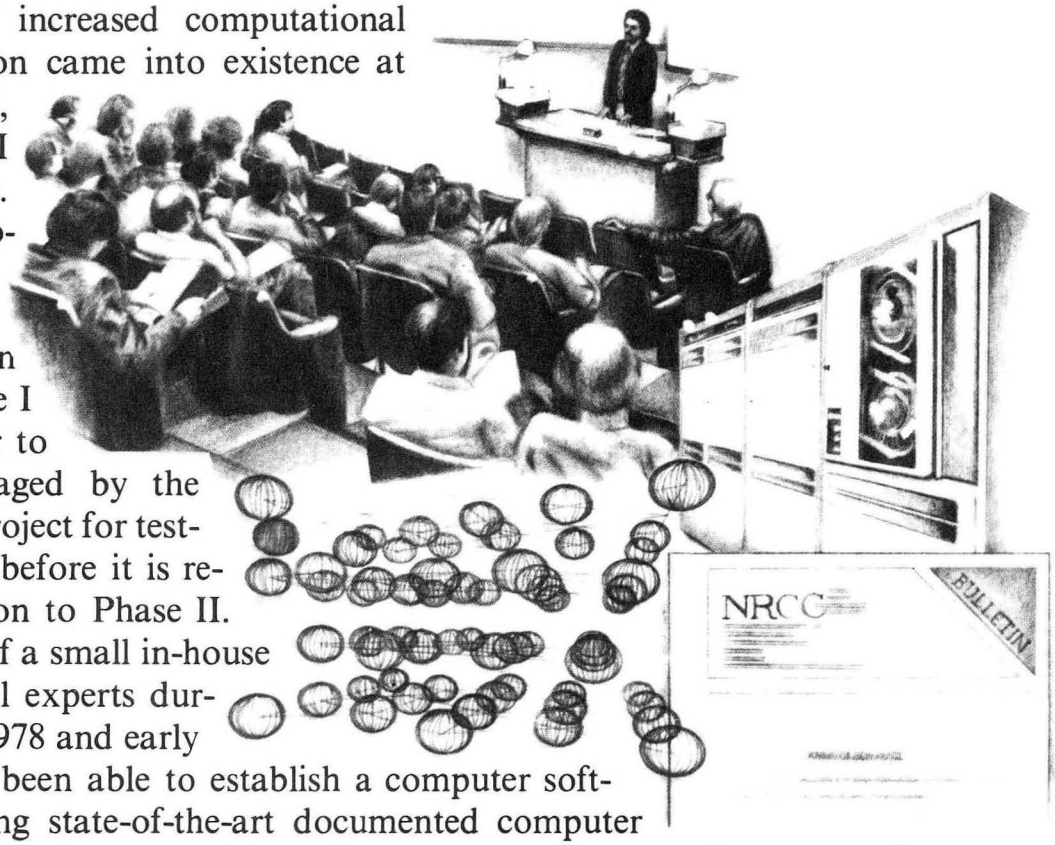
CHEMICAL ENGINEERING

We are establishing scientific foundations for new chemical processes of technical interest: By studying the plasma-enhanced deposition of inorganic thin films, we are developing the ability to control the chemical, magnetic, optical, and electrical properties of these films. We will derive kinetic models of the deposition processes as they affect solar-cell fabrication, integrated circuit processing, and structure-property relationships in catalyst support materials. Then, based on the results of these investigations, we hope to be able to incorporate specific properties in thin-film materials during deposition.

Vapor-liquid equilibria in the methane-water (brine) system are being measured at conditions similar to those prevailing in deep gas-pressurized reservoirs (aquifers at 100 to 250° C, pressures to 2 kilobars) found bordering the Gulf of Mexico. At the same time we have molecular-thermodynamic studies in progress for establishing a partition function, which may be used to give a quantitative description of the phase behavior.

Our scientists here have polymerized ultra-high-molecular weight poly(methyl methacrylate) by using plasma-initiated polymerization. The visco-elastic behavior of this new material is determined by using the Time Temperature Superposition Principle. Molecular models are being developed to describe the chain dynamics of these highly entangled macromolecules.

This division, the National Resource for Computation in Chemistry (NRCC), was conceived as a computational center with facilities and personnel dedicated to the advancement of chemistry and related sciences. It serves the chemistry community by making available the means for systematic collaborative attention to software development, documentation, and improvements in computational methods as applied to chemistry, as well as by making available the benefits of increased computational hardware. The division came into existence at LBL in October 1977, funded for a Phase I period of three years. When I arrived, in February 1978 as NRCC Director, one of my first acts was to obtain the extension of Phase I to four years in order to have the time envisaged by the planners of this new project for testing and development before it is reviewed for continuation to Phase II. With the acquisition of a small in-house staff of computational experts during the latter half of 1978 and early 1979, the NRCC has been able to establish a computer software library containing state-of-the-art documented computer codes in chemical kinetics, crystallography, macromoleuclar science, physical organic chemistry, quantum chemistry, and statistical mechanics. The NRCC stimulates interaction among groups and individuals sharing common computational interests via workshops in which they establish priorities for important and yet unsolved computational problems. In addition, workshops are held to introduce researchers to the theory and practical use of codes in the various areas. As a means of bringing the essence of the workshop activity to those not in attendance, the NRCC develops written proceedings, obtainable upon request; their availability is made known through the NRCC BULLETIN. Equally significant is our visitor program, which brings outstanding scientists together at the NRCC for periods ranging from weeks to months, so that they may interact with each other and with the in-house staff. With a solid core of computer programs to serve as a basis for research in the basic areas, and with a multitude of directions identified by NRCC workshops, we look forward to the coming years with excitement as chemists across the country, many in collaboration with in-house staff, pursue research not possible prior to our advent. In addition, with the acquisition of a minicomputer, VAX 11/780, the NRCC will augment its software efforts by using the minicomputer to make portable documented computer programs available for minicomputers in addition to large mainframes. This is a shift in emphasis from early National Academy of Sciences reports outlining the scope and function of the NRCC spurred by very recent advances in technology.



William A. Lester Jr.

William Lester, Jr.
Head, National Resource for Computation in Chemistry
Associate Director, LBL

National Resource for Computation in Chemistry

William A. Lester, Jr.
LBL Associate Director
Head, National Resource for Computation in Chemistry (NRCC)
Director, NRCC

Division Administration
George E. Towns
Carolyn E. Bryant
Tim R. Clark
JoAnn Kim
Maudie Noyd

Division Staff
Michel Dupuis
†Stanley A. Hagstrom
Arthur J. Olson
Dale P. Spangler
Lowell D. Thomas
John J. Wendoloski

NRCC User Association Executive Committee
Barbara J. Garrison (Chairperson-Elect) Pennslyvania State University

Stanley A. Hagstrom Indiana University

Gilda Loew Stanford University

Gerald M. Maggiora (Chairperson) University of Kansas

David Silver John Hopkins University

George Schatz Northwestern University

John J. Wendoloski (Liaison Officer)

NRCC Policy Board
Bruce J. Berne Columbia University

Charles Bender Lawrence Livermore Laboratory

Mary L. Good University of New Orleans

William Guillory University of Utah

James A. Ibers (Chairman) Northwestern University

Carroll K. Johnson Oak Ridge National Laboratory

Martin Karplus Harvard University

Herbert B. Keller California Institute of Technology

William H. Miller University of California Berkeley

John A. Pople Carnegie-Mellon University

Our newest division at the Laboratory is the National Resource for Computation in Chemistry (NRCC), formed in October 1977. It is the first national effort for systematic advancement of computational methodologies in the field of chemistry. As such, the NRCC Division has special status at LBL, having been organized as an autonomous unit of the Laboratory and retaining sole responsibility for its scientific program. NRCC is organized with its own director, policy board, program committee, and users association.

The NRCC Policy Board is the governing board of NRCC and is broadly representative of the chemical community in the United States. Its 12 members were selected by the LBL Director in conjunction with representatives of DOE's Division for Basic Energy Sciences and the National Science Foundation. This board determines the division's policy and sets scientific goals and priorities.

The Program Committee is appointed to be representative of important areas in computational chemistry. It reviews proposals submitted to NRCC and recommends priorities.

The users association provides feedback to the NRCC director and the policy board.

LBL was selected to be the parent organization for this facility because of its outstanding computer capabilities, its proximity to and close interaction with the University of California, and the expertise of its scientific staff.

Through the NRCC we

- Make information on existing and developing computational methodologies available to all segments of the chemistry community,
- Make state-of-the-art computational facilities (software and hardware) accessible to the chemistry community, and
- Foster research and development of new computational methods for application to chemical problems. For brevity, these three categories are referred to as education, service, and research.

Education figures prominently in the development of NRCC for stimulating the use of our facilities and services by those in the chemistry community. The NRCC BULLETIN provides current information on all aspects of the division's program, including plans and progress on computer code development, and is available to members of the scientific community upon request. We hold workshops to identify new areas of application and to extend existing program efforts. At the same time, these workshops serve to educate the chemists as to our capabilities at the NRCC and to the new developments in computation that have chemical application (for example, the impact of the minicomputer on chemistry is a subject of continuing study and workshop activity). We publish proceedings of these workshops, which are available to those unable to attend.

Our NRCC service function will likely have the broadest initial impact on the chemical community, and be the most visible activity. Documented state-of-the-art versions of general-purpose computer programs are made operational on LBL's computers, and are accessible by the majority of chemists, who are primarily non-experts in applying computational methods to chemical problems. Thus, they are able to access these programs and run them remotely at the NRCC from their home location, or obtain copies of the codes for use at their home installations. Our NRCC staff members serve as consultants in their use. In addition, chemists across the country have access to state-of-the-art computational facilities here through the NRCC. Remote computing is already attractive to many of these chemists who benefit from the many useful programs operational on the NRCC computers. We expect increased growth of this mode of activity.

Research and development of new computational methods for addressing chemical problems are being accomplished by visiting scientists and postdoctoral fellows, as well as by our resident NRCC staff and non-resident scientists, under awards from the NRCC. Our goal here is to develop new, more powerful computational algorithms and to make available the software based on them. Problems in most subdis-

Staff Continued

Anessur Rahman
Argonne National Laboratory

Kenneth Wiberg
Yale University

NRCC Program Committee
Richard Bernstein
Columbia University

Ernest Davidson
University of Washington

William A. Lester, Jr. (Chairman)
NRCC

John Light
University of Chicago

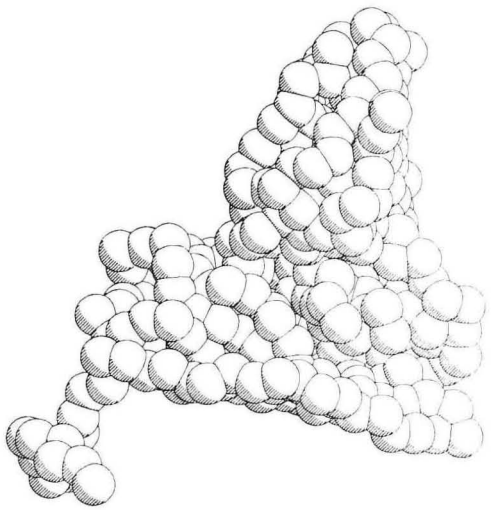
Josef Michl
University of Utah

Robert Parr
University of North Carolina

Stuart Rice
University of Chicago

David Templeton
University of California Berkeley

W. Todd Wipke
University of California Santa Cruz



This computer-generated drawing depicts a single viral protein molecule. One hundred eighty of these molecules combine to form the protective outer shell of the tomato bushy stunt virus. The NRCC is developing computer graphics to aid in the analysis of such complex supramolecular assemblies.

ciplines of chemistry, including chemical kinetics, crystallography, macromolecular science, physical organic chemistry, quantum chemistry, and statistical mechanics, are research areas where we are actively working. For example, in quantum chemistry, the technology for self-consistent field calculations is highly developed, and standardized codes are now included in the NRCC code library. The computational methods for treating electron correlation, however, are still evolving, and only rudimentary general-purpose programs are available to non-experts. We play an important role here by developing powerful straightforward programs for treating electron correlation.

The NRCC program will be implemented in two phases: In the first, we intend to demonstrate the feasibility of this computational principle through this small activity at LBL, which has been funded jointly by DOE and the National Science Foundation (NSF). Implementation of Phase II, which may involve acquisition of state-of-the-art computing facilities, must await the evaluation of the impact and usefulness of Phase I.

WORKSHOPS

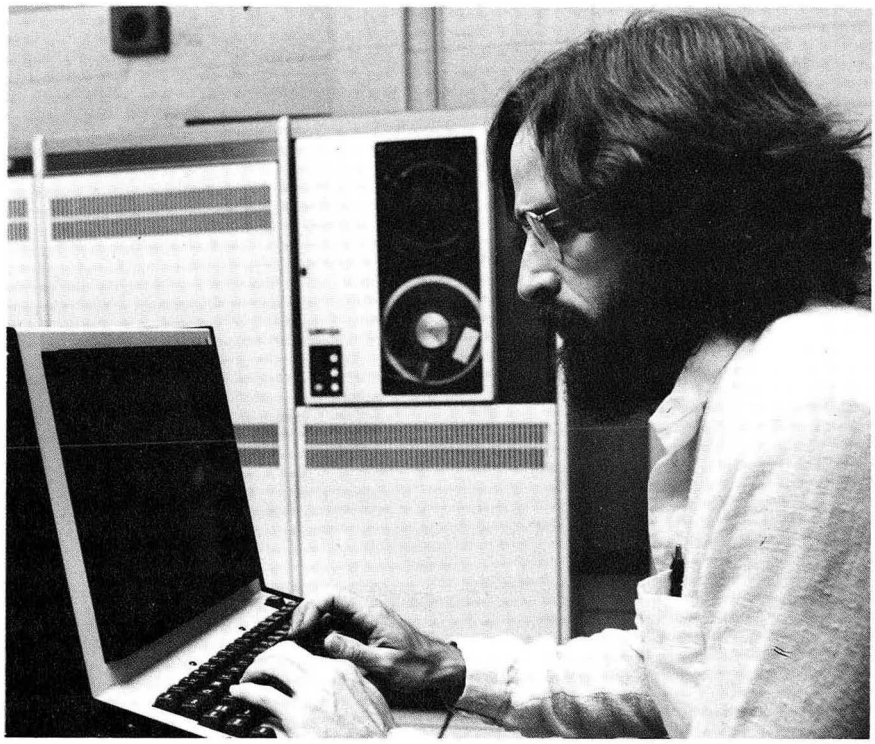
During the summer of 1978 the NRCC sponsored four workshops, bringing together more than two hundred key contributors in the subject areas to discuss the future directions of the computationally oriented field and the possible role of NRCC in assisting such developments. Proceedings of each workshop have been distributed.

"Crystallographic Methodology" brought 45 scientists to Asilomar, California in June with Dr. Carroll Johnson, NRCC Policy Board member and Professor David Templeton, NRCC Program Committee member. Out of this workshop came the consensus requesting that the NRCC serve as a focus of educational activities relating to crystallography, such as workshops, rather than as a source of additional computer time.

A July workshop on "The Minicomputer and Computations in Chemistry" was organized by Professor Philip Certain of the University of Wisconsin because of the rapid growth of interest in minicomputers. More than 105 persons who have either pioneered in the development of the application of minicomputers to chemistry, or who are considering acquisition, participated in discussions on matching equipment to function, trends in computer design, systems maintenance, and the economics of minicomputer use.

In response to the consensus that the NRCC is needed in a leadership role in disseminating information on minicomputers and related software for chemists, we have taken steps that include the purchase of a minicomputer. With its aid, we can develop software for minicomputers and for portable computer programs in general.

"Numerical Algorithms in Chemistry: Algebraic Methods" was the subject of a workshop convened at Oakes College, UC Santa Cruz, by Dr. Isaiah Shavitt of Battelle Columbus Laboratories and Professor Cleve Moler, University of New Mexico. Here, computational chemists, computer



Arthur Olson of the NRCC working at the console of the division's VAX 11/780 minicomputer.

scientists, and numerical analysts gained a clearer picture of the problems confronting them that deal with large in-core and out-of-core eigenvalue problems, systems of linear equations, and the transformation problem for two-electron integrals in quantum chemistry.

A related workshop held soon after at LBL was titled "Post Hartree-Fock: Configuration Interaction," and dealt with methods for treating the correlation problem in the electronic structure of molecules. The workshop was organized by NRCC Policy Board members Dr. Charles Bender and Professor John Pople and drew participants from as far away as Japan, Australia, Sweden, and Germany. Participants suggested ways in which we could assist in the development of improved algorithms and software, and proposed programs for inclusion in the NRCC software library.

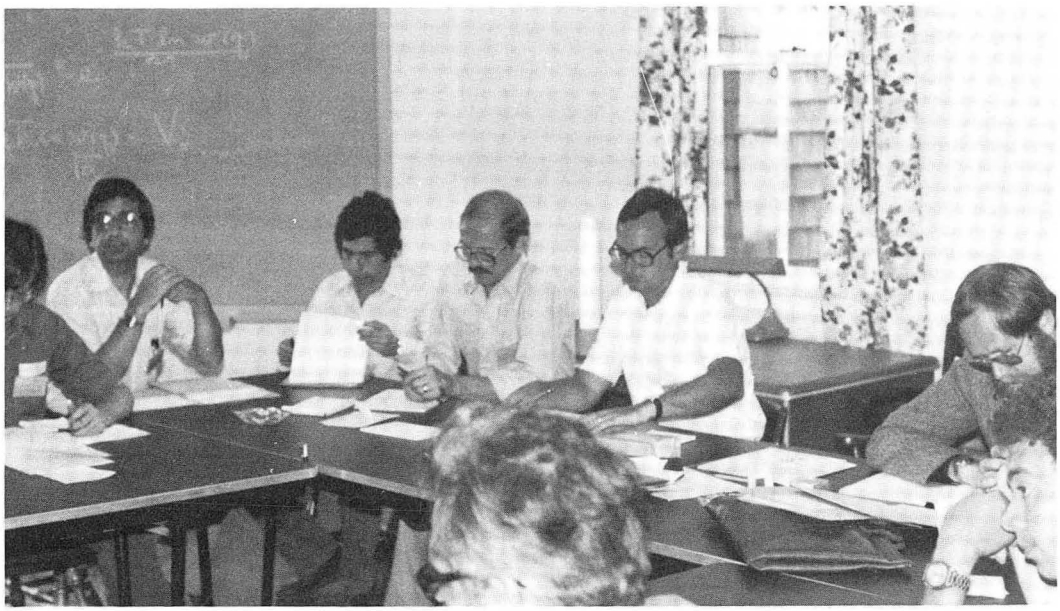
Several workshops were sponsored by the NRCC during 1979:

A two-part workshop on "Algorithms and Computer Codes for Atomic and Molecular Quantum Scattering Theory" was co-chaired by NRCC Program Committee member Professor John Light, University of Chicago, and Dr. Lowell Thomas, NRCC. The first meeting, held in June at Argonne National Laboratory, dealt with the identification, development, testing, and documentation of the best codes for solving the coupled-channel equations of quantum scattering, which are not readily available to the general scientific community. The results of testing these codes against a fixed set of test problems were summarized at the second meeting and made available through the NRCC program library.

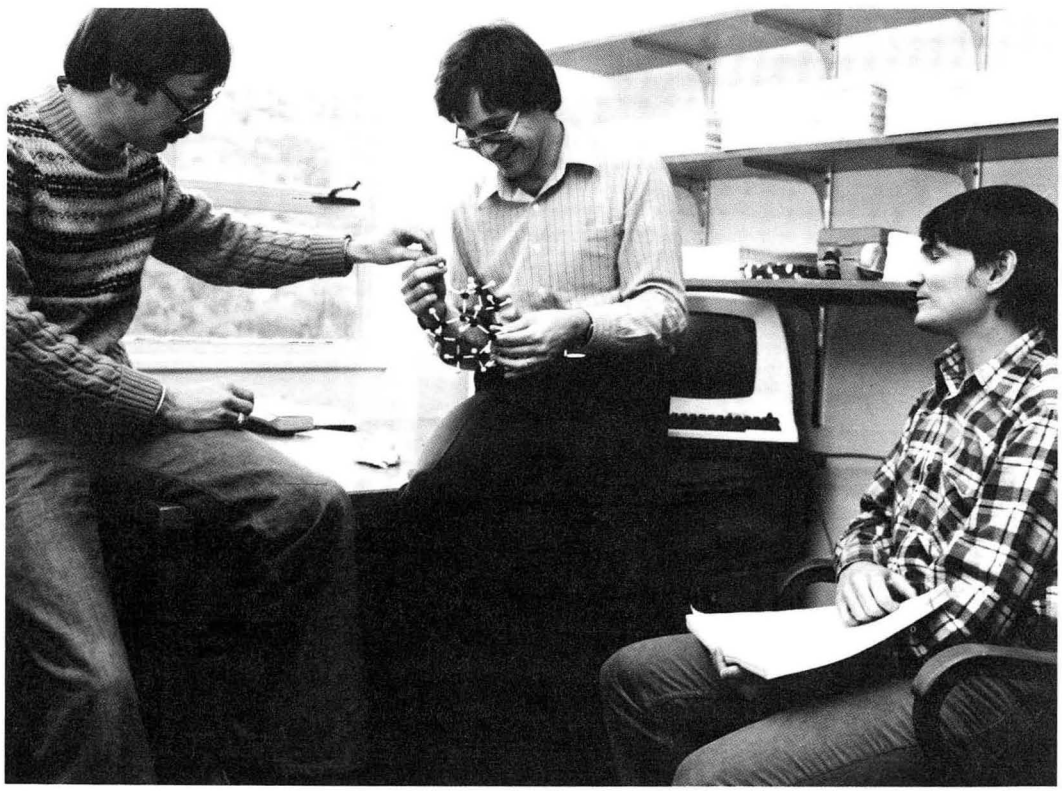
Methods of "Stochastic Molecular Dynamics" were studied at a workshop organized by Dr. John Tully of Bell Laboratories and held in July at Woods Hole, Massachusetts. Here, a small group of workers explored alternative ways to introduce friction and fluctuating forces into the equations of motion. This approach has application in studies of condensed phase processes, polymer dynamics, surface chemistry, and gas phase chemistry.

