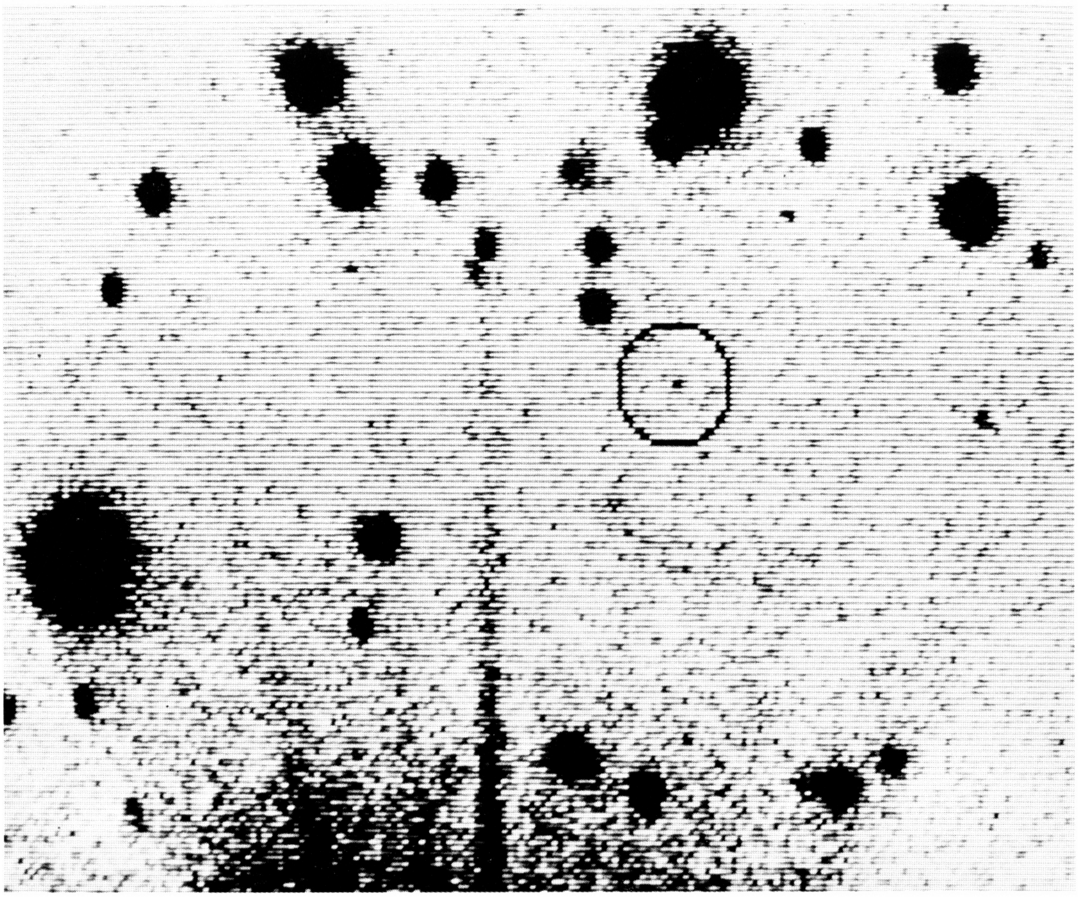
California Institute of Technology

1982-83 Annual Report



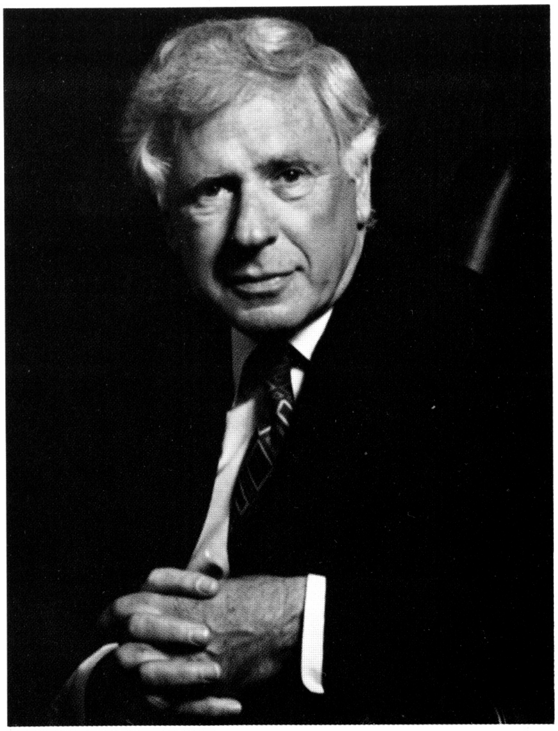
Halley's Comet (circled), as detected by astronomers at Caltech on October 16, 1982. Using an advanced electronic detector system and the 200-inch Hale telescope at Palomar Observatory, they made this premier observation of the comet on its current approach to the sun.

California Institute of Technology

1982-83 Annual Report

Pasadena, California

President's Message



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This annual report introduces a new format for presenting our friends with information about Caltech and its activities. Replacing the traditional *President's Report*, it offers a concise look at the Institute, its programs, achievements, and challenges.

The past year was an exciting one, especially so because of developments suggesting that the future will be even more exciting. In our laboratories, scientists and engineers are developing a generation of tools that will open up dimensions of knowledge—and of scientific and technological capability—previously far beyond our reach.

Tools for genetic engineering, for observing the cosmos, for plumbing the structure of matter and of our planet, for gaining new insights into chemical reactions, and for constructing new materials for electronics and communications—all of these are coming from Caltech's laboratories. And revolutionary developments in computer technology are under way here that will enable us to perform monumental computations, contributing to knowledge in all these areas. This is an exciting time for us and for our friends—and one that makes us feel fortunate to be associated with the Institute.

As we look back on 1982-83, we find many reasons to feel pleased. Nuclear astrophysicist William Fowler was awarded the Nobel Prize in Physics for his work on the dynamics of chemical reactions and the life cycles of stars. Neuroscientist Seymour Benzer was awarded the National Medal of Science.