The NRCC held a conference on "Software Standards for Chemical Computation" at the University of Utah, Salt Lake City, organized by Dr. Frank Harris of that university. The three-day conference focused on specifications for computer systems, which may differ somewhat in different fields of chemistry: modularization; design of generalized data formats; software portability; and recommended standards for programming practices and documentation.

A workshop entitled "Computational Methods for Molecular Structure Determination: Theory and Technique" was held at the Quantum Chemistry Program Exchange (QCPE), Indiana University. This workshop provided an introduction to the use of state-of-the-art computer codes for computing electronic structure and the geometry of small and large molecules.



Some participants in session at the NRCC workshop on "Stochastic Molecular Dynamics," National Academy of Sciences Woods Hole Facility, Woods Hole, Massachusetts. Seated (left to right) Marc L. Mansfield, Dartmouth College; Jack Freed, Cornell College; Itzhak Webman, New York University; John Eaves, Joint Institute for Laboratory Astrophysics (JILA) University of Colorado; David Kranbuehl, William and Mary College; Jack Owicki, Stanford University; Solomon H. Jacobson, Northwestern University.



NRCC staff members discuss geometry of cryton (l,l,l). Left to right: John Wendoloski, Michel Dupuis, and Dale Spangler.

Remote access by interactive terminals to our CDC-7600 gave participants hands-on experience. NRCC and QCPE staff members also instructed participants in the use of computer programs.

The "Problem of Long-Range Forces in Computer Simulation of Condensed Media" is being examined in a workshop sponsored by the NRCC on January 8-11, 1980. The workshop will be held in Menlo Park, California and is being co-chaired by Professor Harold Friedman and Professor George Stell, both of the State University of New York at Stony Brook, New York. There will be seven half-day sessions, each with a review lecture by an invited speaker, followed by short talks and discussion.

PROPOSALS

Computer time at NRCC is allotted on the basis of proposals, which are solicited twice a year from the scientific community. Proposals are sought for an allotment of computer time to be used at the LBL Computer Center or elsewhere upon approval of both the NRCC Program Committee and NRCC Policy Board. Proposals may be from any field of chemistry and should promote the development of chemistry through: the advancement of computational methods; the innovative application of existing methods to problems in some frontier area of chemistry; the study of problems of significant scientific merit that cannot be carried out in the proposer's institution due to lack of large-scale computional facilities; and the resolution of interdisciplinary approaches to forefront problems in chemistry.

VISITOR PROGRAM

We feel that an effective way to assist the development of computational methods in chemistry is to bring interested scientists to the NRCC for periods ranging from weeks to months so that they may interact with the in-house staff and with each other. To assist this effort, we provide limited support for

- Short-term appointments of Senior Visiting Fellows,
- Research workers who need to spend from a few weeks to a few months working on a project,
- Longer term sabbatical visitors,
- Postdoctoral appointments.

Inquiries are welcomed by the NRCC Director.

Both outgoing Division Head, Bernard G. Harvey, and I, as incoming head, see a division as an organizational framework – as slender as possible – that encourages and supports the most imaginative scientific work. It acts as a buffer between the productive scientist and the demands that the outside world would make on his or her time. It provides administrative support so that scientists need not become legal or financial experts. But most of all, the ideal division is a collectivity of people with common interests and ambitions, interacting with one another in a constructive and scholarly way to bring out the best in everybody. What is the role of the division head? First, he is responsible for the administrative functions, but with a staff as competent as ours in the Nuclear Science Division this is no problem at all. Second, while knowing what is happening today on the scientific front, he must always be concerned with the near and distant future, trying to lead the division towards long-range plans and building a consensus around them. This involves not only plans for new accelerators and major equipment but – far more important – the bringing in of the best possible young people who will become the leaders of nuclear physics and of our division in the future.

Joseph Cerny

Joseph Cerny
Head, Nuclear Science Division
Associate Director, LBL

*Joseph Cerny
LBL Associate Director
Head, Nuclear Science Division

Division Administration
Olivia Austria
Eileen Eiland
Wanda Smith-Burnett

Division Staff
Juha Aysto
Ernestine E. Beleal
John Boguta
John E. Bowen
Mark D. Bronson
Edgardo Browne-Moreno
David J. Clark
Homer E. Conzett
Janis M. Dairiki
Richard M. Diamond
Claude E. Ellsworth
Richard Firestone
Hubert Flocard
Erwin M. Friedlander
Jorge V. Geaga
Albert Ghiorso
Norman K. Glendenning
Richard A. Gough
Douglas E. Greiner
Charles R. Gruhn
Hans H. Gutbrod
Miklos Gyulassy
John W. Harris
Bernard G. Harvey
Harry H. Heckman
David L. Hendrie
E. Susana Hernandez
Chin-Cheng Hsu
Won Mok Jae
S. Kenneth Kauffmann
Heinz H. Kluge
Che Ming Ko
Masahiro Koike
Ruth-Mary Larimer
Donald F. Lebeck
Diana M. Lee
Matti E. Leino
Richard G. Leres
Peter J. Lindstrom
Karl H. Luehrmann
Albert Lumbroso
Jeannette E. Mahoney
Michael R. Maier
George Mantzouranis
Creve C. Maples
Grant J. Mathews
**Luciano G. Moretto*
David J. Morrissey
Terry Mulera
Martin Murphy
William D. Myers
Shoji Nagamiya
J. Michael Nitschke
Cornelius Noack
Matti J. Nurmia
Jean Peter
Arthur M. Poskanzer
**P. Buford Price*
Howel Pugh
William Rae
Jorgen Randrup
**John O. Rasmussen*
William H. Rathbun
Martin G. Redlich
Hans Georg Ritter
Herbert Ruck
Andres Sandoval
Lee S. Schroeder
**Glenn T. Seaborg*
Shuang-Hui Shih
Virginia A. Shirley
Claire A. Shuck
Herbert E. Stelzer
Frank S. Stephens
Wladyslaw J. Swiatecki
T. James Symons
Isao Tanihata

Lawrence Berkeley Laboratory has been a leading center of nuclear science research for four decades. Most of the activity in our Nuclear Science Division today centers on heavy-ion studies conducted at three of the Laboratory's accelerators; the Bevalac, the SuperHILAC, and the 88-Inch Cyclotron.

The division's research activities are carried out by 35 staff scientists, approximately 20 postdoctoral researchers, 25 graduate students, and visitors from other institutions in the United States and foreign countries.

A productive interaction takes place between the experimentalists, nuclear theoreticians, excellent mechanical and electrical engineering, outstanding computer capabilities, and of especial value, the Department of Instrument Techniques. In short, the Nuclear Science Division has the staff and tools to open up entirely new fields of nuclear physics.

Nuclear research involves the study of nuclear reactions and nuclear spectroscopy; that is, how nuclei interact upon collision and scattering, and what the properties of the nuclear states are. There are important types of information to be obtained from reaction studies at all energies, from the Coulomb barrier to many GeV/nucleon. (The Coulomb barrier is the energy level of the nuclear force surrounding the nuclear mass, which an impacting particle must exceed if it is to penetrate the nuclear mass.) So it is advantageous to have available as large an energy span as possible, and with the 88-Inch Cyclotron, the SuperHILAC, and the Bevalac, we obtain an almost continuous range of projectile energies.

At the barrier, Coulomb excitation of the colliding nuclei is apt to be the main process, though the transfer of individual nucleons between the nuclei can also take place. The probability of the latter process increases with bombarding energy as a larger proportion of the nuclear surfaces overlap in the collision. If the target and projectile are not too large, the main result for energies above the barrier up to 10 to 20 MeV/nucleon is that the nuclei fuse into a compound system. This compound nucleus then gives up its excess excitation by evaporating a few nucleons and finally emitting a cascade of γ-rays. However, when the product of the atomic numbers of the target and projectile is quite large (high Coulomb barrier) or when higher bombarding energies are used for smaller target-projectile combinations (high centrifugal barrier), the nuclei fail to fuse and may undergo a "deeply inelastic scattering" in which appreciable amounts of the initial kinetic energy and orbital angular momentum of the reactants are transformed into excitation energy and spin of the two product nuclei. At the same time, although there may be large exchanges of mass and charge, target-like and projectile-like nuclei finally emerge.

At still higher bombarding energies, a violent central collision results in an explosion in which the two reactants disintegrate into a large number of pions, protons, neutrons, and larger fragments of nuclear matter. Our studies of these different reaction processes constitute a major part of the research activity in the Nuclear Science Division.

Nuclear spectroscopic research usually involves the lower end of the projectile energy scale; for example, Coulomb excitation studies below the Coulomb barrier, or heavy-ion in-beam γ-ray spectroscopy of discrete states or of the continuum of states above the observed discrete ones, or pick-up and stripping reactions. And we are initiating some exciting studies using high-energy heavy-ion projectiles to make nuclei far from stability (see below). So again, here in spectroscopic studies, these three accelerators are playing a role in nuclear research in the division.

RESEARCH WITH LOW-ENERGY IONS

The 88-Inch Cyclotron provides beams of particles ranging from protons to calcium, and the SuperHILAC yields beams of ions on up to lead (uranium will be available after the third injector is completed). Projectile energies range from a few MeV/

Staff Continued

Karl A. Van Bibber
Anthony Warwick
Howard H. Weiman
Gary D. Westfall
Gordon J. Wozniak
Alfred A. Wydler
Michael S. Zisman

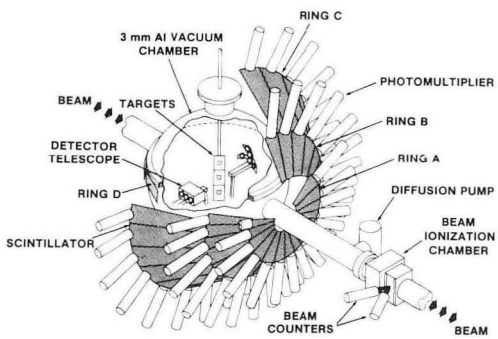
*UCB faculty member

nucleon to 30 MeV/nucleon of light ions (Cyclotron) and to 8.5 MeV/nucleon (SuperHILAC). These energies in some cases overlap, in others nearly overlap with the lower energy range of the upgraded Bevalac when it is completed. In addition, the Cyclotron provides polarized beams of protons and deuterons in which the spins of the projectiles are preferentially oriented in a particular direction. Such beams permit us to study the fundamental processes involving few-nucleon systems and weak interactions. The 100 percent macro duty-cycle of the Cyclotron is very favorable for the complex coincidence experiments now being performed, while the short micropulse ($\leqslant$ 1 nanosecond) of the SuperHILAC is advantageous in time-of-flight experiments.

Nuclear Structure

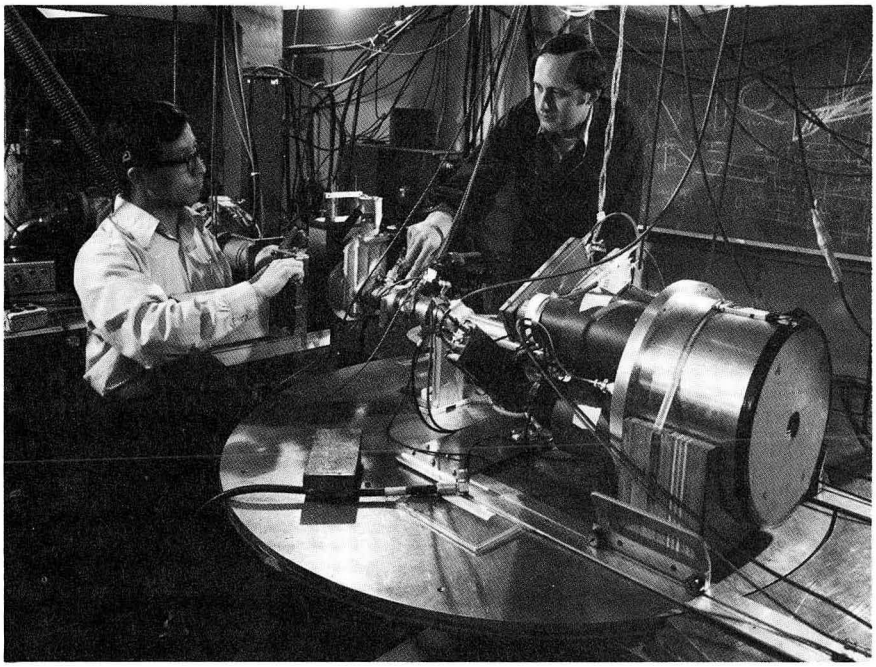
As mentioned, Coulomb excitation is one way we create an excited nucleus so we can study its discrete states. Because such an interaction is purely Coulombic, very important nuclear quantities – the transition probability between two states and the static quadrupole moment – can be determined from relatively simple electromagnetic calculations. This is also the only method by which we can excite high-spin states in most stable nuclei. It thus complements the more usual in-beam spectroscopy that uses a heavy-ion, γxn reaction and generally leads to neutron-deficient products from medium and heavy targets. As a result of recent Coulomb excitation studies on the nuclei in the osmium-platinum transition region where nuclei change from football-shaped to pancake-shaped, it would appear that these nuclei are not as soft toward asymmetric deformation normal to the nuclear symmetry axis as most potential-energy surface calculations indicate.

When a compound nucleus is formed by the fusion of projectile and target nuclei, most of the excitation is used to evaporate a few neutrons while the final amounts of energy are released through the emission of γ-rays. Present-day detectors do not have sufficient energy resolution to differentiate the individual γ-rays, which contain all the information available to us about the properties of nuclei in these high-spin states. So we use "old-fashioned" NaI counters (because they can be large and so give good efficiency, though not good resolution), but we use them in new ways, as in multiplicity-counter arrays and in very large (13″ × 8″) total γ-energy spectrometers. With such tools, researchers have shown that during these high-spin γ-ray cascades, some (non-spherical) nuclei undergo almost rigid rotation like a linear molecule, while others—more spherical—decay by transitions from one excited particle state to another with little indication of any collective motion. This latter behavior leads to a slower decay process, even to the existence of isomeric "traps" along the route. These types of studies are very exciting right now, with many experiments taking place here and in other laboratories in the U.S., Europe, and Japan.



Scattering chamber experiment. In this multiplicity-counter array, eight plastic scintillation counters surround the chamber and detect nearly all the particles coming from nuclear reactions with heavy ions.

This γ-ray spectroscopy of the continuum is neatly complemented by high-resolution particle studies of inelastic scattering of (light) heavy ions with a magnetic spectrometer at the Cyclotron. In these experiments we study the elementary modes of vibration of a nucleus. The well-known giant dipole vibration of neutrons and protons against each other is now supplemented by other giant quadrupole, hexadecapole, and higher vibration modes. The collective energy so injected into a heavy



Visiting scientist Shih Shuang-Hui, from the People's Republic of China, and LBL's Don Hillis prepare a large total gamma-energy sodium iodide spectrometer for continuum gamma-ray spectra studies.

The HISS Group (left to right): Fred Bieser, Margaret Banks, Hank Crawford, Ishmael Florez, Doug McParland, Doug Greiner, Peter Lindstrom, Doug Tuttle. The Heavy Ion Spectrometer System (HISS) developed by the group will permit simultaneous study of more than one nuclear particle.

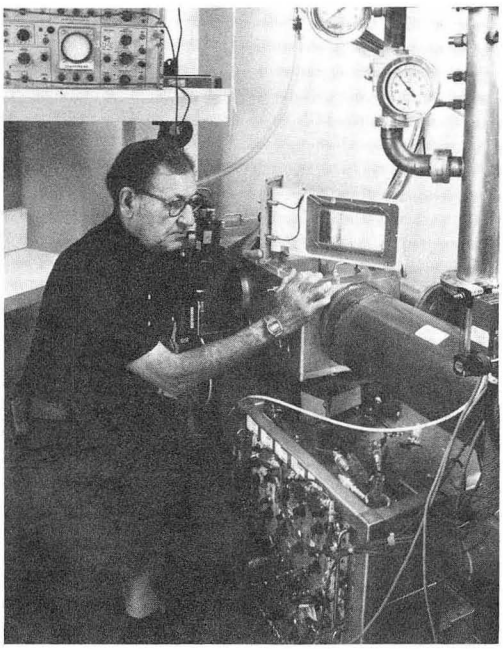
nucleus can also be followed by coincidence techniques that detect its release into the fission channel, offering new insights into the dynamics of fission.

With targets of light nuclei, certain transfer reactions can yield new neutron rich nuclei and can preferentially populate highspin states. For example, at the 88-Inch Cyclotron we have populated the ^{20}O nucleus in the 4^+, 2^+, 0^+ states using the $^{18}O(^4He, {}^2He)^{20}O$ reaction.

Exotic Nuclei and Heavy Elements

Only a fraction of the possible nuclei with measurable lifetimes have been made, and most of these cluster around the line of stability. We are using a number of different techniques, including exotic transfer reactions, rare radioactive heavy-element targets, and relativistic-energy heavy-ion beams, to explore the as-yet-unknown regions of the periodic table. Researchers at the Cyclotron are determining the properties of light nuclei having unusually high neutron-to-proton ratios. These experiments test theoretical mass formulae and the general symmetry principles of the nuclear interaction. An isotope separator known as RAMA (recoil atom mass analyzer) is capable of mass analysis of exotic nuclides with half-lives as short as 50 milliseconds for many of the chemical elements. With RAMA, new radioactive decay modes such as proton radioactivity, or the predicted but still undiscovered two-proton radioactivity, can be investigated.

Our Heavy-Element Research Program centers on the synthesis of transuranic elements and the yet-to-be-found superheavy elements, as well as on clarifying the systematics of the reaction mechanisms between heavy nuclei (for the purpose of synthesis) and the systematics of heavy-element decay processes (so we can reliably predict the properties of the nuclei being sought). Chemical elements become increasingly difficult to make, identify, and study as they have shorter lifetimes, calling for the continued development of increasingly complicated and specialized apparatus. One such example is SASSY, a small-angle separator system at the SuperHILAC, another type of recoil mass separator.



Al Ghiorso in the counting area of SASSY.

Nuclear Reactions

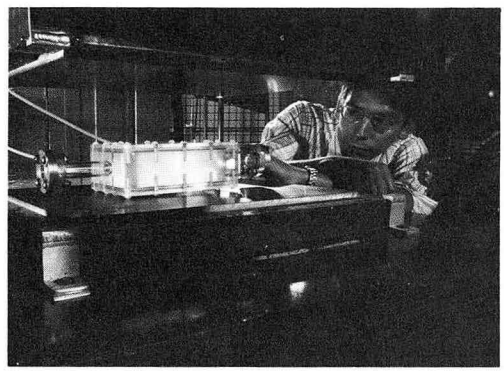
The reaction mechanism receiving major attention by many users at the Super-HILAC, and 88-Inch Cyclotron, is the so-called "deeply inelastic scattering (or reaction)" (DIR). In this process, relatively heavy projectile and target nuclei collide, and (if not too heavy) may even rotate a little together; they do not fuse, but quickly separate into two fragments again. During their brief contact, much of the initial kinetic energy and orbital angular momentum is transformed into excitation energy and spin of the final fragments; a large number of nucleons may be exchanged, thus changing the mass and charge considerably from those of the initial reactants. We measure, in time, the progress toward equilibration by using the rotational angle of the temporary two-nucleus molecule as a built-in nuclear clock, ticking on a time scale of the order of 10^{-22} seconds.

There is great interest in determining the underlying microscopic mechanism for these transformations. Two major processes have been proposed, namely, that vibrational waves on the particle surfaces (giant resonances) are excited in the collision, or that particle exchange is the origin of the relaxation processes. Our experimenters are busy trying to determine the answer, and it appears likely that both mechanisms occur. We also have questions involving sequential fission of one or both fragments, if they are heavy enough; problems having to do with the emission of high-energy nucleons in the forward direction; and the degree of alignment of the fragments with respect to an axis normal to the reaction plane. All told, a very large effort is going into our search for clarification of the deeply inelastic processes.