This past year, we welcomed three new members to the Caltech Board of Trustees. Donald L. Bren is chairman of the board of The Irvine Company and The Bren Company. Howard B. Keck is chairman of the W. M. Keck Foundation, as well as sole trustee of the five other W. M. Keck Trusts. Gordon E. Moore, a Caltech alumnus, is chairman and chief executive officer of Intel Corporation. In addition, L. F. McCollum, a member of the board since 1961, has been elected a life trustee.

We were sorry to lose four board members. Robert S. Ingersoll, a trustee since 1961, has resigned, as has Deane Johnson, after 15 years of service on the board. Two of our life trustees passed away: Lawrence Williams, on December 1, 1983, after 29 years of service; and John O'Melveny, a board member for 45 years, on March 1, 1984.

Financially, fiscal year 1982-83 was a successful year. Caltech received $21.7 million in gifts, and our endowment fund reached a record $248 million. Our campus budget for the 1983-84 fiscal year totals $117 million—about eight percent above last year's actual expenditures of $108 million. The budget is balanced.

The Jet Propulsion Laboratory continues to increase our knowledge of the solar system and the universe. Preparations are well under way for the Galileo mission to Jupiter, scheduled for launch in May 1986. Voyager 2 is cruising toward encounters with Uranus in January 1986 and Neptune in August 1989.

JPL's Infrared Astronomical Satellite (IRAS) achieved spectacular success. Orbited in January 1983 to scan the entire universe for sources of radiation in the infrared spectrum, it has returned a wealth of information about previously undetected phenomena in the cosmos.

The past year has been filled with many achievements—and with the continuing emergence of challenges. One of these is posed by the decline in the number of college-age young people, and what this means for our student recruitment program. While our 1983 freshman class was of comparable quality to previous freshman classes, we nevertheless recognize that we must compete more aggressively than in the past for top students. As part of this effort, we have revised recruitment materials, emphasizing the opportunities created by our new educational computing program. In addition, alumni involvement in student recruitment is being expanded.