The evolution of these reactions to the limit where there is insufficient time for diffusion to occur can just be reached at the Cyclotron. Rapid changes occur when the collision time becomes comparable to the intrinsic time of nucleonic motion within the nucleus; this is associated with the Fermi energy of $\approx$35 MeV/nucleon. We are studying the global features of the heavy-ion interaction up to this limit, using broad-range devices such as a small streamer chamber recently brought into operation at the Cyclotron. Beyond the Fermi energy, reaction mechanisms are more characteristic of relativistic heavy-ion collisions, which are under investigation at the Bevalac.

Another group in the Nuclear Science Division is using radiochemical techniques to study the transitions between the different reaction mechanisms over the entire range of bombarding energies available. That is, we are interested in outlining for heavy targets the shift from fusion to deeply inelastic reactions as a function of bombarding energy and projectile size.

Still another group here is interested in the dependence of the basic nucleon-nucleon interaction on the relative orientation of the nucleon spins. That is, the interactions of nucleons and deuterons with various nuclear systems may be spin-dependent. For these experiments, the beam particles are polarized, and the spin orientation controlled and preselected. The cross sections are measured for selected spin states. An important goal of the pro-



Karl Van Bibber peers into the jaws of the Jupiter magnet at the 88-Inch Cyclotron where the small streamer chamber is being installed to permit observation of collision reactions occurring with beams up to 35 MeV/nucleon.

gram is to investigate the effects on polarization observables that follow from particular symmetries of the nuclear interaction, such as charge symmetry and parity conservation. We are also investigating the parity-violating weak interaction components in the nucleon-nucleon force.

Ion-source development is the heart of improving the performance of heavy-ion accelerators and is critical to the subject of nuclear reactions. So the Nuclear Science and the Accelerator and Fusion Research (AFR) Divisions are collaborating currently on the development of an improved axial injection source for the Cyclotron. During the next two years these two divisions will be collaborating on a more advanced source based on the electron beams ion source principle, which should double the energy of the heavy-ion beams and greatly increase their intensity. Likewise at the SuperHILAC, the AFR Division is constructing a third injector, which should provide reliable beams of ions through ^{238}U at much greater intensity than is currently available.

ISOTOPES PROJECT

A traditional and important function of the division, the systematic compilation and publication of nuclear structure data, is carried out by the Isotopes Project. In 1978, the group published the 7th edition of the *Table of Isotopes,* following a seven-year compilation effort. This massive, 1600-page book includes properties for the more than 2600 known isotopes; it has quickly become an indispensable reference source for nuclear physicists and chemists involved in basic research and for applied users of radioactivity in industry, medicine, and other fields. The Isotopes Project subsequently published Nuclear Wallet Cards, a pocket-size offshoot of the *Table of Isotopes* that provides scientists with some of the most frequently used atomic and nuclear properties.

The Isotopes Project is currently coordinating its compiling efforts with similar groups at other laboratories as part of the National and International Nuclear Data Network. The library and reference files, carefully maintained by the group for its compiling work, provide members of the Nuclear Science Division with extremely convenient and up-to-date bibliographic information.

THEORY

It is the task of our nuclear theorists to digest the enormous amount of information accumulated over the years and to try to fit the new results into the framework that has been developed for understanding nuclear properties. For this purpose they use all the mathematical tools of modern science and the computational power of the Laboratory's large computers.

In spite of its small size, which results in some degree of specialization, this group pursues a relatively broad range of interests. Most of the current work concerns the nature of the reactions that result when nuclei collide with each other. To match the facilities at the Laboratory, these collisions are studied over an enormous range of energies.

At the lower end of this range, nuclei collide, exchange some particles and energy, then separate again. These deeply inelastic collisions promise to be even more useful

Miklos Gyulassy leads a weekly meeting of the nuclear theory group. Pictured in this international group of scientists are: Miklos Gyulassy, Jorgen Randrup, Norman Glendenning, Ester S. Hernandez, George Mantzouranis, Che-Ming Ko, Bernard Ramaud, Joe Kapusta.

than nuclear fission in revealing the large-scale collective properties of nuclei. Recently the Theory Group developed the one-body theory of nuclear dissipation, a theory which predicts that in many situations nuclei ought to exhibit highly damped (super-viscous) characteristics. It also predicts a specific "creeping" behavior of nuclei in the process of fission, and it has been applied to the interpretation of deeply inelastic collisions. It has been extended further to the calculation of transport coefficients in the diffusion treatment of nuclear interactions.

At high energies, where the collision takes place too rapidly for the nuclei to respond smoothly, there is the possibility of shock waves, density build-ups, and fragmentation. At these energies the collision process is often described in terms of "abrasion-ablation" or in terms of the "fireball" and "firestreak" models; these seem to provide a semi-quantitative understanding of the main features of a high-energy nucleus-nucleus collision. We are attempting to account for the finer features through non-statistical aspects of the collisions, while continuing to formulate a quantum many-body theory of scattering appropriate for a detailed description of such inclusive processes. Already the "fireball" model has been derived from such a fundamental theory in a suitable approximation.

In addition to developing models of nuclear collisions based on known ingredients such as nuclear geometry and nucleon-nucleon scattering, the Theory Group is also carrying out speculative studies on possible exotic collective phenomena at high nuclear densities. These speculative studies include the role of pionic instabilities on the scattering dynamics and the experimental signatures of such phenomena.

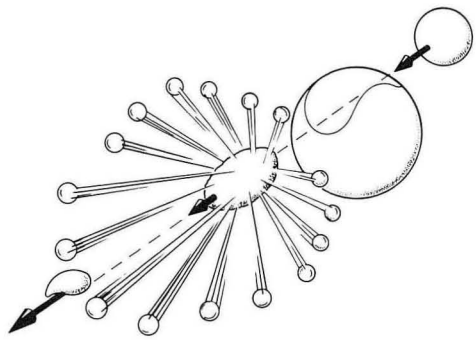
When we consider collisions of even higher energy, particle production begins to play an important role. In this fascinating new region, nuclear physics begins to overlap with high-energy particle physics.

We hope eventually to be able to study the nuclear equation of state at high density and excitation energy; at sufficiently high energies, the quark structure of the nucleons themselves should become manifest in nucleus-nucleus collisions. In this way the extension of nuclear physics to the relativistic regime should throw light on the next level of the quantum structure of matter and provide tests for the emerging theory of quantum chromodynamics.

RESEARCH WITH HIGH-ENERGY IONS

Our study of relativistic heavy-ion reactions at the Bevalac has focused on head-on nuclear collisions, which are selected by requiring that a large number of fragments are produced. Our goal in these studies is to observe nuclear matter at high density and temperature in order to learn about the equation of state of nuclear matter.

One group of our nuclear scientists, in collaboration with Japanese researchers, has measured the high-energy protons and



LBL researchers working at the Bevalac have developed this picture of what takes place when a highly energetic neon-20 ion collides with a uranium target nucleus. Nucleons in the area of impact momentarily fuse together forming a "nuclear fireball," which then decays in an explosion of particles. Calculations indicate that the fireball reaches a temperature of 50 million electron volts—the hottest nuclear matter ever seen.

pi mesons produced in such collisions. We can interpret the spectrum of the energies of these particles in terms of the temperature of the matter produced in the collision: the protons exhibited an appreciably higher temperature than did the pions. This has now been interpreted in terms of a blast wave from the compressed nuclear matter. The idea is that protons of the same energy as pions have lower thermal velocities because they are heavier. Thus a blast velocity, added to the thermal velocity, affects the protons much more than the pions, giving the protons the appearance of a higher temperature.

In collaboration with German scientists, another of our groups has been studying the emission of light fragments and positive pions in relativistic nuclear collisions. For the case of an ^{40}Ar beam bombarding a ^{40}Ca target, we have observed an enhanced yield of positive pions in the sideward direction. Standard models for relativistic nuclear collisions offer no explanation for this effect.

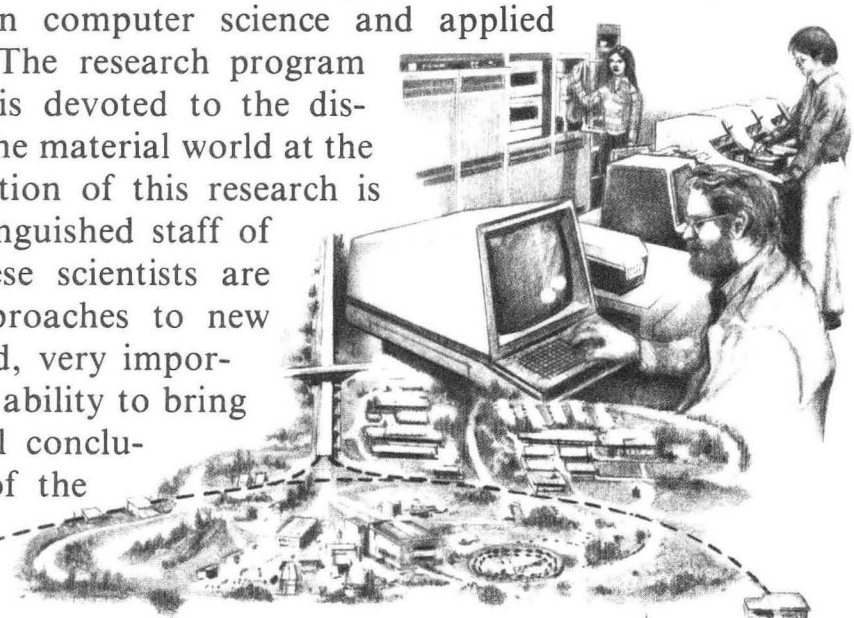
This same group measured the production of heavy fragments ($Z \sim 26$) and found that they tended to be emitted on the opposite side of the beam from the fast, light particles. This observation is consistent with a hydrodynamic description of the reaction and may lead to information about compression effects.

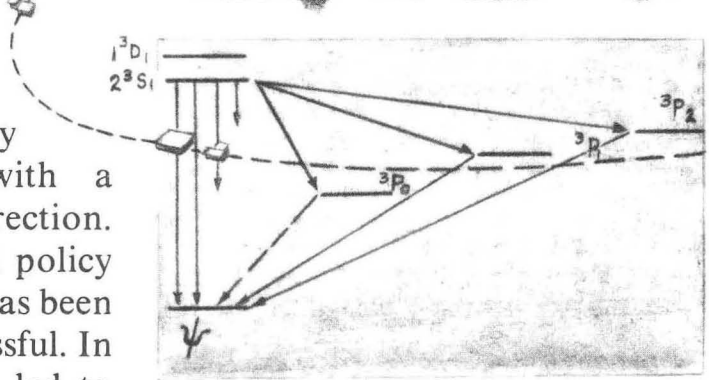
Fragmentation of high-energy heavy-ion beams is another promising technique for producing isotopes far from stability. At the Bevalac, experimenters have already identified many new nuclides by using ^{40}Ar and ^{48}Ca beams. This technique will increase in importance as heavier beams become available there.

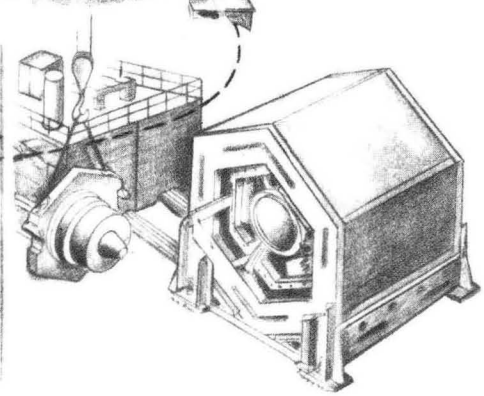
In a collaboration between Michigan State University and LBL scientists, we have observed positive and negative pions emitted along the beam direction. A startling peak was observed in the negative-pion yield, with a corresponding small decrease in the positive-pion yield. The velocity of the pions was the same as the velocity of the beam, indicating that the peak was due to very slow pions emitted from the projectile. The explanation we are pursuing is that the negative pions are temporarily bound in atomic orbitals around the projectile, which greatly enhances their yield.

Many other studies are in progress at the Bevalac, which we hope will clarify these very complex reactions and reveal the secrets of nuclei.

The major research activity of the Physics, Computer Science and Mathematics Division is in the field of high-energy particle physics. Other physics research is devoted to medium-energy particle physics, nuclear science, astrophysics, and astronomy. In addition, there is a strong program in computer science and applied mathematics (CSAM). The research program in high-energy physics is devoted to the discovery of properties of the material world at the deepest level. The direction of this research is determined by the distinguished staff of physicists at LBL. These scientists are renowned for their approaches to new research possibilities and, very importantly, for their unusual ability to bring such plans to successful conclusion. It is the policy of the division to encourage this creativity and to maintain an atmosphere in which it can flourish by management with a minimum of direction. This traditional policy of the division has been eminently successful. In the past, it has led to decisive work on particle physics, and at present to plans for further important experiments, to be carried out at our national laboratories and facilities. LBL has an especially close relationship with the Stanford Linear Accelerator Center (SLAC) with which we are engaged in the construction of the Positron-Electron Colliding Beam Project (PEP). PEP, as a national facility, offers unique opportunities for fruitful experimental research, and the LBL program is aimed at fully exploiting them. As a consequence the major and most important portion of our experimental work for the next few years will be carried out at PEP when it becomes operational in the fall of 1979. The CSAM department, which is semi-autonomous, engages in research in mathematical and computational areas, in computer networking, database management and graphics, and simultaneously provides service to other divisions of the Laboratory. The association with the Physics Division proves fruitful for both areas.







Robert W. Birge

Robert W. Birge
Head, Physics, Computer Science and Mathematics Division
Associate Director, LBL

Physics, Computer Science and Mathematics

Robert W. Birge
LBL Associate Director
Head, Physics, Computer Science and Mathematics Division

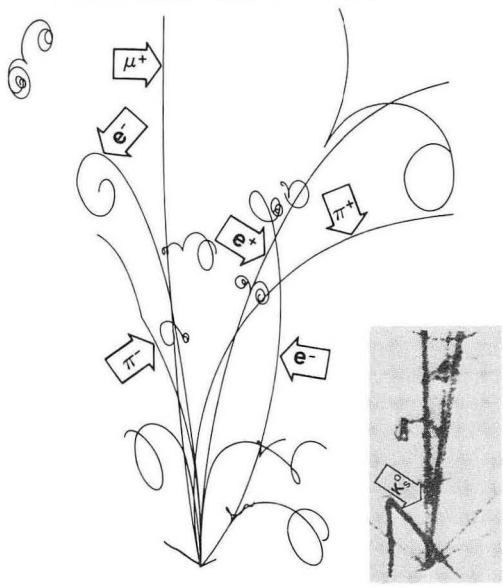
Division Administration
Jane Kennedy
P. Wes Weber
Gary Williams

Division Staff
Physics
Gerald Abrams
Teri Ahmadvand
Norman Andersen
Frances Armstrong
**Korkut Bardakci*
Josephi Barrera
Charles Berman
Harry Bingham
Kenneth Birman
James Bistirlich
Donald Blackman
Craig Blocker
James Bowlby, Jr.
Donald Briggs
Arlette Brink
Sharon Buckingham
Dessa Bucksbaum
Andrew Buffington
James Burge
Robert Cahn
William Carithers, Jr.
John Caron
**Owen Chamberlain*
Michael Chanowitz
Angela Cheer
Denyse Chew
**Geoffrey Chew*
**William Chinowsky*
Alan Clark
Carl Clawson
Mark Coles
Susan Cooper
Charles Covey
**Frank Crawford, Jr.*
**Kenneth Crowe*
Mark Cutter
Orin Dahl
Tim Daly
Julia Davenport
Christopher Day
Philipp Deforcrand
Melvin Deneau
William Dieterle
John Dillon
Bruce Director
William Dodge
Mark Eaton
Philipp Eberhard
Mark Elola
**Robert Ely, Jr.*
David Fancher
David Favot
Joseph Feller
Neil Fleishon
Curt Flory
Simon Fok
Abraham Fong
Marguerit Fox
Seth Fraden
Christina Frank
Daniel Friedan
Miguel Furman
Raymond Fuzesy
Angela Galtieri
Margaret Garnjost
George Gibson
George Gidal
**Gerson Goldhaber*
Frederick Goozen
Christina Graham
Deborah Haber
Howard Haber
Nicholas Hadley
Ray Hagstrom
**Martin Halpern*

LBL's research activity in high-energy physics is part of a world-wide effort aimed at determining the ultimate structure of matter. Our work here is the modern extension of an endeavor that started with pure speculation four millenia ago, but only began to bear the rich fruit of solid scientific information a little more than a century ago when the periodic table of the chemical elements was devised.

This table of elements represents a certain dynamic order of nature, and from the outset, missing entries led to the search and discovery of these new elements as well as to profound understanding of chemistry, the science that has so enriched life. An even deeper knowledge of atomic physics has been achieved during the past sixty years, and it is fair to say that all the technology, biology, and medicine of the present rest on this base of pure knowledge.

In addition to the experimental research in high-energy physics planned for PEP, other work will be carried out with the particle accelerator at Fermi National Accelerator Laboratory (FNAL), Brookhaven National Laboratory (BNL), and other laboratories. Our physicists carry out extensive planning and design of these experiments here at LBL. In this work there is a rich interplay between experiment and theory, since new experiments lead to new developments in theory, which in turn point to the most probable directions for future fruitful experimental research. Specifically, our research at LBL is concentrated on the weak, electromagnetic, and strong interactions between particles that are ultimately responsible for the properties of matter.



A rare neutrino-induced event seen in an LBL collaborative experiment in the Fermilab 15-ft bubble chamber. The event produced four leptons: two electrons, one positron, one muon, a $K_S^0 \rightarrow \pi^+\pi^-$ decay, and multiple gammas. The inset provides a magnified view of the vertex and shows the leptons originating at the vertex and the K_S^0 decay.

In our experimental research in medium-energy physics, we are studying basic nuclear interactions and nuclear structure using mesons, nucleons, and light nuclei in scattering and radiative capture experiments. Most of this research work is carried out at the Los Alamos Meson Production Facility (LAMPF) and the Tri-University Meson Facility (TRIUMF)at the University of British Columbia, where intense pion beams are available.

We maintain a small, but highly significant program in astrophysics and astronomy. Three very important consequences of this work are the measurement of the anisotropy of the primordial blackbody radiation, the development of the "rubber mirror," and the first precise measurement of the mass of a neutron star. LBL scientists have now shown that our galaxy is moving toward the constellation Leo at a speed of 600 kilometers per second. This has raised profound questions in cosmology.

HIGH-ENERGY PHYSICS

Our planned research on e^+e^- annihilation includes three collaborative experiments in which LBL plays a major role. These are the Time Projection Chamber (TPC), the Mark II Magnetic detector and the Free Quark Search. It is highly significant that these experiments have been selected by an independent expert com-

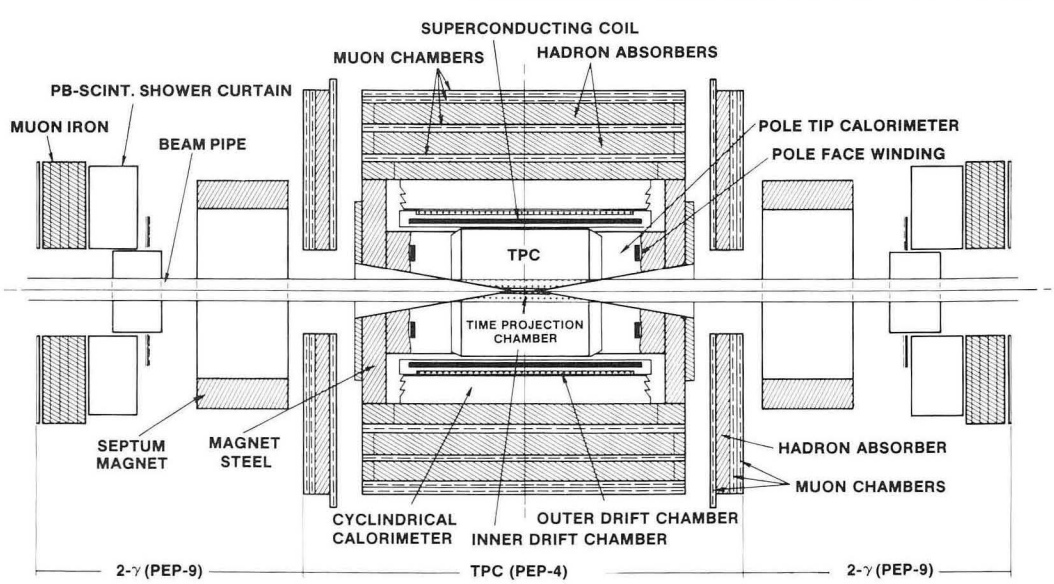
Staff Continued

Robert Hamilton
Andrew Hanson
Philip Hanson
Peter Harding
**A. Helmholz*
Ian Hinchliffe
Charles Horne
Leslie Hunt
**John Jackson*
Patricia Johansen
Walter Johansen, Jr.
Karl Johnson
Colleen Johnson-Joy
Donna Jones
**David Judd*
John Kadyk
**Selig Kaplan*
Omer Kaymakcalan
Robert Kelly
Robert Kenney
**Leroy Kerth*
June Kinoshita
Simcha Knif
Werner Koellner
Beverly Koop
Andrew Lankford
John Lauderdale
Edward Lee
Joseph Lepore
Michael Levi
Shao-Sh Lin
Stewart Loken
Michael Long
Michael Losty
Patricia Low
Elaine Lucas
Lora Ludwig
Gerald Lynch
Jeremy Lys
Ronald Madaras
Paul Madden, Jr.
Richard Majka
**Stanley Mandelstam*
Thomas Markiewicz
Philip Martin
Charles Martoff
Jay Marx
Terry Mast
Earl McCann
Peter Meyers
John Middleditch
James Miller
Jeanne Miller
Ross Millikan
Ali Mireshghi
Leonard Mlodinow
Susan Moore
Richard Muller
Irene Muskovich
Leslie Nakae
Jerry Nelson
Mark Nelson
Peter Nemethy
Luanne Neumann
Timothy Nuzum
David Nygren
Piermaria Oddone
Arthur Ogawa
John Orthel
Chan Pang
Barrie Pardoe
James Patrick
†Victor Perez-Mendez
Georgella Perry
Juan Porcar
Morris Pripstein
Gerald Przybylski
Ting Pun
Eliezer Rabinovici
Paul Reinsch
Wendy Reynolds
Harriet Rice
Robert Riddell
Alan Rittenberg
Peter Robrish
Michael Ronan
**Ronald Ross*
Allan Sagle

mittee to be carried out in three of the five experimental areas at PEP when it becomes operational. The TPC is a radically new concept for particle identification and measurement that requires an extensive computer facility. Physicists, engineers, and highly-skilled technicians have been devoted to its development and construction. It is the central component of a powerful PEP detector for particle identification over the entire momentum range for electrons, pions, kaons, and protons. This detector will provide us with exceptionally broad sensitivity in the search for new phenomena anticipated at PEP energies. It consists of four major functional systems: the TPC, a superconducting solenoid magnet, an electromagnetic calorimeter, and a muon detector. With this facility we expect to maximize the useful information content per event at acceptable cost, and to greatly enhance the understanding of e^+e^- annihilations in the PEP energy range.

In the last few years, many of the major new developments in high-energy physics have come from coupling electron-positron storage rings with powerful and flexible detectors. The SLAC-LBL Mark I detector, with the lead-glass wall, at the SLAC Positron Electron Accelerator Ring (SPEAR) demonstrated convincingly the power of these techniques. As a result, a new magnetic detector of substantially greater sophistication, Mark II, was built in collaboration with SLAC and installed at SPEAR. It has been moved to PEP where exploratory work is planned using the much higher energies to be available there. Early observations at SPEAR energies show a clear step in baryon production near 5 GeV, which strengthens our earlier results obtained with the Mark I detector, and may correspond to a threshold for charmed baryon production. At PEP the Mark II detector is being made ready to search for new charmed objects such as the charmed baryon, Λ_c, to study jets and τ leptons, to scan the total cross section between 3.8 and 5 GeV, and to search for F mesons.

Present day experimental results in high-energy physics could largely be explained if the as-yet-unseen free quarks were identified as being the fundamental building blocks of elementary particles. PEP opens up a new domain for this search. We are



The Time Projection Chamber is the central component of the PEP-4 facility. Its exceptional sensitivity range may open new vistas in high-energy physics.

Stuart Samuel
Laura Scales
Stephen Schnetzer
Gerald Schnurmacher
Particia Schoenfield
Stephen Shannon
**Gilbert Shapiro*
Marjori Shapiro
Douglas Shigley
Garth Smith
Wesley Smith
Robert Smits
George Smoot, III
Henry Stapp
**Herbert Steiner*
**M. Lynn Stevenson*
James Strait
**Mark Strovink*
**Mahiko Suzuki*
Gene Szemanski
Kwok-Ch Tam
John Taylor
Lois Tinay
**George Trilling*
**Robert Tripp*
Thomas Trippe
Chin-Py Tzeng
Jerry Van Polen
Harold Van Slyke
Eric Vella
Vincent Vuillemin
Tony Vuletich
John Waters
**Kenneth Watson*
Thomas Weber
William Wenzel
Edgar Whipple
Pamela Wiedenbeck
Clyde Wiegand
Joel Wissmar
Charles Wohl
Philip Yau
William Zajc
Farshid Zarbakhsh

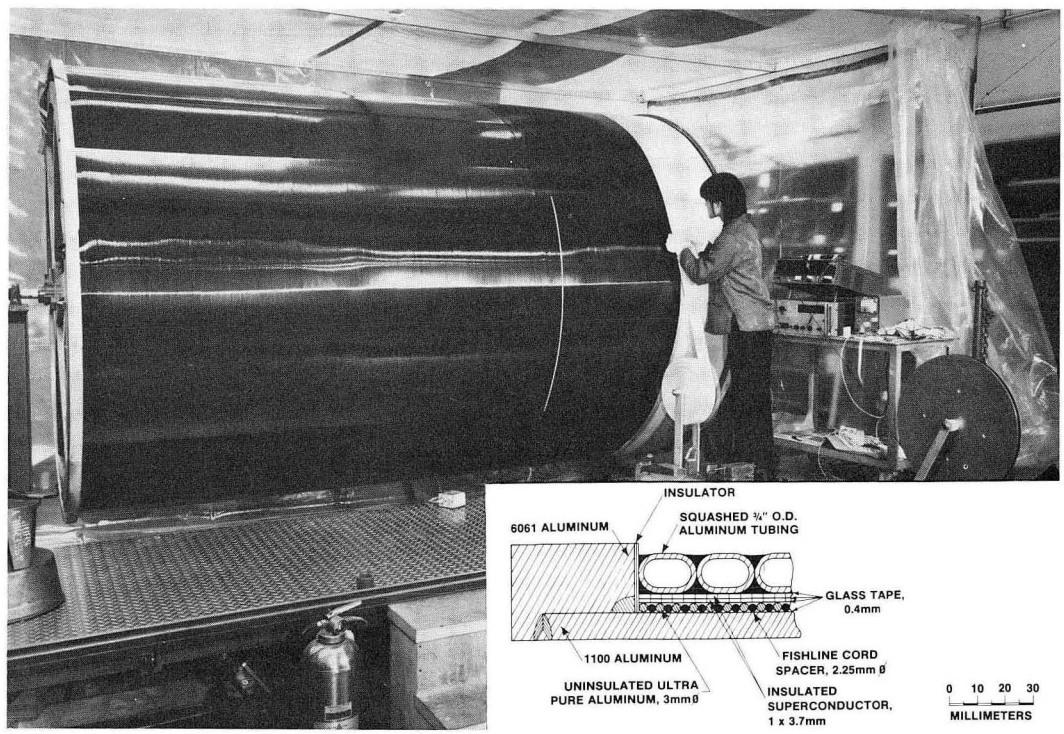
Computer Science and Applied Mathematics
Carole Agazzi
Herbert Albrecht
Norman Albright
Rosemary Allen
Donald Austin
**Herbert Baskin*
William Benson
Victor Brady
Noel Brown
Bruce Burkhart
Deborah Cahn
Shirley Cassinelli
Chun-Fa Chan
Paul Chan
**Alexandre Chorin*
Thomas Clements
Elon Close
Tricia Coffeen
Phillip Colella
John Colonias
**Paul Concus*
Peter Cook
Donn Davy
Shirley Dawson
Susan Eggers
Sheldon Furst
Isabell Gee
Fredric Gey
Helena Gin
William Greiman
**Alberto Grunbaum*
**Ole Hald*
Dennis Hall
Paula Hawthorn
Robert Healey
Valerie Heatlie
Bradford Heckman
Ruth Hinkins
William Hogan
Harvard Holmes

readying a simple detector to respond to quarks of mass up to the maximum PEP energy of 15 GeV and with such sensitivity that a negative result will raise serious doubt about the existence of these hypothetical objects. This quark detector will be capable of detecting quarks even if produced within a jet of hadrons.

Experiments on rare muon-induced reactions are now underway at FNAL. Preliminary analysis has shown that a full data sample includes on the order of 10^6 deep inelastic muon scattering, $10^5 \psi \rightarrow \mu^+\mu^-$ decays, and 2×10^6 examples of muon-induced extra muon production. At these high statistical levels, finely detailed analyses are meaningful, and we anticipate further results with increased scope and precision. So far, we have considerably increased our understanding of these processes. We have identified ψ production through virtual photon diffraction off nuclear, nucleon, and "quark" targets, and measured the respective cross sections. In addition, we have obtained unmistakable evidence of final states containing more than 3 muons.

The interactions of neutrinos and antineutrinos are being analyzed from film we have taken at the FNAL 15-foot bubble chamber. The hadronic behavior of dimuon and μe events appears to be consistent with the production of charmed mesons and their semileptonic decay. A search for effects of the hypothetical gluons of quantum chromodynamics in new physics research involving neutrino interactions of high-momentum transfer is now underway.

The elastic scattering of charged pions and protons by a polarized proton target has been studied to determine the polarization effects for incident $\pi^+\pi^-$ and for protons of momenta 100 and 200 GeV/c.

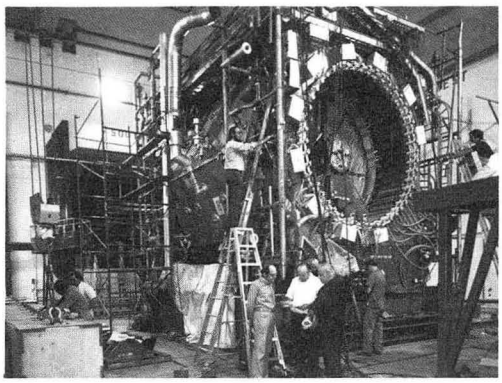


During assembly of the Time Projection Chamber solenoid, June Kinoshita applies a wrap of glass tape insulation over the superconductor. Inset shows cross section of solenoid construction, including tubing for cooling and aluminum short-circuit winding for protection should coil "go normal."

Staff Continued

Marjorie Hutchinson
Patricia Iqbal
Alfred Johnson
Rowland Johnson
William Johnston
Daniel Kane
Ilkka Karasalo
Ardith Kenney
Suzanne Kranz
Peter Kreps
Ru-Mei Kung
Ivy Kuo
John Kurylo
Linda Kwok
Claudet Lederer
Barbara Levine
Gladys Lewis
James Livingston, Jr.
Rita McLaughlin
Loren Meissner
Deane Merrill
James Miller
Fanya Montalvo
Vivian Morgan
Lesta Nadel
Frank Olken
Arthur Paul
Mark Pekker
Jos Polman
Carl Quong
Deborah Scherrer
James Schofield
Esther Schroeder
Arie Shoshani
**Alan Smith*
Silvia Sorell
David Soroka
Ludmila Soroka
**Lawrence Stark*
Joseph Sventek
Virginia Sventek
Lester Tabata
Irma Villagomez
Clinton Ward
Edna Williams
Peter Wood
Albert Yen

*UCB faculty member
†UCSF faculty member



In position at PEP, the Mark II detector looms up behind LBL's Gerson Goldhaber, and Bill Davies-White and Burton Richter (center foreground) of SLAC. Gerald Abrams and Andrew Lankford (on ladders) inspect the progress of the large detector as it nears readiness in the search for new charmed particles.

More determinations on depolarization parameters are forthcoming from this collaborative effort involving physicists from Harvard, Yale, Argonne National Laboratory (ANL), FNAL, and LBL.

A facility for studying the production of lambda and anti-lambda particles is being planned. These particles are so abundant at FNAL energies that enriched antiproton, polarized proton, and polarized antiproton beams with reasonable intensity for use in counter physics can be readily obtained.

Experiments on $k^{\pm}p$ cross sections have yielded measurements of the total and a series of differential cross sections for $k^{-}p \rightarrow \bar{K}^{\circ}n$ in the region from 500 to 1100 MeV/c. A study of $\bar{p}p \rightarrow \bar{n}n$ was also carried out. These experiments were to search for baryon resonances, to study the nucleon-nucleon system at low energy, and to investigate the kaon-nucleon system and the resonances it displays.

In a new effort with BNL, a measurement is being made of the differential cross section for the elastic scattering $K^{\pm}p \rightarrow K^{\pm}p$ and $\Sigma^{-}\pi^{+}$ at 180°. Having received only cursory attention in the past, this backward region is proving to be important because a resonant amplitude can be detected there more easily than at other angles.

Experiments conducted at BNL and which are still undergoing analysis are an investigation of the anti-nucleon system below 1 GeV/c measured by the backward elastic scattering of $\bar{p}p$, and the small angle scattering of π^{+}, k^{+}, p, and $\bar{p}$ on protons measured in the Coulomb-nuclear interference region.

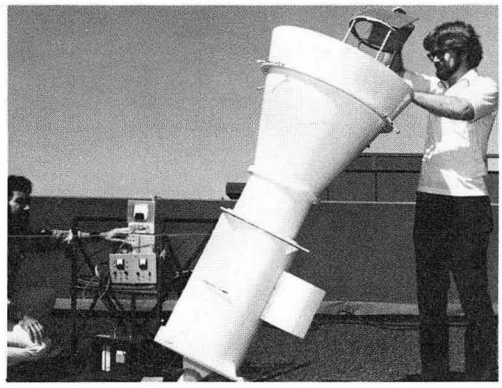
LBL is the international headquarters of the Particle Data Group, which compiles and documents information on all known subnuclear particles. We make this information available to the international scientific community.

In studying the design of super conducting magnets required for particle detectors in high-energy physics, the physics of quench phenomena has been examined. Quenches occur when the cryogenic system fails. Techniques of quench protection have been studied, and some resulting techniques are finding application to public and commercial magnets, increasing their safety. A sound theoretical base for such a magnet with a conducting bore tube and an external protection circuit has been developed and demonstrated successfully.

Instruments and instrumentation systems that have broad and general applications in high-energy physics are developed by engineers in this division. They have also developed a variety of particle detectors and detector methods, such as the combinations of drift and multiwire proportional chambers, and various readout schemes with their associated electronics. Commercially available devices and instruments are also evaluated. New devices under study are highly sophisticated position-sensitive instruments that detect and amplify light and are capable of recording large multiplicity events from high-energy elementary particle interactions and from heavy-ion collisions. These detectors find broad application in physics and nuclear medicine.

ASTROPHYSICS AND ASTRONOMY

Efforts to detect anisotropies in the cosmic background (3° K blackbody) radia-



From the roof of a laboratory building, this radiometer searches the cosmos for polarized background radiation. Data collected by astrophysicists George Smoot (left) and Philip Lubin support the theory that if the Universe is homogenous, the background radiation should be unpolarized. Deviations from this preliminary result, if found, will suggest departures from the simple "big-bang" model of the universe.

tion have continued. The measurement of the cosmological motion of the Milky Way galaxy will be checked by flying the microwave radiometer in the southern hemisphere aboard a U-2 aircraft. This measurement will be improved by a later satellite experiment.

A binary radio pulsar (PSR 1913+ 16) has been suggested as a uniquely valuable laboratory to test General Relativity. These tests can only be made if the companion to the pulsar is a compact object (a white dwarf or a neutron star). LBL scientists have found there is a 97% probability that a large companion star is indeed associated with the pulsar, and consequently, its tidal effects will prohibit the observation of the general relativistic effects sought. This extremely important result will be carefully scrutinized.

Time-resolved photometry and time-resolved spectrophotometry were used to study the optical pulsations of several white dwarfs and neutron stars. The recurrent nova, WZ Sge, was found to have a rotation period of 28 seconds. A prediction made several years ago was confirmed, namely the optical pulsations from near the x-ray source of HZ Her/Her X-1 are indeed the excitation of a part of the accretion disk by the pulsed x-rays.

The early rubber mirror telescope that so successfully resolved diffraction-limited star images at Mt. Wilson has been modified and used with the 30-inch solar telescope at Sacramento Peak, New Mexico. Further equipped by a star guider, we have used this solar telescope successfully for a nighttime observing program and have obtained diffraction-limited stellar images (1/4 arc-sec) in the presence of 2 arc-sec seeing. Our astrophysicists are working on further refinement.

The design study for the UC 10-meter telescope is an important effort in that the segmented primary mirror has undergone substantial development, and computer control has been added. A new technique for making off-axis parabolic mirrors has been successfully developed. By 1981 this project should be under way.

RADIOISOTOPE DATING

By considering radioisotope dating as a problem in trace-element analysis, and by using the LBL 88-Inch Cyclotron as a high-energy mass-spectrometer, the maximum age that can be dated has been greatly increased while simultaneously reducing the size of the required sample. For Carbon-14 dating we can go back 40 to 100 thousand years with carbon samples of only 10 to 100 milligrams. In collaboration with other universities, we are building and testing equipment to make radioisotope dating a practical tool. The known samples of ^{10}Be and ^{14}C will be used to establish the accuracy and precision of the systems, and when the technique is established, it will be applied to dating specimens whose ages have been indeterminable by previous techniques.

THEORETICAL PHYSICS

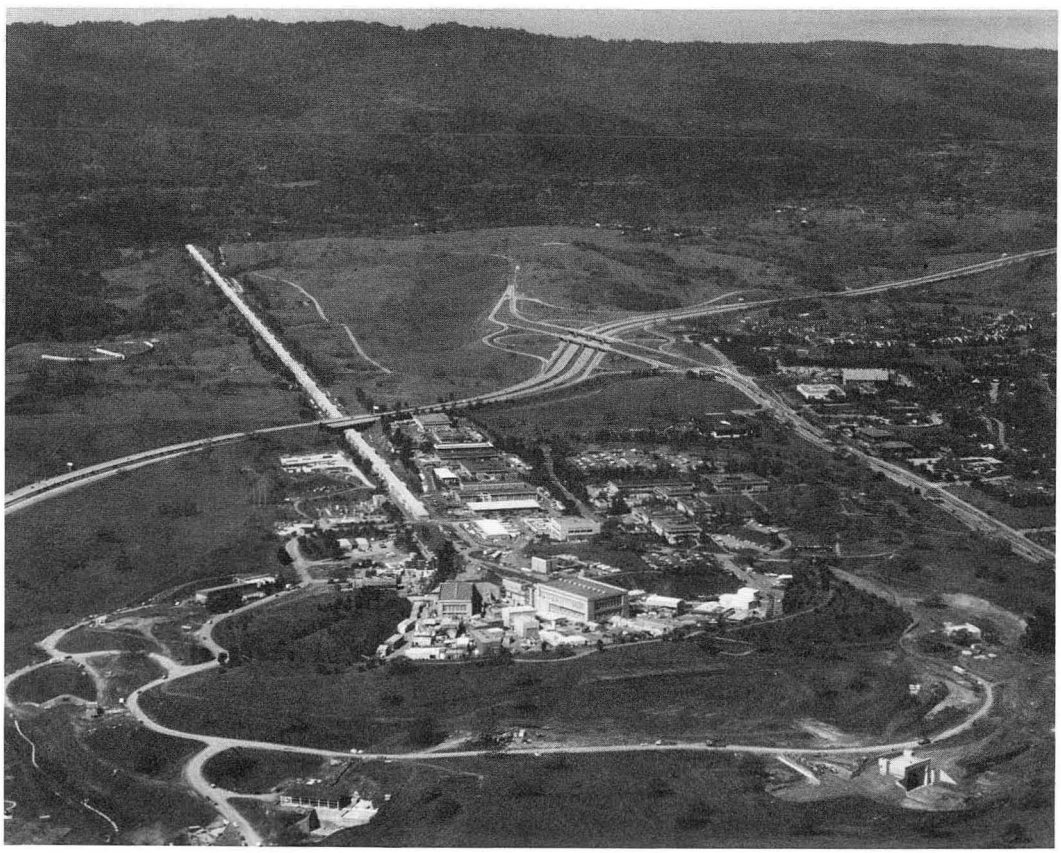
The theory of interactions of fundamental particles is the principal area of theoretical research. Other areas of importance are statistical mechanics and the theoretical study of high energy particle accelerators. Many theorists actively support experimental programs of the

Laboratory from the theoretical side.

Research in particle theory encompasses the strong, electromagnetic, weak, and gravitational interactions. They are investigated both by field theoretical methods and by S-matrix methods. Although both methods assume relativistic invariance, the S-matrix approach is based on a direct assumption of conservation of probability and further assumptions about the mathematical properties of scattering amplitudes. It has the virtue of dealing more directly with experimental quantities.

Bootstrap S-matrix theory made dramatic progress in 1978. A special handling of the unitarity principle called the topological expansion is employed. This expansion is being treated in a revolutionary new way using combinatorial methods. Many basic features of the strong interactions, such as quark structure, color, and selection rules for reactions appear naturally in this scheme and the way now appears open to a quantitative understanding of all particle phenomena in terms of self-consistency. It is about to encompass even weak interactions.