Even as we face a shrinking pool of applicants, our financial aid office has encountered a tightening in governmental funds available for student financial assistance. We need these funds badly if we are to continue to honor our historic commitment to make education at the Institute feasible for outstanding students from all economic backgrounds. Traditionally, the great majority of our undergraduates has received some form of financial aid.

Efforts to significantly increase our endowment and gift support for scholarship and low-cost loan programs are currently under way. The Caltech development office continues to emphasize student aid as a top fund-raising priority. Meanwhile, the financial aid office is developing incentives to encourage students to tap scholarship resources outside the Institute whenever possible.

Another challenge—this to our educational program—lies in the growing enrollment in engineering and computer science. In 1973, 30 percent of our students majored in engineering. By 1982 that number had risen to 62 percent. This shift has meant larger class sizes and substantially increased pressures on our engineering laboratories and classrooms, and on our faculty members—especially in computer science, electrical engineering, applied physics, and chemical engineering.

To meet the growing demands in these fields, we have initiated an educational computing program that will make computer use an increasingly integral part of the Institute curriculum and enable the students themselves to govern one of the campus's major computing facilities. We are also seeking a number of new faculty members in engineering, but competition for the best is rigorous.

Another problem—one that we share with universities across the country—is the need to modernize laboratory equipment. This situation is reaching crisis proportions. It was dramatized in 1983 when the Department of Defense issued a request for proposals from universities for research equipment grants. University proposals totaled $645 million; the Department of Defense responded with $30 million—or about 4.5 percent of what the universities assessed as their need. Caltech's requests alone amounted to $7.3 million for immediate needs.

Earlier I noted that our endowment fund reached $248 million in 1983. We are grateful for this achievement, and we must build on it. Endowment funds provide a solid foundation that allows us to plan on a long-range basis, to respond flexibly to unanticipated opportunities and needs, and to meet expenses not covered through federal funding—equipment maintenance, for example, or start-up funds for a new faculty member whose laboratory may cost up to $700,000. Last year, endowment income provided 15 percent of Caltech's revenues.

But endowment funds are difficult to build. The corporations and foundations that provide two-thirds of Caltech's private support do not usually give to endowment. Thus these funds generally come from individual donors. Despite a steady flow of generous gifts to endowment, the need for endowment income at a research institution of Caltech's caliber far exceeds the current level of gifts and appreciation of the existing endowment. Increasing our endowment continues to be an important priority.

Let me conclude with a summary of where we are now. Caltech is a strong and vital institution. Our research programs are well supported by federal agencies and, to a growing degree, by the private sector. Our educational and research activities are generally regarded by our peers as outstanding. In a recent national survey of graduate program faculties, we were ranked first, or tied for first, in chemistry, geology, molecular biology, and physics. We have been successful in recruiting bright young faculty members, and we have had several outstanding years of fund raising.

We do, however, have some problems that can only be solved by income beyond what we need to stay even. This support is required to ensure for the future the unique position that we now enjoy. To address this need over the coming months, we are looking at plans for intensifying our fund raising. With such support, the exciting scientific era that we are entering can be fully realized.

Marvin L. Goldberger

Marvin L. Goldberger
President

The Year in Review

The year 1982-83 witnessed many significant achievements and changes at the Institute.

Education

In 1982-83, as the last of the baby-boom generation entered its twenties, Caltech began to feel the impact of the national decline in the number of college-age students. The Institute received applications from 1,382 students—down from 1,665 in the previous year. From this group, 151 men and 34 women were chosen to make up the freshman class of 185—the smallest number of entering freshmen since 1970. Undergraduate enrollment for the fall of 1983 totaled 829. Faced with the prospect of a shrinking applicant pool, Caltech elected to admit fewer students rather than lower its standards. So the new freshman class was as intellectually impressive as always, with the average SAT scores in the top two percent of the nation.

Senior Candice McCoy conducts research in biology under a grant from Caltech's SURF (Summer Undergraduate Research Fellowships) program, which since 1979 has provided funds for selected undergraduates to remain on campus during the summer and pursue student-designed research projects under the guidance of a faculty sponsor.

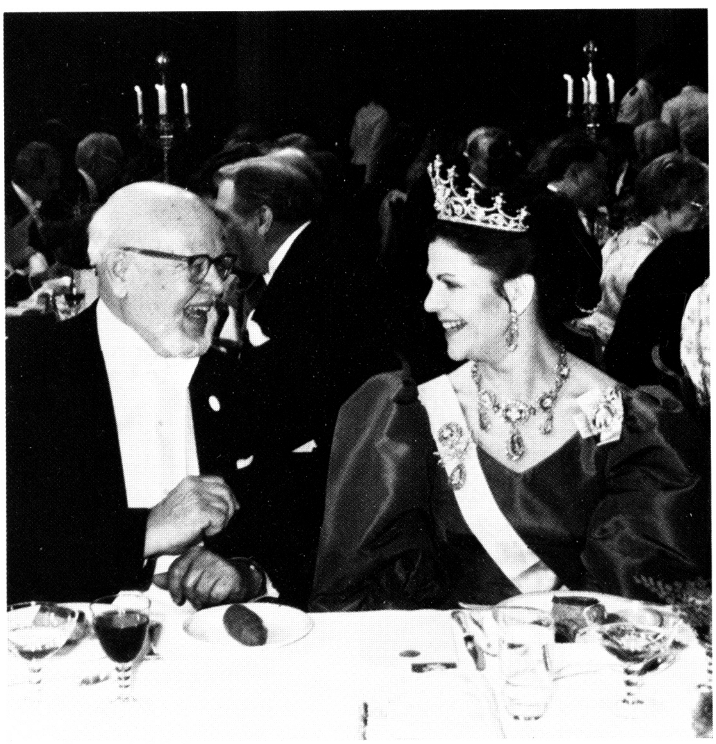
With undergraduate tuition and other expenses totaling $13,299 for 1983-84, Caltech also noted some decline in both applications and accepted offers of admission from students whose middle-income families fall in the $25,000 to $55,000 bracket. However, the Institute continues to offer admission on the basis of merit, regardless of ability to pay. Approximately 80 percent of undergraduate students receive financial aid of some sort. Thus far, graduate students have been less affected by rising tuition rates, as 99 percent receive financial assistance. Graduate enrollment reached an all-time high of 936 in October of 1982 and remained the same in the fall of 1983.

Caltech students graduating with B.S. degrees in June 1983 received salary offers averaging $2,500 above the national norm—benefiting from a job market in which employers were hiring more selectively and bidding more competitively for top people than in the past. The average annual salary offer for Caltech B.S. degree recipients was $28,000; for M.S. degrees, $31,600. By August, 33 percent of the B.S. recipients had accepted full-time positions, 52 percent planned to enter graduate school, and the rest had other plans. Of the 154 M.S. students, 28 percent took jobs, and 58 percent planned to continue at graduate school, most of them at Caltech. Of the 136 Ph.D.s, 57 percent accepted academic positions, and 37 percent went into industry.

In September 1983, Caltech created a new position—dean for educational computing—and appointed Professor of Theoretical Physics Geoffrey C. Fox. In this capacity, he will monitor Caltech's investment in computing facilities, oversee the development of innovative ways to use them, and supervise the creation and use of educational software, or "courseware." The goal is to produce students who are comfortable with a variety of computers and operating systems and who can routinely and effectively use the computer to investigate scientific and engineering problems.

Director of information resources is another new position, charged with managing the development of information technology in the Caltech libraries. Glenn L. Brudvig, formerly director of the Bio-Medical Library and director of the Institute of Technology Libraries at the University of Minnesota, has been appointed to the post. In addition to planning and implementing ways for the library system to take advantage of evolving technologies, from personal computers to large national data bases, Brudvig is responsible for integrating existing information networks on campus with the main library holdings.