In parallel to the S-matrix approach, a substantial effort was devoted to the study of strong interactions using field theoretical methods. As noted earlier in this report, much of high energy physics results can be explained if quarks are regarded as the fundamental building blocks of matter,



This westerly view of SLAC shows the PEP facility under construction in March 1979. The looping roadway in the foreground roughly traces out the beam tunnel and peripheral structures of the interaction regions where experiments will be conducted.

but as yet none have been observed. Consequently a central issue is to explain the confining mechanism of quarks and gluons in the non-Abelian gauge theories. Toward this goal, many aspects of different Abelian and non-Abelian gauge theories were examined.

Another issue is how the quantum chromodynamics manifests itself in lepton-hadron processes and heavy quark systems.

Weak interactions were investigated in the framework of gauge models and also more generally. Studies were made of gluon corrections to heavy quark decays, and weak interactions of strange and charmed hadrons. Extensive and fruitful contact with experimentalists was made in the course of this research. The properties of heavy particles with new quantum numbers continued to be a subject of interest. The baryonium spectra were studied systematically.

ACCELERATOR THEORY

A new conceptual design for a possible future PEP proton-electron system has been developed. It includes a 300 GeV superconducting proton ring in the present PEP tunnel, situated above and below the present electron ring, which it crosses in four of the six straight sections. The beams cross at a small angle, and are separated beyond the interaction region by a spectrum-magnet system acting on the proton beam. Crossing of the electron ring by the proton ring, rather than the reverse, is chosen in order to avoid synchotron radiation in the experimental areas, which would result if the electons were bent away from the protons. A set of general parameters and lattices have been worked out.

Theoretical work in connection with the heavy ion fusion (HIF) program covered three major areas: stability of transport of intense beams, final transport and focusing of beams onto a target, and parametric studies of accelerator systems. Final focusing requires delivery of a beam onto a spot of few millimeters in radius at a distance of several meters from the last focusing element. In this situation aberrations are important considerations. The consequences of these aberrations have been investigated and requirements established for delivering most of the beam to the target. Since these requirements are sufficiently restrictive, some preliminary work was done on correcting schemes.

A systematic parametrization of the constraints from source to target was formulated and used to examine various proposed scenarios generated here and at other laboratories. As others have also found, schemes involving synchrotrons as the major accelerating elements appear unattractive and have been abandoned, at least for the present. A computer program has been developed to optimize induction lineal accelerator design.

It is universally agreed in the HIF community that a substantial accelerator facility is urgently required to prove out some of the necessary aspects of accelerator performance. While the exact nature of this facility is still under debate, LBL will be heavily involved in its design. If heavy ion fusion is to be a real competitor to other approaches to fusion energy, there must be a substantial increase in activity, with accelerator theory continuing to play an important role.

MEDIUM ENERGY PHYSICS

Most of the LBL program in medium-energy physics is conducted at other research facilities. At the Los Alamos Meson Production Facility (LAMPF) we are measuring the photon spectra associated with the capture of negative pions by nuclei, using a high-resolution electron-positron pair spectrometer. In previous research some of the fine structure observed in these spectra between 100 to 140 MeV were identified. Also observed were the giant magnetic dipole states in several nuclei; a search for the giant quadrupole states is now underway. Quantitative analysis of these results provides further clarification of fundamental processes,

while testing the application of theory to complex nuclei.

In studies of weak interactions, muon decay remains the only purely leptonic weak interaction accessible to precise measurements. Interest in rare decays is quite high, although many of the systematics of the main decay mode are incomplete. Consequently, extensive plans are being made to measure the lower one-fourth of the positron energy spectrum for decay.

Recent work on the scattering of mesons, nucleons, and light nuclei by light nuclei has provided further insight on nuclear structure and wave function.

The absorption coefficient of kaonic potassium x-rays in erbium has been determined. This allows calculations of the mass of the negative kaon. In cooperation with the University of Victoria group at TRIUMF, the pionic x-ray intensities of 60 chemical elements were also found.

Preparations are being made for collaborative experimentation at TRIUMF on muon-induced fission.

At the Bevalac an experiment to study multiple pion production in heavy-ion collisions is in its initial stage. In the past ten years, exotic phenomena have been predicted as possible states for nuclear matter in a heavy-ion collision. Since then it has been pointed out that one way to observe the effect of pion instabilities in heavy-ion collisions is to look for the correlation of like pions in the situation when the relative momentum is extrapolated to zero. The detection system is being set up to observe the momentum distribution of two pions made in Argon-KCl central collisions at 2.1 GeV/nucleon.

COMPUTER SCIENCE AND APPLIED MATHEMATICS

Our research in applied mathematics is directed toward developing methodologies and tools applicable to a wide range of major DOE programs. Broadly applicable methods for mathematical and computational analysis focus on techniques for solving partial differential equations, and on applications to capillary phenomena and image reconstruction. At the same time, techniques for analyzing turbulent combustion engines, and multiphase flow in porous media (as in a petroleum reservoir) are being examined.

In advanced systems development and data management our efforts are toward the integration of computer systems connected by networks, facilitating resource sharing and offering a uniform program development environment at DOE sites. Data management research is oriented toward information retrieval and display, with an important related area being the development of mass storage systems based on the new optical disk technologies.

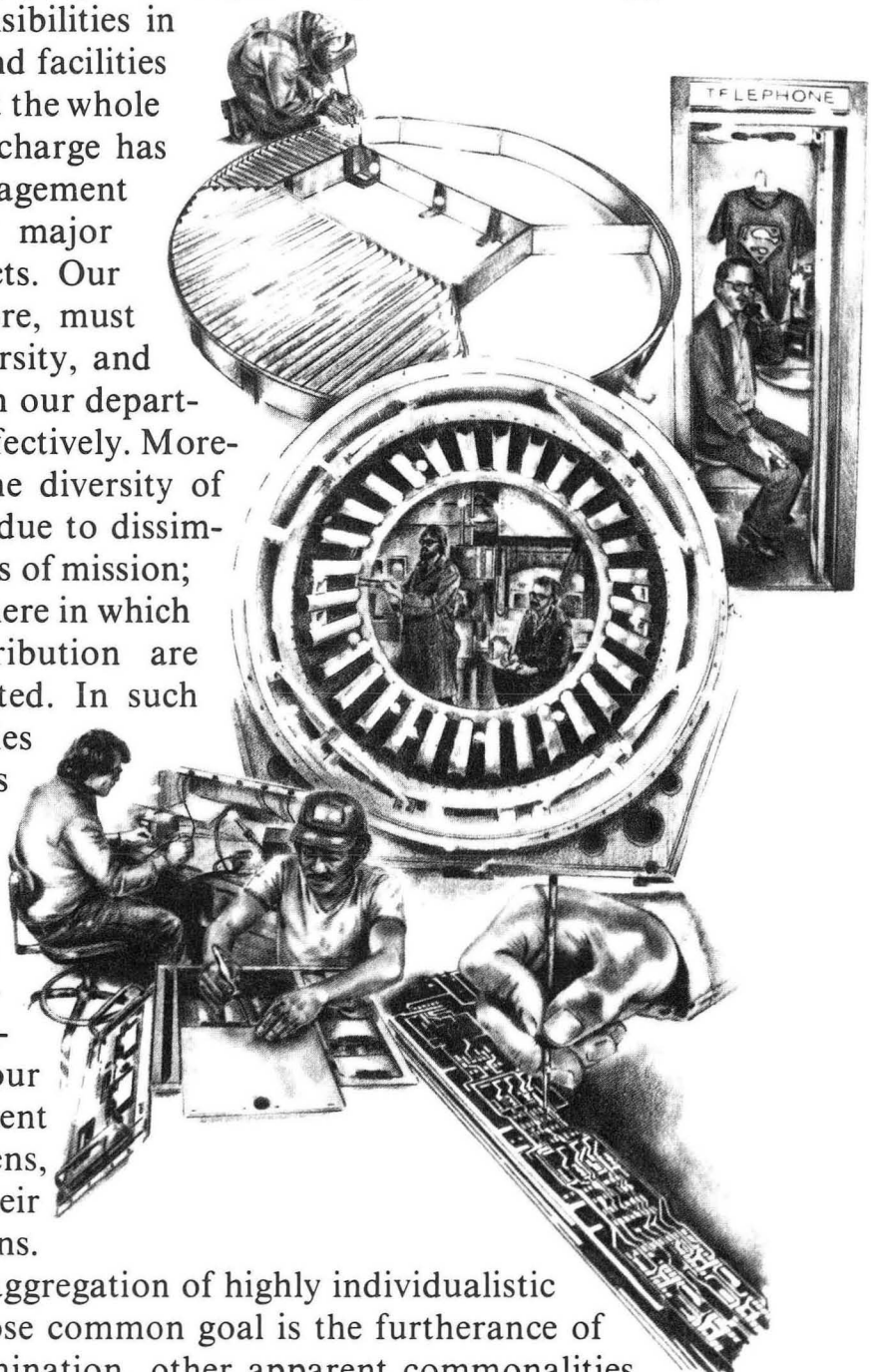
The Socio-Economic Environmental Demographic Information System (SEEDIS) under development is designed to provide researchers and planners with a coherent, comprehensive computer-based system for data management, analysis, and display capabilities. SEEDIS will be expanded with the 1980 Census data, thus making LBL a unique resource for information from both the 1970 and 1980 Censuses, to be used for analysis, modeling, and time series studies.

In the Populations at Risk to Environ-

Teleconferencing and telecommunications via the ARPANET are used extensively in collaborative research with DOE laboratory and university contractors and in research planning, review and management. Department Head, Carl Quong, and administrator, Lesta Nadel respond to messages via electronic mail on the network.

mental Pollution (PAREP) project, we are developing an integrated county-level database for the entire United States, containing information on environmental quality, socioeconomic indicators, human mortality, and cancer incidence. This database will be used for epidemiological investigations into the relationship of disease (particularly cancer) and environmental pollution. New developments in SEEDIS will include advances in distributed information systems technology, environmental and health-effects databases, and the incorporation of large socioeconomic and energy use/production models.

Management of a division as large and diverse in its activities and organizational structure as is the Engineering and Technical Services Division has certainly presented me with an unusual challenge. While our primary purpose is engineering and technical support of research programs, we have major responsibilities in other areas. Health and safety, and facilities management are areas that impact the whole Laboratory. In recent years our charge has been broadened to include management and program responsibility for major R&D and applied science projects. Our management philosophy, therefore, must take into consideration this diversity, and must foster an ambiance in which our departments and projects can function effectively. Moreover, I should emphasize that the diversity of which I am speaking is not only due to dissimilarities in disciplines or differences of mission; it is more the result of an atmosphere in which creativity and individual contribution are encouraged rather than subjugated. In such an atmosphere, management styles reflect in great measure the strengths and personalities of departments rather than a style imposed by the division office. It is my belief that the functions of the division office are to achieve a balance in our support programs, to serve as an information channel, and to free our departments to the greatest extent possible of administrative burdens, leaving them free to pursue their programmatic and support missions.



The Laboratory as a whole is an aggregation of highly individualistic research and support groups whose common goal is the furtherance of understanding. Under close examination, other apparent commonalities tend to fade away. And, in my view, that's the way it should be. We are after all a research institution. The importance of individuality and personal contribution cannot be overstressed. It is the collective ambitions, energies, skills, and talents of each member of the Laboratory that is its unique strength.

Walt Hartsough
Head Engineering and
Technical Services Division
Associate Director, LBL

Engineering and Technical Services

Walter D. Hartsough
LBL Associate Director
Head, Engineering and Technical Services Division

Division Administration
Robert L. Hinckley, Deputy Division Head
Marinell Coleman
Donald G. Eagling
James A. Harris
Paul Hernandez
Edward H. Hoedemaker
Howard L. Smith
Ralph H. Thomas

Division Staff

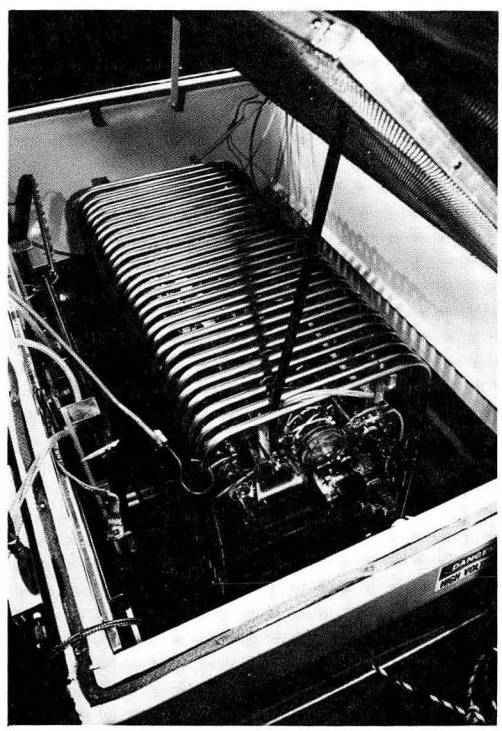
Computer Center
David F. Stevens
Uzi Arkadir
F. Marvin Atchley
Michelle H. Aguer
James A. Baker
Eric R. Beals
Donald S. Berkowitz
Philip E. Bernzott
Jerry T. Borges
Douglas N. Brainard
Barbara Britton
David H. Cleveland
John L. Dilworth
Robert L. Fink
Kevin R. Fjelsted
Edwin A. Fourt
Joan F. Franz
Richard S. Friedman
David L. Fry
David G. Gok
Donald L. Henrich
Bryan L. Higgins
Robert C. Hoffmann
Martin S. Itzkowitz
Joyce P. Johnston
Nancy E. Johnston
Jeremy A. Knight
J Michael Long
Everett S. Magnuson
Steven T. Oki
Lorraine J. Osterer
Robert E. Rendler
Paul A. Rhodes
Joyce A. Rybandt
Judith Sarna-Wojcicki
Edward H. Sheena
Marjory C. Simmon
Thomas H. Strong
G. Daniel VanZile
Leo S. Vardas
Howard S. White
John D. Wood
Karlyn S. Wright
Donald H. Zurlinden

Construction and Maintenance
Robert L. Stewart
Paul J. Buckholz
Ralph A. Frey, Sr.
George W. Goranson
George E. Mathews
Inez Montano
Robert L. Wilson

Electronics Engineering
Edward C. Hartwig
Alan F. Altman
Sypko W. Andreae
Kam F. Ang
Derik V. Armstrong
Allan A. Arthur
William R. Baker
John J. Barale
Paul J. Barale
David L. Bates

The Engineering and Technical Services Division is staffed by approximately 1,300 engineers, scientists, technicians and administrators, who support the Laboratory by

- Providing direct support to the scientific programs through engineering services, shop facilities, and technical support. These functions are largely performed by the Electronics Engineering, Instruments Techniques, and Mechanical Engineering Departments.
- Maintaining and providing buildings and facilities, planning new facilities, and providing for the health and safety of LBL employees. The Construction and Maintenance, Environmental Health and Safety, Medical Services, and Plant Engineering Departments fulfill these responsibilities.
- Managing the Computer Center
- Conducting research and development programs in applied science and engineering.



Acting as a spark plug for the cesium ion source, the Marx generator delivers 500 kV of energy to start the beam. Heavy ion beams are being developed as an essential part of the inertial confinement fusion program.

ELECTRONICS ENGINEERING

The Electronics Engineering Department provides engineering and technical support for the Accelerator and Fusion Research (AFR) Division and for applied science and engineering projects. On a Laboratory-wide basis, our staff in this department provides systems design and maintenance for real-time computer systems and electronics shops support.

Engineering support for the AFR Division is largely of a research and development nature, and so it is likely to involve one-of-a-kind facilities that advance the state of the art. The technical challenge may be in providing systems for computer control of the PEP storage ring, in designing power supplies and driver electronics for the eight types of beam control magnets used in PEP, or in the design of microprocessor controllers and systems as part of our continuing LBL Accelerator Improvement Program.

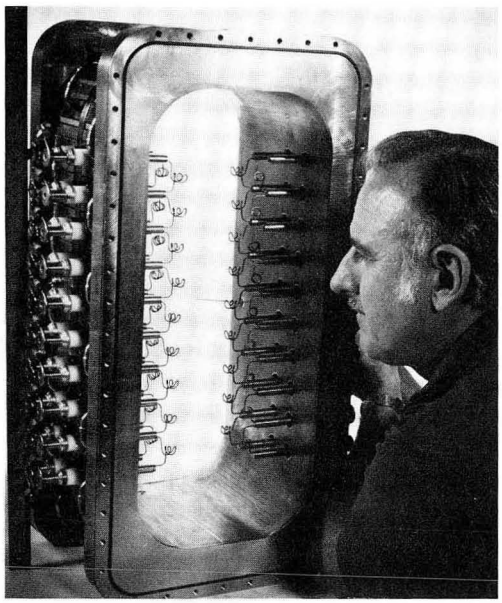
We are now participating in upgrading the PEP storage ring to the higher energy PEP-II phase, and are engaged in studies of superconducting magnet systems and conceptual analysis on the feasibility of circulating protons.

Under way also is a five-year program of participation in the 50-GeV Beijing Proton Synchrotron. Jointly with Chinese scientists and engineers who will be in residence at LBL, we will be designing, testing, and installing the distributed computer control systems and the main-ring magnet power supplies for this first large accelerator in the People's Republic of China.

Engineering for our nation's fusion research program is a significant activity in this department. The neutral beam sources for both the Tokamak test reactor project at Princeton and the Doublet-III test reactor at General Atomics Company, San Diego have been developed by the AFR Division with engineering design, prototype fabrication and Neutral Beam project responsibility in ETSD. The Electronic Engineering Department's aim is to simplify the circuits while providing beams that exceed the original design intensity and energy for

Staff Continued

Eleanor K. Batho
Robert A. Belshe
David Bereznai
Louis A. Biagi
James E. Braley
Donald A. Brodzik
Terrence E. Byrnes
John Y. Chu
Mansfield L. Clinnick
Albert R. Conrad
James M. Cox
Worrell H. Deuser
Jan G. De Vries
Roger D. Dwinell
Victor P. Elischer
Delvin R. Embree
Andris Faltens
Jerry Fiddler
William S. Flood
Jack V. Franck
Robert Frias
Jock A. Fugitt
Jeffrey M. Gallup
Paul S. Gee
Dalia Geller
Diana L. Grand
Michael I. Green
James B. Greer
Michael G. Harms
Everett H. Harvey
William E. Hearn
James A. Hinkson
James P. Holl
Donald B. Hopkins
Leslie T. Jackson
Nicholas J. Jacobs
Van L. Jacobson
Richard W. Johnson
Ronald W. Jones
Leonid Kaplan
Stephan R. Keith
Russell L. Kilgore
Spencer J. Knoll
Robert S. Lam
Henry D. Lancaster
Richard L. LaPierre
Joseph P. Lavelle
Richard D. Lawhorn
Stephen A. Lewis
Edward G. Lieberman
Raymond Louis
Ivan C. Lutz
Jarmon A. Lynch
John P. Lynch
Maurice B. McEvoy
Jane C. McGrath
Stephen J. Mellor
Joseph Michelson
Kenneth A. Milnes
Donald D. Morris
Donald H. Nelson
Mark A. Nyman
Harvey J. Oakley
Michael A. O'Brien
Harvey M. Owren
Bernard J. Pech
Nels S. Peterson
Chester D. Pike
Samuel Pitluck
Leverett A. Pope
Oliver B. Rasmussen
Mathew J. Renkas
Sig G. Rogers
Darrell H. Rohde
Donald J. Rondeau
Stephen H. Rosenblum
Sandra L. Rovanpera
Pope C. Sealy
Loren L. Shalz
Sally D. Shlaer
Rajinder P. Singh
Gary E. Smith
Robert W. Sorensen
Gregory D. Stover
Edward H. Theil
Richard F. Thomas
Arthur D. Turney
Donald C. Uber



Builder Lou Biagi displays the latest generation of neutral beam injectors that will use this "magnetic bucket" component. Magnets will produce a multiple field that will reflect electrons from the filaments seen here to produce a more efficient plasma source.

Tokamak and Doublet-III. The computer control systems for both of these systems are being designed by and assembled under the direction of our Real-Time Systems Group.

We are supporting the Heavy-Ion Fusion program with R&D engineering on a one-ampere, 500-kV cesium source and a pulsed Linac 2-MeV preaccelerator. Proposed later developments include a linear induction accelerator to follow the Linac, which will accelerate the bunched charge to about 30 GeV to provide nominally a megajoule energy burst to the target fuel.

The Real-Time Systems Group provides a resource of personnel with minicomputer and software expertise to service the expanding demands for system control and data acquisition.

Our Magnetic Measurements Engineering Group provides design support and instrumentation for most of our magnetic-field mapping and monitoring projects. For example PEP, PEP-II, NBSTF, Doublet-III, and TPC are all supported by the services of this group.

Microwave links to LLL and SLAC enable data transmission by telephone, video, and (soon) computer. Other communications services are also provided as required.

Our support to the electronics shops includes fabrication, quality assurance, installation, drafting, computer-aided design of printed circuits artwork, cable assembly, electrical standards check, and instrument loan and repair.

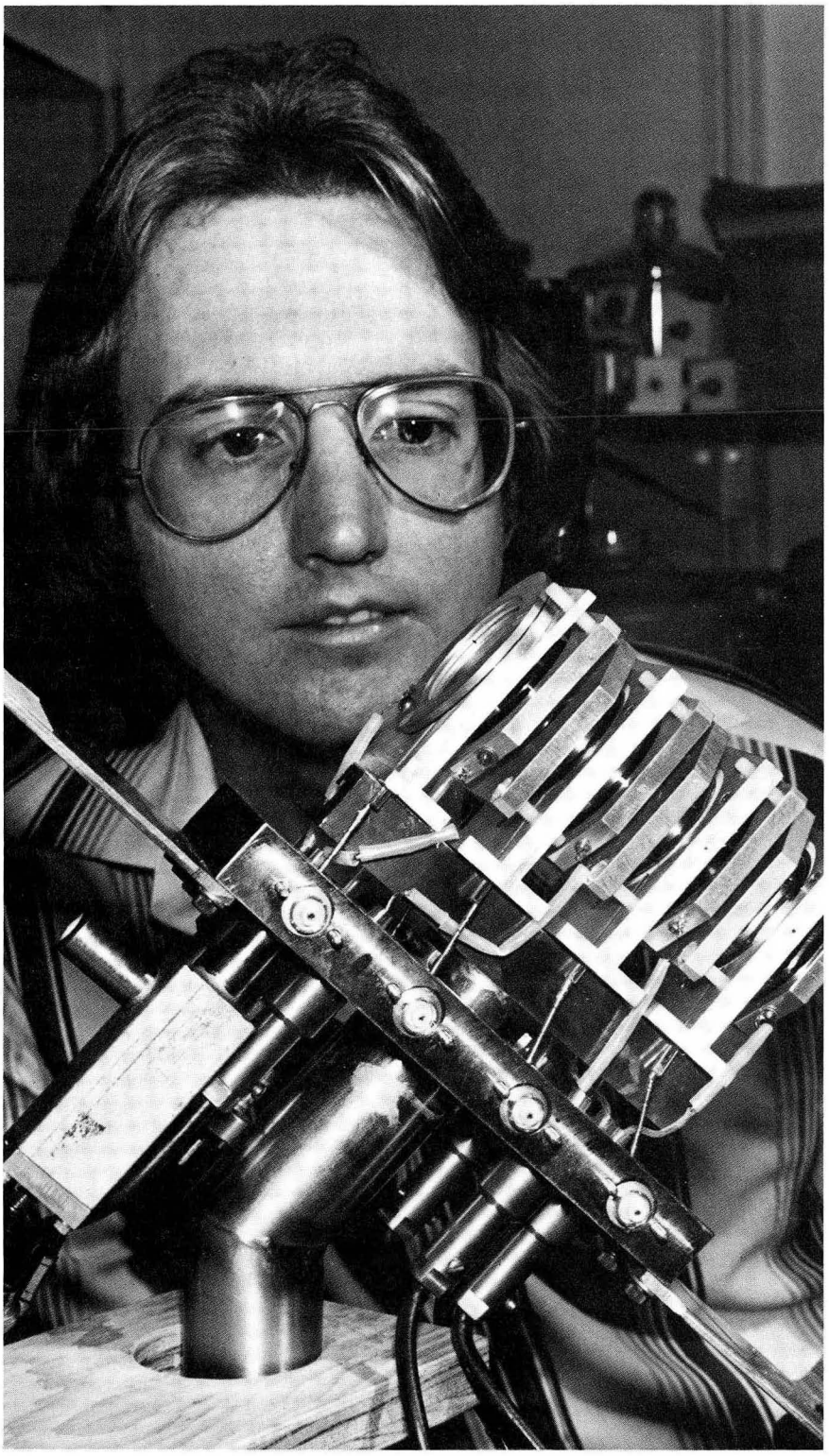
INSTRUMENT TECHNIQUES

LBL is well-known as a leader in the technology of measurement and instrumentation for which this department is the focal point. In addition to providing service to LBL research divisions, this department independently undertakes research and development programs on the physics and technology of semiconductor detectors, including basic studies of high-purity germanium, its purification and production. Specialized detectors are being developed to meet nuclear research and space science needs.

Here we also develop measuring techniques and instruments for monitoring and characterizing environmental contaminants, focusing mainly on physical methods such as x-ray analysis, microwave absorption, laser-light and scattering spectroscopy to replace the slow and inaccurate chemical methods commonly used in the past. Our emphasis in this work has recently shifted from the detection of atomic species, to that of molecular species and to determining the chemistry of processes in the environment.

In another program, we are working to improve methods of measuring the water/vapor behavior at the liquid-gas interface and walls of high-temperature, high-pressure heat exchangers such as are used in power stations.

Developmental work is carried out on instruments required by LBL research divisions. During the past year we have developed a major portion of the electronics for the Time Projection Chamber (TPC), an instrument involving 15,000 channels of very sensitive electronics, and for which the signal processing problems are severe.

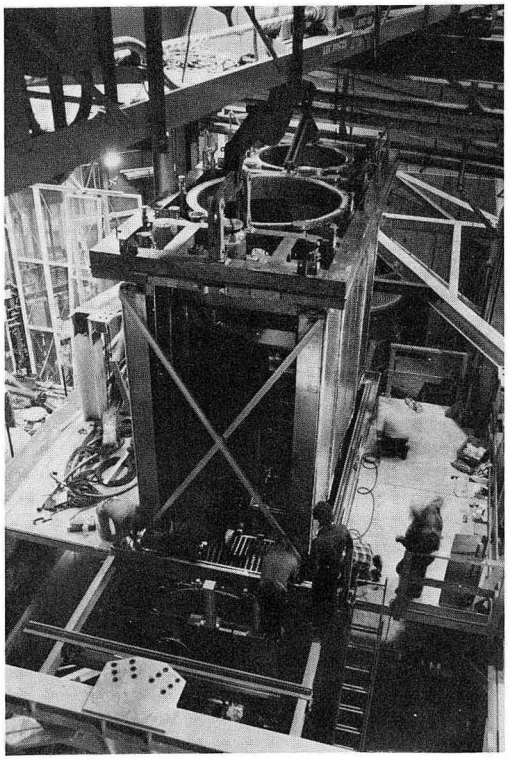


Scott Hubbard and colleagues refined the techniques of ion implantation which led to the development of this high-purity germanium detector telescope for particle physics.

MECHANICAL ENGINEERING

The Mechanical Engineering Department is heavily engaged in engineering management, design, and fabrication for Magnetic Fusion Energy including the two neutral beam projects NBSTF (for Princeton TFTR) and the Neutral Beam Injector (for General Atomics' Doublet-III), and for high energy physics at the TPC for PEP. Our staff here has begun fabrication on the heavy-ion superconducting spectrometer (HISS) in collaboration with the Nuclear Sciences Division.

This department also provides support shop facilities in the accelerator buildings and research laboratories at a dozen locations as well as in the main technology and mechanical shops. The shops are separated into several specialties: assembly, ceramics, electroplating, glass, machine, sheetmetal, spray paint, and chemical coating and welding.



The TFTR injector prototype main cryopanel structure, being lowered into its containment vessel, will maintain ultra-high vacuum in the beam line of the Neutral Beam System Test Facility.

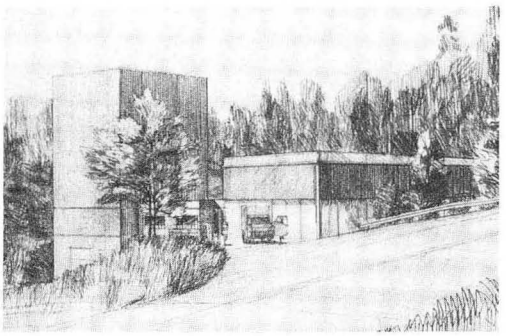
Staff Continued

Robert B. Upshaw
Eugene Veklerov
Ferdinand Voelker
Jean C. Waddell
Lee J. Wagner
Ronald I. Wallace
Jacque Wilcox
Kenneth G. Wiley
Charles H. Wilkinson
David N. Wilner
Gerald V. Wilson
Lillian A. Wirth
Sheldon G. Wong
Ivan E. Wood

ENVIRONMENTAL HEALTH AND SAFETY

Ralph H. Thomas
Raymond G. Aune
Rosemary J. Barrett
Peter S. Bringham
Howard J. Browne
Herbert P. Cantelow
T. M. deCastro
S. Kirk Collins
George R. Dietrich
Willian L. Everette
Elio R. Giusti
Dennis R. Gonzales
Robert W. Gribben
Harold R. Haas
James T. Haley
Earl E. Hart
Kenney R. Hernandez
John Izzo
Harry J. Jelonek
Joseph B. McCaslin
Robert E. McCracken
Ronald O. Pauer
Joseph E. Rainey
Gary E. Schleimer
Richard H. Schueller
Elmer J. Silva
Alan R. Smith
Lloyd D. Stephens
Roberta B. Trout
Jensen Young

Instrument Techniques
Frederick S. Goulding
Robert K. Abbott
Richard S. Adachi
Charles A. Arthur
Paul G. Banchero
Eugene P. Binnall
Alan K. Biocca
Charlie F. Carr
George A. Constantian
Christopher P. Cork
Charles G. Dols
Vicky D. Donelson
John M. Dorsey
Ted Y. Fujita
George Gabor
Raymond C. Gatti
Fong Gin
Tetsuo Hadeishi
Eugene E. Haller
William L. Hansen
G. Scott Hubbard
Horace G. Jackson
Joseph M. Jaklevic
Richard C. Jared
Blair V. Jarrett
Joseph E. Katz
Frederick Kirsten
William F. Kolbe
Edward J. Lampo
Donald A. Landis
Almon E. Larsh, Jr.
Kai L. Lee
Mon K. Lee
Branko Leskovar
Jaff C. Lin
Jorge Llacer
Chu-C. Lo
Billy W. Loo



Conceptual drawing of the High Voltage Electron Microscope facility due for completion in FY1980.

PLANT ADMINISTRATION AND PLANT ENGINEERING

The Plant Administration, Plant Engineering and the Construction and Maintenance Departments under the Plant Manager form a "plant team" responsible for LBL's physical plant facilities planning, design, construction, and operation, as well as maintenance.

A group of 60 engineers and administrators is responsible for the long-range planning, design, and use of LBL facilities, land, and other resources, as well as their conservation. They design, adminster contracts, and manage construction of plant facilities, in addition to providing programmatic engineering support.

Recent new facilities designed for the Laboratory include the cell culture laboratory (Building 83), to be completed August 1979; the high voltage electron microscope addition to Building 72, which started construction in March 1979; the high-bay cryogenics laboratory (Building 60), for the Accelerator and Fusion Research Division, to be completed by the end of 1979. Other buildings designed include an office addition to Building 70, a high bay addition to Building 58A, modular offices (Building 50D) and an addition to Building 62.

CONSTRUCTION AND MAINTENANCE

All physical plant facilities at LBL including buildings, utility systems, plant equipment and roads and site improvements, are maintained for continuous operation by the Construction and Maintenance Department (C&M). Plant maintenance technicians provide services to research programs as requested. Physical plant mechanics, including plumbers, carpenters, painters, laborers, and equipment operators support research programs and carry out alterations and repairs to buildings and facilities. Janitorial services are provided for all "Hill" buildings, and gardeners take care of the LBL site.

ENVIRONMENTAL HEALTH AND SAFETY

Those services necessary to create and maintain a safe working environment for LBL staff are provided by the Environmental Health and Safety Department. Specialized services in environmental monitoring, fire protection, radiological safety, health physics, industrial hygiene and toxicology, industrial safety, non-destructive testing, and traffic safety are provided. Here we also offer thorough specialized training and programs in safety skills and maintain a resource library on safety standards and technology.

In support of the scientific programs, the radiation environment of PEP-II is being studied, and the Low Background Facility is used to determine the absolute intensity of

A stack of filter papers containing air samples from throughout the Laboratory await radionuclide counting as Gary Schleimer readies the automatic activity counter. In background, Winnie Corniea monitors water samples with another automatic counter.

Staff Continued

Michael R. Maier
John D. Meng
Jacques E. Millaud
Duane F. Mosier
Michiyuki Nakamura
Lung B. Ng
Curtis Nunnaly
Stanley R. Olson
Richard H. Pehl
James H. Pepper
Paul Salz
Steven B. Sidman
Michael D. Strathman
Rai-Ko S. Sun
Albert C. Thompson
Bojan T. Turko
Frank T. Upham
Frederick Vogelsberg
John T. Walton
Alfred A. Windsor
Stuart D. Wright

Mechanical Engineering
Paul Hernandez
Dane H. Anderberg
Robert T. Avery
Philip C. Bean
Gerd U. Behrsing
John H. Bercovitz
Arthur R. Bergen
Donald R. Bliss
Ted W. Bowers
William I. Brobeck
Lawrence E. Brown
William A. Burns
Roy F. Burton
Roscoe A. Byrns
John G. Carrieri
Shlomo Caspi
Robert J. Caylor
Edmund Chan
Sylvester Clark
Donald E. Coyle
John E. Cullen
Arthur J. Dancosse
Kim Dao
James V. Davey
Theodore J. DeBonis
Edgardo M. DeGuzman
Juan M. DeOlivares
Robert A. DeWitt
Padraic A. Doyle
William F. Eaton
Robert D. Edwards
Donald R. Elo
Richard H. Escobales
Albert J. Ferrari
Vernon A. Fletcher
Martin Y. Fong
Robert L. Fulton
Lee R. Glasgow
Gary L. Glick
Abraham Glicksman
William G. Godden
George M. Gordon, Jr.
Michael A. Green
Jack T. Gunn
Carson B. Haines
Klaus Halbach
Leif J. Hansen
Frank E. Hart
James M. Haughian
Nathaniel L. Hawks
Thomas F. Henderson
Paul Hernandez
James C. Hodges
Seymour Horowitz
Egon H. Hoyer
Harlan A. Hughes
Donald B. Hunt
J. Frederik Jansen
Gregory P. Jones
Vernon B. Jones
Yoichi Kajiyama
Massoud Kaviany-Nejad
Andrew M. Kennedy, II
Kurt D. Kennedy
Richard D. Kopa

A rapid and total exhalation of air is measured to test the lung's vital capacity. Nurse Polly Vaughn, of Medical Services, keeps an eye on Joseph Nausin during this part of his physical examination.

accelerator beams and neutron spectra outside accelerator shields.

MEDICAL SERVICES

Operating as a clinic for the benefit of LBL employees, our Medical Services Department provides physical examinations for employees, and serves as a first-aid facility. In all of these services, the department adheres strictly to the usual patient-doctor ethics.

All LBL employees receive comprehensive pre-employment and periodic follow-up medical examinations during their employment at LBL, which an employee may elect to augment.

Our first-aid facility, which includes a two-bed emergency unit, is maintained primarily for job-incurred injuries or illnesses, and medical assistance is available or on call at all times. Recently we have instituted the Coronary Prevention Program and, in conjunction with the Personnel Department, offer an Employee Assistance Program, a confidential counseling and referral service.

COMPUTER CENTER

The principal responsibility of our Computer Center is to provide large-scale computational support to LBL's scientific programs. For example, the CDC 7600 computer, with its very large mass storage system and a complete selection of peripheral devices, processed one and a quarter million jobs in 1978 with 71% of the jobs completed in 20 minutes.

Our interactive facilities here at the Center offer comprehensive capabilities, including text editing, document preparation, program preparation and submission,several interactive graphics subsystems, and the ability to interact with any job running on the CDC 6600 and 6400 computers. We have approximately 400 remote users who interact with the CDC 6000s via the Computer Center's Remote Entry Computer Console (RECC) ports, which accommodate teletype, video terminal, and micro-minicomputer communications.

A User Services Group maintains all existing Computer Center documentation. It produces two regular publications, and has recently produced extensive new documentation on graphics and has adapted documentation for the new UNIX system. The group regularly offers classes for new users and provides professional consulting services.

LBL is a member of the ARPANET, a system that connects more than 100 computer centers (some of them overseas) and carries both interactive and batch traffic. LBL is also a member of the TYMNET commercial network.

Excess computing capacity at the center is made available to other DOE laboratories and contractors, and a number of university physics groups find remote use of LBL's Computer Center to be convenient and economical.

The Computer Center facilities and capabilities are continuously being maintained and improved. Outstanding current developments are:

- The Hyperchannel Network—a very high speed, 50 megabit, single coax link system that interconnects the various machines in the Center. The system is scheduled for completion by the end of FY 1979. Data reduction for PEP experiments

Staff Continued

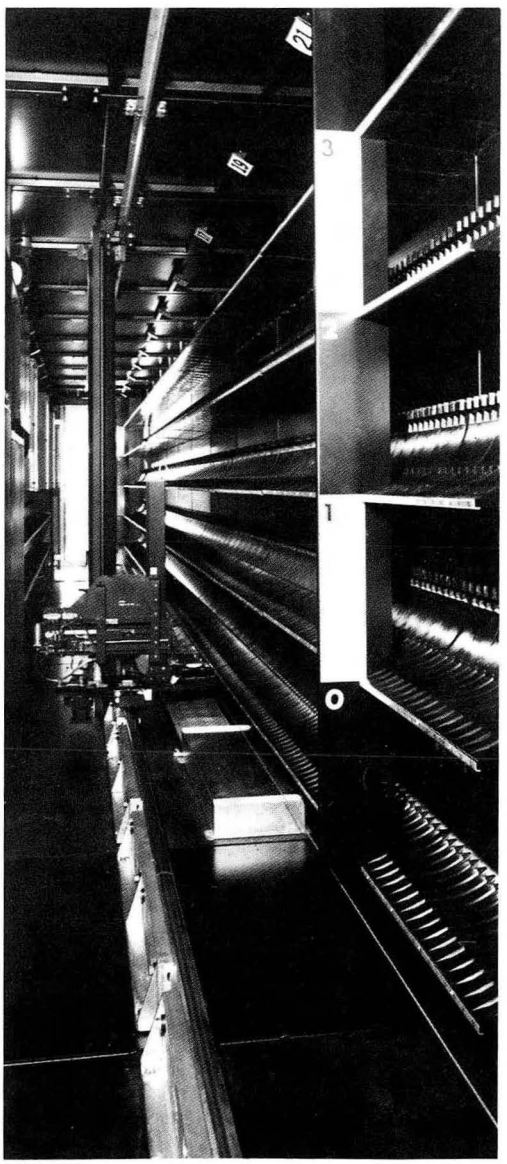
Emery I. Kozak
Jack Kroll
Addison A. Lake
Ted Lauritzen
Thomas B. Lewis
Richard W. Lindberg
Kenow H. Lou
Steven A. Lundgren
Steven B. Magyary
Yoshiyuki Maruyama
Edwin F. McLaughlin
John R. Meneghetti
Robert B. Meuser
Paul B. Miller
C. Eugene Miner
Sofia Mitina
Milton C. Moebus
Edward L. Molishever
Donald R. Mullen
Dale D. Nesbitt
George A. Newell
Duane U. Norgren
Douglass J. Ohmen
Norman C. Parrish
J. Alan Paterson
Craig Peters
Maggie Petersen
Howard S. Pines
William L. Pope
John R. Porter
Peter Purgalis
Pascal M. Rapier
Richard M. Reimers
Larry Resnick
C. Adair Roberts
Donald F. Roth
Donald F. Rothfuss
William W. Salsig
D. Theodore Scalise
Richard V. Schafer
Virgil E. Schrock
Curtis Schuppe
Leonard F. Silvester
Jitendra K. Singh
Donald W. Stallings
Louis A. Sylvia
Jack T. Tanabe
David L. Vanecek
Gustavo A. Vazquez
Thomas M. Vercelli
Robert E. Walton
Richard P. Warren
Paul W. Wells
Russell P. Wells
Richard C. Wolgast
Robert M. Yamamoto
Roland B. Yourd

Plant Engineering
Donald G. Eagling
Charles R. Healy
Frank E. McClure
Ross S. Bausone
Steven A. Blair
George W. Bondurant
Thomas R. Bowen
William P. Carpender, Jr.
Lawrence G. Custus
Derek R. Daniels
Maritza B. Delgadillo
Warren L. Dexter
Marilyn O. Dorsey
Barbara A. Edwards
Eugene Eno
Robert E. Furey
Ross Grazier
William C. Harrison
Robert A. Hart
Frank W. Haubrock
Harry G. Hebel
Michael S. Holmes
Douglas Holster
Donald R. Hopkins
Robert V. Jones
Yongyop Kim
John Klein
Edwin C. Litsinger
William Lopez

will be handled by this system via a data communication link to SLAC, called PEPNET.

- Automated Tape Library (ATL)—capable of storing a cache of 2500 reels of high-density tape (2.25×10^{12} on-line bits), the ATL has been acquired as a first step in replacing the IBM Photodigital Chipstore (0.3×10^{12} on-line bits). Resembling a large juke box, the ATL can automatically mount and thread reels of magnetic tape for use by programs running in the Center's various computers.
- GETTAPE/STOTA PE System (GSS)—a newly developed software handling system allows the ATL to store unrelated sets of information on the same high-density magnetic tape, thus making it possible to fill the tape to capacity without danger of overwriting existing data.
- The GANDALF—a terminal switch allows 250 user terminals to be switched among 120 different terminal ports on our several host computers. This capability (i.e., terminal switching or networking) is essential for allowing the use of multiple, small front-end computers. We plan to increase this terminal switch capability in the coming year.

The present excellence of the Computer Center had its beginning and growth in the Physics Division where it was born over 20 years ago with the arrival of the first digital computer (IBM 650, 1957). In supporting the last major purchase (CDC 7600, 1970) the Physics Division demonstrated its perceptiveness of the growing demands on computational power for research in the basic sciences. The other research divisions at LBL are more and more the benefactors of this farsightedness. In response to their expanding needs, the Computer Center moved from the Physics Division to the Engineering and Technical Services Division on January 1, 1979.



The Computer Center's Automated Tape Library (ATL) prior to being stocked with 2500 reels of magnetic tape. The system automatically locates and loads the selected reel.

ENGINEERING SCIENCES

The concepts of advanced engineering technology are applied to selected problems

Staff Continued

James H. Mafit
Robert G. McDavid
Alfred Mercado
Vishwas D. More
Oliver C. Morse
Torleif H. Myhrer
Warren Ng
Joseph G. Nicholas
Robert Penman
Sherwood R. Peters
John H. Pickrell
June E. Poole
Walter Popenuck
Fenwick H. Salter
Victor L. Schmidt
Richard S. Shaw
Robert C. Shilling
Thomas W. Sibary
Hugh Stoddart
Ernie L. Sykes
Sharad J. Talati
Richard K. Tegen
Eustace Tombras
Charles W. Tucker
John H. Voulkos
Thomas L. Webster
Pio A. Winston

MEDICAL SERVICES

Medical Services
Marcy Wales
Gladys A. Copland
William G. Donald, Jr.
Connie E. Grondona
Alberta P. Proteau
Thornton W. Sargent
Charles T. Schmidt
Lisa Snow
Henry H. Stauffer
Pauline N. Vaughan

in the areas of transportation technology, earthquake response modeling, and nuclear reactor safety with major emphasis on transportation.

Bay Area Rapid Transit (BART) Operations

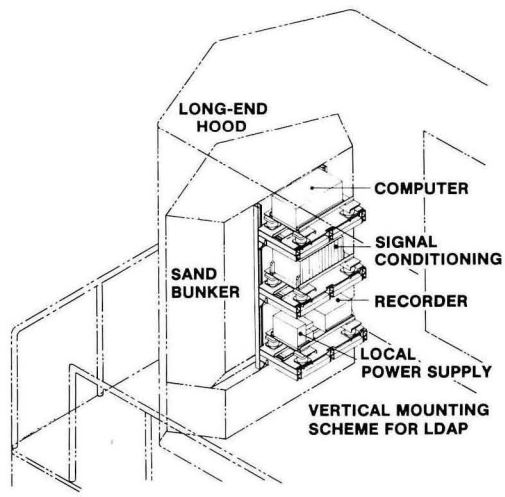
Becasue of BART's complexity, we have supplied systems engineering consulting services since 1973 at the request of the California State Legislature. Our engineers supply the State Senate with an independent assessment of operational capability, reliability, and safety of the BART Automatic Train Control (ATC) System. Especially, they identify the system constraints and technical deficiencies that must be overcome to realize the full potential of the BART system, the first instance in which modern solid-state technology has been adapted to railroad conditions. The recommendations of this department, published in seven reports, have carried substantial influence, and LBL has received formal commendation from both the California legislature and the BART Board of Directors. Consequently, BART has funded LBL in performing engineering studies directed toward improving the reliability of BART's ATC equipment. As a result, we are designing a completely new Integrated Computer Control System five-year project. The majority of this work is accomplished by members of the Real Time Systems Group.

WMATA Operations

We have been involved in a technical assessment of the Washington, D.C. Metropolitan Area Transit Administration ATC system, primarily to identify technical problems and recommend solutions, as well as to advise the Urban Mass Transit Administration on the needs for long-range research in transit-system technology. The results of this study have been published by DOT.

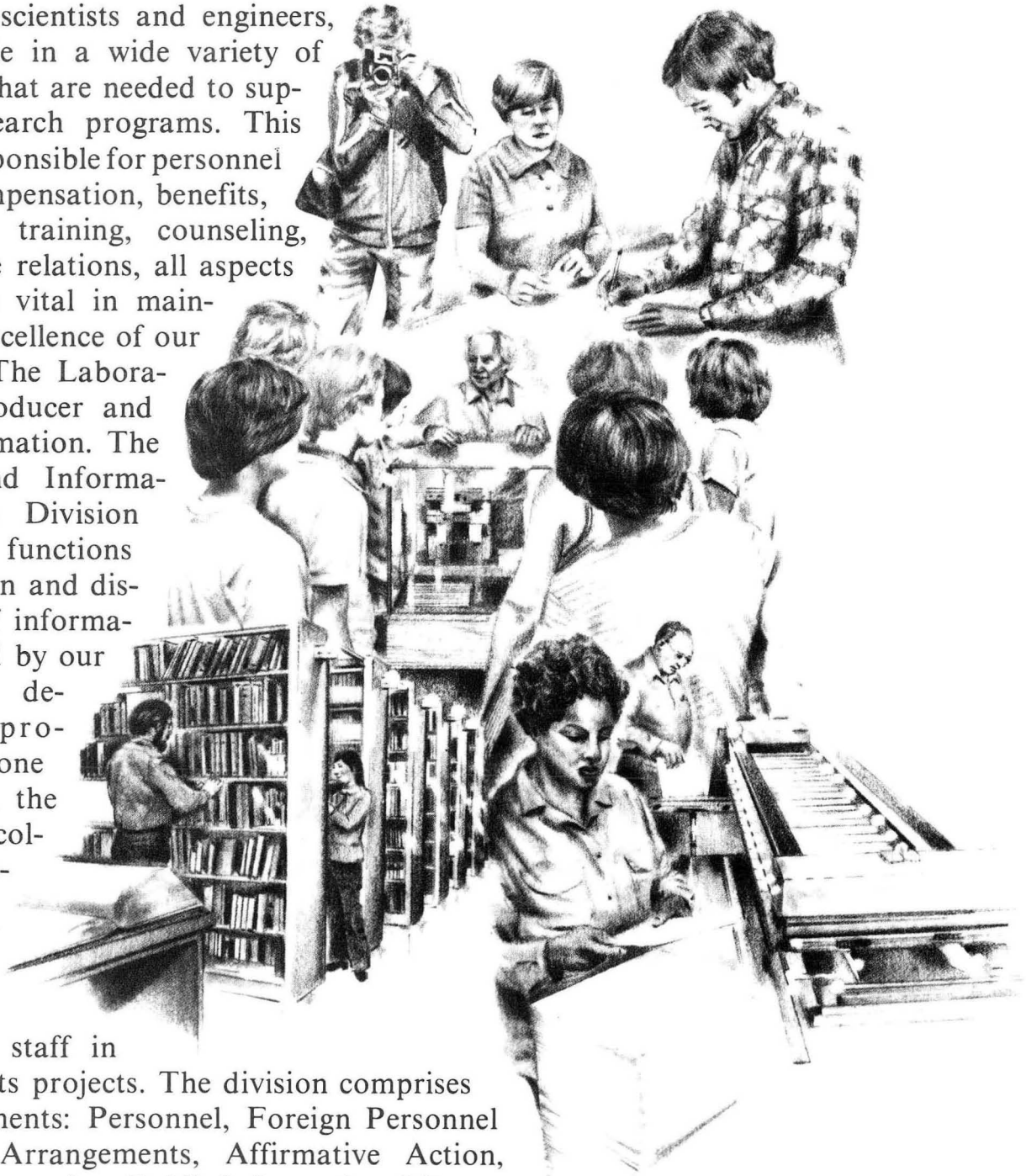
Railroad Locomotive Instrumentation Systems

Under sponsorship from the Federal Railroad Administration, we are developing a portable Locomotive Data Acquisition System (LDAP) to obtain engineering data. LDAP includes a data recorder based on a minicomputer and designed to be installed in a freight locomotive. While our immediate objectives are to prove validity of the LDAP concept, we plan near-term applications of this instrument system to support FRA's Locomotive Performance Analysis Program and the DOE Energy Conservation Program.



The Locomotive Data Acquisition System will be designed around a minicomputer for installation in a freight locomotive.

The Employee and Information Services Division is responsible for the broad areas of human resources and communications. A research establishment such as LBL is staffed not only by scientists and engineers, but by people in a wide variety of occupations that are needed to support the research programs. This division is responsible for personnel selection, compensation, benefits, development, training, counseling, and employee relations, all aspects of which are vital in maintaining the excellence of our work force. The Laboratory is a producer and user of information. The Employee and Information Services Division has as major functions the publication and dissemination of information produced by our research and development programs on one hand and on the other, the collection, processing and supplying of information needed by the technical staff in carrying out its projects. The division comprises seven departments: Personnel, Foreign Personnel and Visitor Arrangements, Affirmative Action, Technical Information, Public Information, Library, and Information and Data Analysis, with a total work force of 215 employees.



R. K. Wakerling

Ray Wakerling
Head, Employee and Information
Services Division
Associate Director, LBL

Employee and Information Services

Raymond K. Wakerling
LBL Associate Director
Head, Employee & Information Services

Division Administration
Mabel C. Smith

Division Staff

Affirmative Action
Lorenzo A. Hernandez
Nora M. Brusuelas
Bari W. Evans
Donald H. Hirabayashi
Frederick Hughes
Bernice Moore

Foreign Personnel and Visitor Arrangements
Pearl C. Cone
Lee B. Davenport
Eugenia L. Hull

Information and Data Analysis
Michael C. Lederer
David F. Cahn
Barbara A. Cerny
Jack H. Howard
Douglas Kreitz
Dennis J. Lawrence
Susan Lepman
Gerald Litton
Christopher V. Murano
Huseyin Ozbek
Sidney Phillips
Steven T. Rosenberg
Mehdi Tavana

Library
Roy J. Nielsen
Carol D. Backhus
Victoria A. Davis
Dorothy E. Denney
Maria K. Feder
Cecile E. Grant
Gloria L. Haire
Margaret S. Hu
Rita Y. La Brie
Jose A. Olivares
Stephen B. Parker
Josephine M. Robinson
Richard L. Robinson
John Rollefson
Helaine R. Simmons
Laura J. Spurrier
Virginia Sternberg

Personnel
Harold A. Wilson
Barbara A. Birkett
Maurice J. Copeland
Willie T. Drinks
Joseph A. Finn
Georgia M. Gaskin
Phyllis C. Hartwig
Katherine A. Henmi
Ryon T. Huffman
Suzanne E. Koehn
Ronald D. Lowder
Cheryl J. McIntyre
Robert E. Mortiboy
Douglas A. Smith
John W. Smith
Catherine J. Stitt
Amerigo R. Villacara
Judith A. Williams
Belinda A. Worthen

PERSONNEL

Our Personnel Department carries out three major activities: personnel placement, employee relations, and compensation and benefits administration. The department has always maintained an active recruiting program, but with the expansion of the Laboratory's research program, beginning in January 1975, employment activities set a record pace, which they have maintained. The Laboratory's population increased from 2400 employees in early 1975 to over 3700 in September 1978.

The Training and Employee Development group works with the Laboratory divisions to design, coordinate, and conduct training programs and other services. These services have included a comprehensive management and supervisory training program, general skills training, and formal education programs for a broad spectrum of employees.

The Employee Relations section provides consulting and administrative services involving employee relations and labor relations for the Laboratory. These include counseling employees and supervisors, coordination of policies with the University of California, and resolution of employee complaints.

The Compensation and Benefits Administration staff handles the salary, wage, benefits and records management programs. They develop job classifications and structures, and coordinate jobs and salaries by audit and survey. They also administer the health insurance, life insurance, and retirement programs and provide counseling and health services in coordination with the Medical Services Department to employees and their families aimed at resolution of personal problems that may be affecting their work.

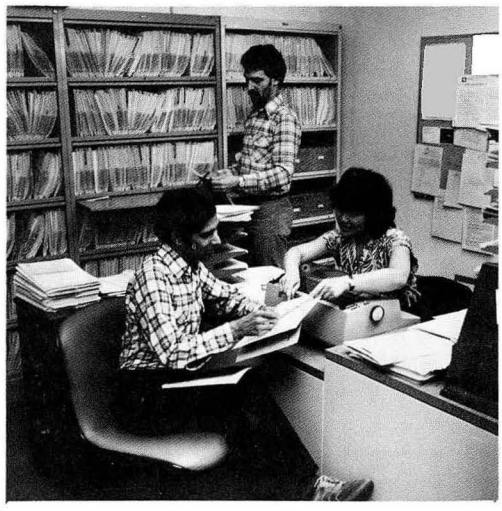
FOREIGN PERSONNEL AND VISITOR ARRANGEMENTS

This department encompasses the Foreign Personnel Office, Pass Office, Citizen Guests Office, and Laboratory Tours.

We have many visiting scientists at LBL that come for short or extended periods who may require assistance in any of the matters involved in relocating to another country.

In addition to providing such assistance, the Foreign Personnel and Visitor Arrangements Department is responsible not only for the employment of foreign visitors but also for processing our foreign guests; it

Georgia Gaskin, benefits representative, helps employees solve the problems that can revolve around compensation, retirement plans or other employee benefits.



Visiting scientists and personnel from around the world are assisted by our Foreign Personnel and Visitor Arrangements Department. Carol Yoshimoto is helping Ashwani Mathur complete a form.

Staff Continued

Public Information
John Feack
Paul A. Bendix
Judith Goldhaber
Charles S. Hurley
Carole L. Reed
Phila J. Rogers
Carol J. Zeitlin

Technical Information
Theodore H. Kirksey, Jr.
Elliott A. Amon
Shirley J. Ashley
Richard A. Bailey
Rudolph G. Barton
Sandra K. Berlowitz
Robert C. Bigelow
Josephine A. Camp
William B. Channel
Irene S. Croft
Ellen Diamond
John P. Flambard
Stephen D. Gerber
James G. Halverson
George T. Kagawa
John W. Knight
Caroline K. Little
Loretta R. Lizama
H. Louise Millard
Robert J. Morris
Susan B. Ovuka
G. Donald Paxson
George S. Pappas
F. Arlene Spurlock
Candace L. Voelker
Catherine L. Webb

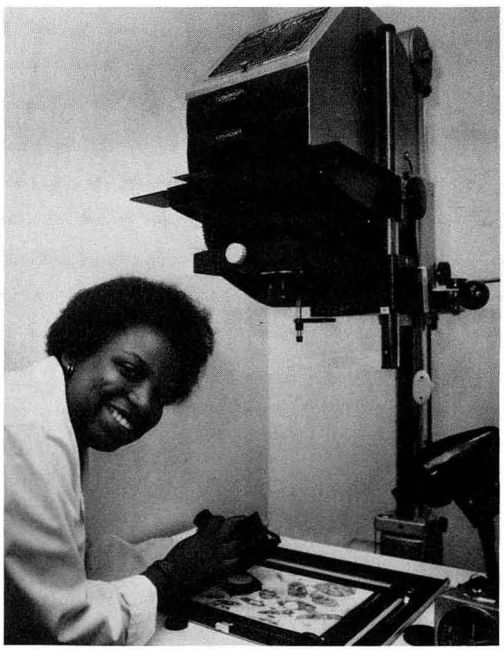
has aided the 500 visitors from other countries who are currently at the Laboratory.

All employees and guests receive their identification badges and parking permits from our Pass Office. An average of 350 people are "badged" each month.

The Tour Office arranges tours for approximately 4000 visitors annually—for groups such as science classes, technical societies, and parents of incoming freshmen. For our employees and the general public, tours are held on a regularly scheduled basis with scientific staff members assisting in presentations as necessary.

AFFIRMATIVE ACTION

Preparation of LBL's annual Affirmative Action Program is a major project in this department; it outlines the Laboratory's policies and commitments regarding affirmative action. On the basis of the approved program, this department implements the affirmative action policies and monitors all personnel actions. They help our employees resolve any problems of a discriminatory nature.



In her second year with the LBL Summer Youth Employment Program, Katherine Green worked as a biomedical photolab assistant.

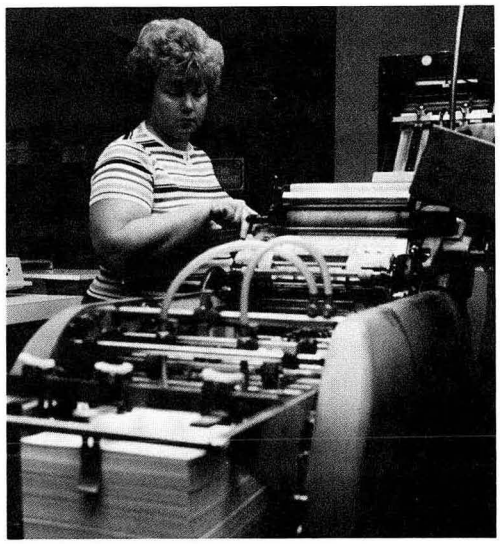
With the cooperation of LBL divisions, the Affirmative Action Department has been effective in organizing and administering various youth programs, apprenticeship and intern programs, and externally funded programs such as WIN (Work Incentive Program) and CETA (Comprehensive Employment and Training Act).

These activities have contributed in a large way to the Laboratory's forward-looking position in promoting a work force that is more representative of the community in its use of minorities, women and other members belonging to a protected class.

TECHNICAL INFORMATION

From the Technical Information Department (TID) we disseminate technical information generated by the Laboratory's scientists in their research programs. Generally, this is accomplished through the publication of scientific and technical reports. Annually, over 1500 publications, representing over 100,000 pages of technical information, are processed through TID. Many of the Laboratory's scientific and technical reports are processed for publication in leading journals, conference proceedings, and reference books. In addition, entire conference proceedings, reference and handbooks, division and laboratory annual reports, and other major special reports are published here.

Our TID staff members provide assistance to authors in preparing their technical reports for publication. Typically, publication specialists coordinate the many functions required for final production; illustrators and artists conceptualize ideas through graphs and drawings; photo specialists capture visual representations of hardware and experiments; editors and writers assist with text preparation; word processing/composition technicians set the reports in type for camera-ready copy; patent personnel review for inventions and



Donna Coakley keeps the press running. Over 30 million pages are printed annually by the Technical Information Department.

other patentable material; and printers transfer the product into final form for publication.

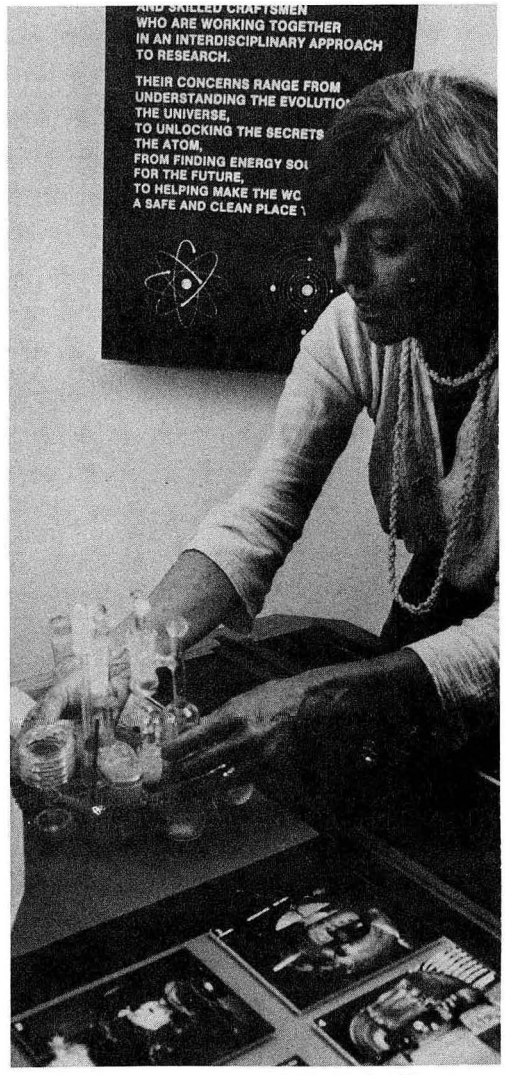
In addition to the dissemination of technical information through the publication of technical reports, we produce multimedia presentations, motion pictures, and other visual presentations at TID in a continuing effort to communicate the results and progress of LBL research, and related activities.

Other functions of TID include: technology liaison, for transferring our technical knowledge to appropriate state and local governmental agencies; conference coordination, for arranging the numerous official meetings and conferences hosted by the Laboratory; and data systems, for providing computer support to TID.

PUBLIC INFORMATION

Because of its illustrious history, the nature of its work, its affiliation with the University of California and the U.S. Department of Energy, and the many important accomplishments of its scientific and technical staff, LBL holds a position of prominence in the community, in the nation, and in the world. Our Public Information Department (PID) is the conduit for communicating information about LBL's scientific achievements and activities to the general public, to the local community, to LBL employees and to various other segments of the public.

PID works closely with the information offices of both UC and DOE for the timely release of news to be distributed through the general news media and in regular publications for employee information. PID also produces information leaflets, as well as exhibits and displays on a variety of Laboratory topics.



Phila Rogers prepares an exhibit of scientific apparatus for the LBL Visitor Center.

LIBRARY

Our libraries at LBL operate in the traditional sense of acquiring, processing, and indexing, in order to furnish our technical staff with the information they need to carry out their projects. This information is found in a variety of special sources including maps, patents, product literature, and some 50,000 books and bound journals.

We maintain library materials and services in four different locations: The main library plus three specialty libraries in Donner (biology and medicine), Building 62 (materials and molecular research), and Building 90 (engineering, earth sciences, and energy and environment).

An unusual service that we provide through the Library Department is computer-assisted information retrieval. Through this service, our employees have access to over 150 databases in a number of scientific fields, many at no fee.

INFORMATION AND DATA ANALYSIS DEPARTMENT

Within the laboratory, there are a half dozen "information analysis" projects—groups that scan the literature for information on a particular subject, abstract and evaluate the data, and disseminate the results to those who need them. Although much of this work requires a highly specialized knowledge of the specific subject, such as in nuclear physics or geothermal energy, there are common problems faced by the various projects, the importance of which increases as large databases and complex computer techniques are developed. Our Information and Data Analysis Department (IDAD) was established in 1978 to coordinate the efforts of these data projects in areas of common interest, and to foster the development of new projects

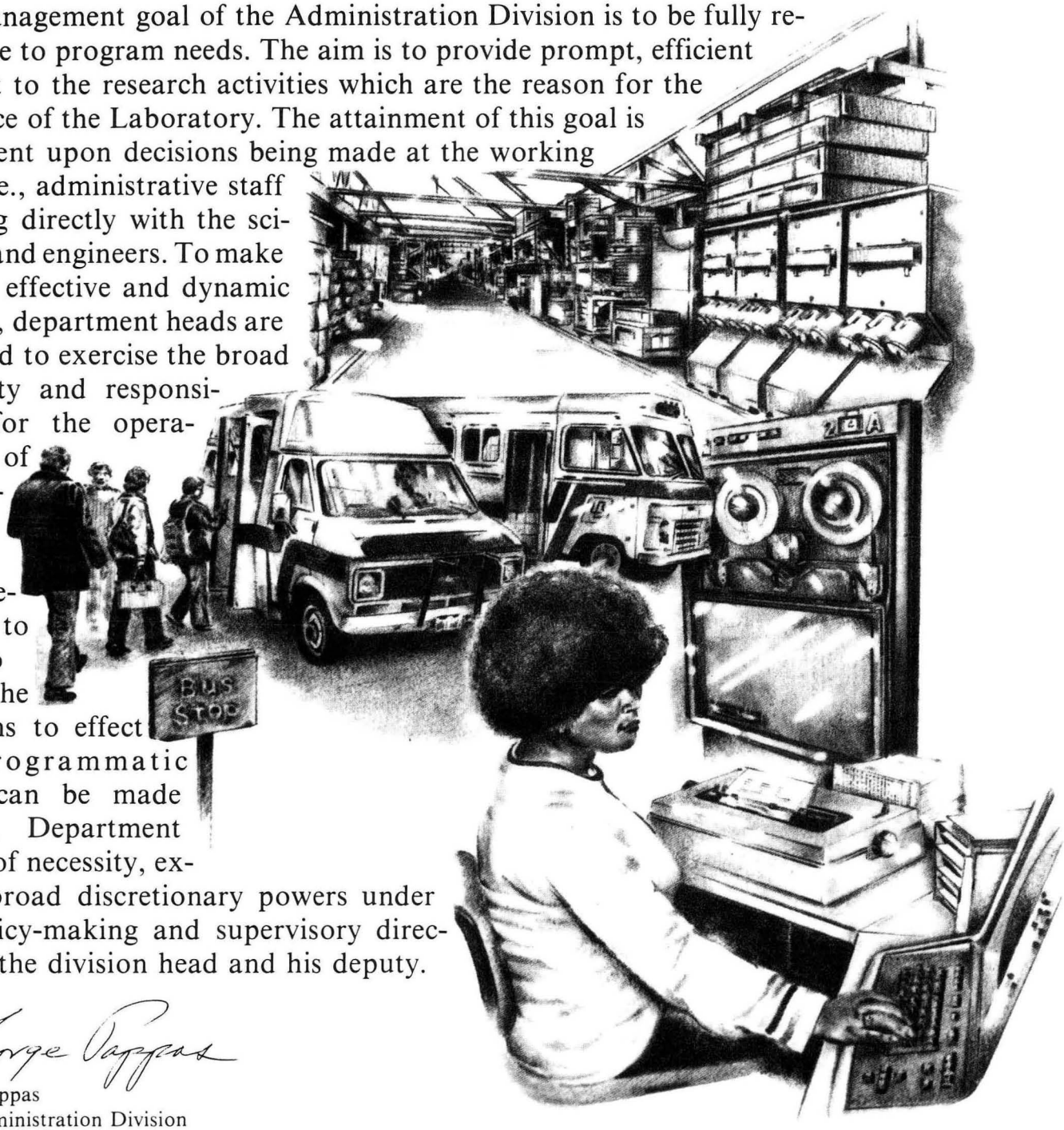
The library's computerized search system provides a list of publications covering the subject in question. Jo Robinson and Margaret Hu demonstrate the system.

Mehdi Tavana, Gerry Litton, and Vickie Santiago refine a file definition for a geothermal database. Geoscientists nationwide will have telephone access to extensive computer databases of numeric fact and bibliographic data developed by the GRID project.

in fields in which the compilation and evaluation of data are needed.

IDAD maintains a small staff to assist investigators of data projects with the development of their computer programs and databases, and with the composition of specialized publications by a combination of computer and manual techniques. The department also administers the National Geothermal Information Resource (GRID) and the Information Methodology Research Project, which has as its mission the development of new techniques for dealing with complex numeric fact and bibliographic databases.

The management goal of the Administration Division is to be fully responsive to program needs. The aim is to provide prompt, efficient support to the research activities which are the reason for the existence of the Laboratory. The attainment of this goal is dependent upon decisions being made at the working level; i.e., administrative staff working directly with the scientists and engineers. To make this an effective and dynamic process, department heads are expected to exercise the broad authority and responsibility for the operations of their departments as delegated to them so that the decisions to effect the programmatic needs can be made rapidly. Department heads, of necessity, exercise broad discretionary powers under the policy-making and supervisory direction of the division head and his deputy.



George Pappas

George Pappas
Head, Administration Division
Associate Director, LBL

George L. Pappas
LBL Associate Director
Head, Administration Division

Mark Owens, Jr.
Deputy Division Head

Division Staff

Accounting Office
Edward J. Pollak

Budget Office
William J. Shanahan

Business and Auxiliary Services
Igor R. Blake
Daniel S. Andes
Thomas P. Hitchcock

Contracts and Grants
Gertrude Young

Supply Department
Donald A. Bruce
J. Thomas Beales
Richard A. Lanzit
D. Vendelboe Nielsen

Administering the business aspects of a research facility as large and complex as LBL is a complicated and demanding task. Those who carry out these activities must be attentive to multiple sets of guidelines and regulations, while providing full support for the research activities.

The Laboratory occupies a position in the University of California equivalent to that of an independent campus, while the research at LBL is conducted under the aegis of a major contract with the Department of Energy. This contract was first negotiated in 1943 between the federal government and The Regents of the University of California, and is officially designated as Contract W-7405-ENG-48. In 1971 Lawrence Livermore and Berkeley Laboratories were given independent status, although we continue to operate under the one contract. By coordinating several administrative functions, we both achieve economy and efficiency of operation.

It is our Administration Division's responsibility to ensure that the terms of this contract are met. In so doing, we must be responsive to three systems, not all of which may be in concert at any one time. Still, a smooth operating balance has been achieved and maintained by our staff of 260 in the Administration Division, which is organized into departments dealing with accounting, budget, business and auxiliary services, contracts and grants, and supply.

At the present time, DOE supports over 85% of the Laboratory's budget. The remaining funding comes from different sources, mainly other federal agencies such as NASA; the Departments of Labor, and Health, Education and Welfare; and from government contracts in the private sector.

CONTRACTS AND GRANTS

Funding for R&D from sources other than DOE is obtained through our Contracts and Grants Office. Such funding is now at a level of about $8.0 million annually, covering about 100 active projects.

BUDGET

Each year a projected budget for LBL is drawn up by our Budget Office in coordination with the director's and division offices. The process actually starts 17 months prior to the beginning of the target fiscal year with the Budget Office requesting information from each division as to its planned research, estimated funding, and manpower needs. The accumulated information is analyzed by computer, which incorporates many variables of Laboratory operation and then projects a budget for the next two fiscal years.

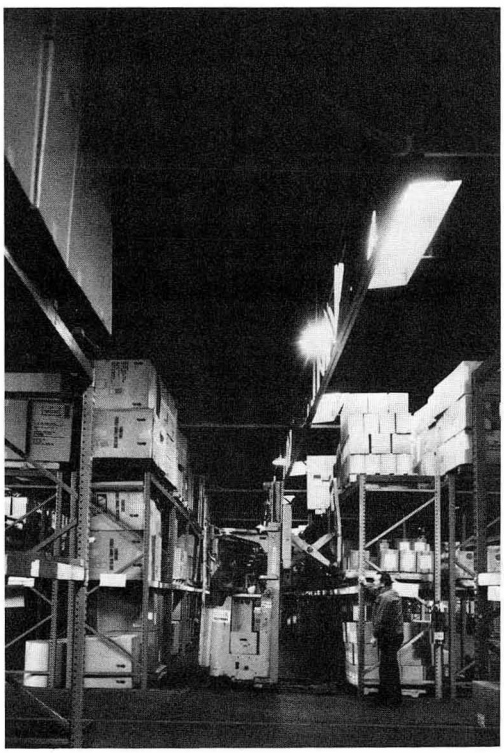
We submit this budget information to DOE, which in turn works with the Office of Management and Budget to prepare a budget that the president submits to Congress. After extensive deliberation by Congress, and inevitable changes, the general budget appropriation is passed and DOE receives a specific amount which is distributed to its contractors including LBL.

Since fiscal year 1971, when LBL funding was no longer combined with LLL funding, $600 million have passed through the Budget Office to support research at LBL. That funding has contributed to some of the most important scientific discoveries of our time.

ACCOUNTING

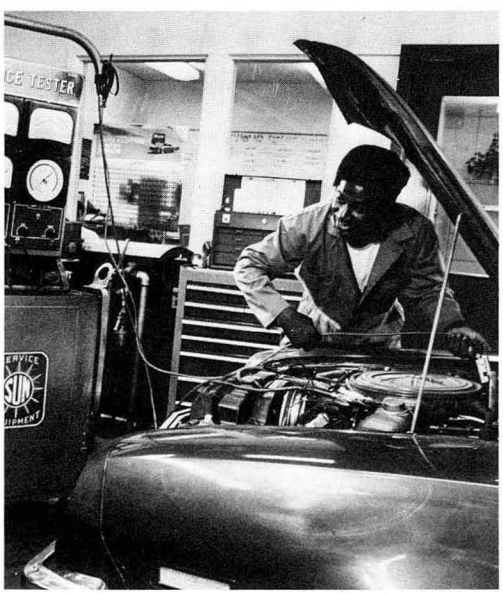
Coordinating closely with the accounting group at Livermore, our Accounting Office provides the Laboratory with services in payroll, accounts payable and receivable, property accounting, cashiering, and general accounting. Economies of scale, the administrative computer at LLL, and the need for consolidation of financial data, account for our use of LLL personnel and facilities.

Payroll answers all local questions regarding pay and deductions, distributes checks, and distributes and collects time cards and forwards them to Livermore. From there, over 60,000 paychecks are issued annually to Berkeley employees,



Nearly 1100 stock items are stored in bulk at Building 901 in Oakland. This warehouse also holds inactive research equipment and surplus storage items and will be relocated to Emeryville in 1980.

The central repository contains about 2500 cubic feet of inactive records of nearly all LBL activities. Bonnie Acuna and Dorothy Tuley keep track of every page.



Phil Mitchell tunes up a lab vehicle at the motor pool.

A recent addition to the shuttle fleet is our largest bus, which can carry up to 35 people. Its airbag suspension and diesel engine give a smooth ride and improved fuel economy. The LBL Shuttle system, which keeps four on-site and two off-site buses on the road each workday, transported some 600,000 passengers around the Laboratory last year.

based on over 100,000 time cards that also serve as the basis for monitoring the progress of projects.

Our payment for materials and services is carried out through two main channels: invoices on regular purchase orders are processed through the Livermore office, while those on special orders (university orders, blanket orders, construction orders orders) are processed by our Berkeley office. In both cases, checks are written at LLL.

On the Accounts Receivable side of the ledger, about $2.0 million in miscellaneous receipts are handled each month. These funds arise primarily from 2000 accounts of work done for others.

The Laboratory has an inventory of over 35,000 pieces of capital equipment valued in excess of $125 million. Property Accounting maintains the financial property records for this equipment and also keeps records of users of precious metals and other sensitive items.

One office under Accounting with which many of us are familiar is the Cashier's Office. Here over 10,000 transactions are conducted annually, amounting to almost $2 million for petty cash reimbursements and travel advances.

All of these accounting functions are combined by General Accounting for general ledger input and analysis, rate calculation, and report generation. It is this office that "keeps the books" and supplies management with accurate, timely, and concise reports on their activities.

SUPPLY DEPARTMENT

Our Supply Department provides a broad variety of services needed to conduct the work of the Laboratory. Its three principal operating groups are Purchasing, Inventory Management, and Supply Services.

Purchasing buys, or otherwise procures, the required equipment, non-stores supplies, common services, specially engineered fabrications, low-value construction, research and development work, and expert technical and professional consultant-type assistance. Types of activity range from simple shopping for common off-the-shelf items, to negotiating complex cost-type subcontracts for securing highly specialized assistance in support of the Laboratory's programs. The staff processed 17,000 transactions totaling $21,490,000 during fiscal year 1978.

Inventory Management operates the Laboratory's storeroom system and buys, through a variety of sources, most of the stock items kept at both the Lawrence Laboratories. Much of this group's work is computerized. For example, STAP (Stores Analytical Program) is used by both laboratories to control inventories, while a companion program, RELEASE, when triggered by STAP or a buyer analyst, generates either a purchase order against an existing contract, or a requisition for regular buying. The storeroom staff maintains a stock of 16,400 line items valued at some $2,300,000 and makes 260,300 issues exceeding $5 million. The procurement staff processes 28,000 transactions totaling $15 million in maintaining a combined Berkeley and Livermore inventory of 29,600 line items and $9 million.

Supply Services provides a wide variety of services to all segments of the Laboratory. These services include support to the basic procurement activities via receiving, shipping and internal delivery services. In addition, however, Supply Services is responsible for the laboratory fleet of over 200 vehicles including a maintenance/repair facility; a shuttle bus system which transports more than 600,000 passengers annually; an inter-office and U.S. mail system handling over 2 million pieces of mail annually; a records storage and management system; a transportation of materials function; reclamation and excess material services which recycle materials and dispose of material via sale or excess and acquire material via excess, shop stock, substoreroom, and industrial gas service for supplies maintained in various program areas; and an office machine pool and maintenance service operation.

Administrative work for this department is centralized in the Supply Office. Typi-

cally the work includes personnel and salary administration, budgeting and cost control, regular and special reports, and related files and records. In addition, considerable effort is devoted to developing and maintaining policies and procedures for all supply functions, many of which are needed to fulfill prime contract obligations and requirements. In particular, the Supply Office carries the bulk of this policy and procedures responsibility in procurement for both the Berkeley and Livermore Laboratories since the staffs of both use much of the same written materials in their work under the common prime contract.

BUSINESS AND AUXILIARY SERVICES

A variety of our business functions are managed by the Business and Auxiliary Services Department. Important recent accomplishments include the conversion of our basic telephone service to a new electronic switching system called Centrex, which permits outside callers to dial in directly. Each station has been redesigned to make best use of the new features available with Centrex.

The continued diversification of the Laboratory's scientific program has been responsible for a substantial increase in volume in the Travel Office. The number of trips processed increased by 43% from 3,631 in calendar year 1977 to 5,203 in calendar year 1978. To accommodate this volume, our Travel Office has initiated an agreement with a commercial travel agency for assistance – a service provided at no cost to the Laboratory. We plan to promote direct reservation arrangements between our staff and the agency.

Over 500 outside organizations use time on the Laboratory's computer and account for the major share of jobs handled by our Business Services Work-for-Others Section. Total volume was $8.609 million in 1978.

The biennial capital equipment inventory is always a major effort in Property Management. Over 32,000 items valued at $1 million were surveyed by our inventory-team personnel during fiscal year 1979. In alternating years, sensitive items and precious metals are inventoried.

Various other business functions for which this department is responsible include managing the cafeteria, responding to audits, and approving outside business activities of employees.

All administrative data-processing acquisitions are closely controlled by DOE, and for that agency Business Services reviews and reports on all such LBL acquisitions and on the use of such equipment.

The overall management authority and responsibility for administrative information systems and associated programming effort is vested in Administrative Data Processing.

The administrative information programs now total 217, representing a large profile of users. The newest systems include Space Analysis for Plant Engineering, Contract Labor for Accounting, and a new Coordinated Accounting Reports Distribution system (CARDS). CARDS is a major improvement in handling broadly distributed reports. The system maintains a distribution list for each recipient, with detailed information. When producing reports, the system gathers together the data for noncontiguous accounts and addresses the packets. In a typical month, it aids in distributing about 25,000 pages to some 250 addressees. The Expense Statement and Detail Ledger are now in the users' hands about a week earlier than before.

In the next two years, our Data Processing will acquire a remote job entry terminal for Livermore's new administrative computer. In addition, a minicomputer will be provided for the supply systems, which will have links to the LBL Computer Center and to LLL's new administrative computer. These new links will facilitate our keeping the research divisions informed currently on financial commitments.

Personnel in Protective Services safeguard LBL personnel and property, enforce traffic and parking regulations, and con-

Officer Mary Anderson handles telephone and radio communications, emergency alarms, dispatches police services, and maintains the logs in the course of a day. After normal working hours this becomes the Laboratory's main communications center.

trol access to LBL. During nonworking hours, this office serves as the general communication center.

In the course of protecting our LBL staff and property, the Protective Services staff in 1978 drove 76,000 miles, investigated 218 criminal offenses and 72 traffic collisions, cited 2,332 traffic violators, and issued 1,950 reports on their work.

Since 1977 the Laboratory has experienced a growth of almost 50% in plant and equipment from $14 million in FY77 to $20 million in FY79. Likewise, operating costs rose from $82 million in FY77 to $112 in FY79 and are projected to $118 for '80. Our Administration Division, which must control all financial aspects of this expanding institution, finds itself constantly challenged. Progressive management, aided by new technologies, is ready for the challenge.

Summary: Manpower and Financial Data

Manpower (1)

	(estimated) 1979	1978	1977
Scientific Groups	1283	1280	1106
Support Groups	1265	1202	1038
Administration	502	440	376
Training Programs	20	71	36
TOTAL	**3070**	**2993**	**2556**

Financial Data

COST OF OPERATIONS *(in millions of dollars)*

DIVISIONS	(estimated) 1979	1978	1977
Accelerator	18.6	18.5	15.5
Biology and Medicine	10.5	9.8	7.8
Chemical Biodynamics	2.5	2.2	2.2
Earth Sciences	13.6	10.9	—
Employee and Information Services	0.6	0.3	0.2
Energy and Environment	14.5	12.4	18.7
Engineering and Technical Services	12.1	14.0	4.1
Materials and Molecular Research	9.9	9.8	8.5
Nuclear Science	7.4	8.7	6.7
Physics, Computer Science and Mathematics	15.9	16.0	14.2
National Resource for Computations in Chemistry	1.2	1.0	—
Other	5.2	5.4	3.6
TOTAL	**112.0**	**109.0**	**81.5**

Lawrence Berkeley Laboratory

PLANT AND EQUIPMENT *(in millions of dollars)*

COSTS	(estimated) 1979	1978	1977
Plant	4.5	1.1	5.6
Equipment	10.5	7.8	8.4
TOTAL	**15.0**	**8.9**	**14.0**
INVESTMENT			
Plant	52.0	49.0	49.0
Equipment	126.0	122.2	113.0
TOTAL	**178.0**	**171.2**	**162.0**

(1) Average full-time equivalent persons

Pub 296/February 1980/Technical Information Department/12,500M