William A. "Willy" Fowler, Institute Professor of Physics Emeritus and co-recipient of the 1983 Nobel Prize in Physics, chats with Queen Silvia of Sweden at the Nobel awards banquet in Stockholm.



The Summer Undergraduate Research Fellowships (SURF) program, in which students carry out original research under a faculty member's direction, is now a vital part of the Caltech experience. As the fifth summer session drew to a close, a total of 220 students and 55 percent of the science and engineering faculty had been involved in the program. In 1983, out of 106 students who submitted research proposals, 77 were selected to receive fellowships. In large part, SURF owes its success to the leadership of Professor of Chemical Engineering Fredrick Shair and his colleagues, and to generous gifts by corporate and private donors.

The cameras keep rolling on "The Mechanical Universe," an innovative telecourse inspired by Professor David Goodstein's Physics 1 lectures to Caltech freshmen. Funding for the first semester's 26 half-hour programs on classical mechanics was provided by a $2.1 million grant from the Corporation for Public Broadcasting/Annenberg School of Communications. CPB/ASC recently granted $2.85 million for an additional 34 half-hour programs covering electricity and magnetism, relativity, waves and optics, thermal physics, and modern physics. Together, the programs will constitute a one-year introduction to college-level physics that is both intellectually rigorous and visually exciting through its use of special effects such as computer graphics and dramatized segments shot on location. Goodstein is executive director and host for the series.

Honors

It was time for celebration on the Caltech campus when William A. Fowler, Institute Professor of Physics Emeritus, was awarded the Nobel Prize in Physics in October 1983. He shared the honor with Subrahmanyan Chandrasekhar of the University of Chicago. The Nobel Committee cited "his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements of the universe." Fowler, who has been at Caltech since 1933, when he became a graduate student in the Kellogg Radiation Laboratory, said the prize was in recognition of "how much the lab has contributed to a very fundamental field of human knowledge." He is the twentieth faculty member or alumnus to have received a Nobel Prize.

Seymour Benzer, James G. Boswell Professor of Neuroscience, was awarded the National Medal of Science for his research on gene structure. President Reagan made the presentation in a White House ceremony in May. Another honoree was Charles H. Townes of UC Berkeley, a Caltech alumnus and trustee. Benzer and Townes are the seventeenth and eighteenth faculty members or alumni to have received the award, the nation's highest scientific honor.

Professor of Physics Felix Boehm was elected to membership in the National Academy of Sciences, bringing the total of NAS members at Caltech to 53. Boehm's research has focused on nuclear structure and the nature and behavior of subatomic particles. He is best known for his pioneering work on the symmetry properties of nuclear interactions.

Caltech conferred the Distinguished Alumni Award—its highest honor—on four of its graduates at Alumni Seminar Day in May 1983. Duane McRuer (B.S. 1945, M.S. 1948) co-founded Systems Technology, Inc., an engineering consulting firm. George E. Solomon (M.S. 1950, Ph.D. 1953) is the executive vice president and general manager of the electronics and defense sector of TRW Inc. C. C. Tan (Ph.D. 1936) is one of China's most respected geneticists. Dean E. Wooldridge (Ph.D. 1936), a noted scientist and author, co-founded Ramo-Wooldridge Corporation, and later served as president of the expanded company, TRW.

Gifts and Support Groups

In 1982-83, Caltech received a total of $21.7 million in gifts from corporations, foundations, and individuals, down slightly from the 1981-82 record high of $22.8 million.

One fund-raising effort that exceeded all past records was the Caltech Alumni Fund. In the first year of the Irvine Challenge Campaign, the fund surpassed its goals for both donors and dollars—with 52 percent of alumni (7,394) contributing more than $1.6 million. As a result, Caltech earned $224,000 in unrestricted matching funds from The James Irvine Foundation. Trustee James W. Glanville is chairman of the Irvine Challenge Campaign, and Harry J. Moore was national chairman of the 1982-83 Alumni Fund, followed by Lee Carleton for 1983-84.

Speaking at the general session of Alumni Seminar Day in May, Lew Allen Jr., Caltech vice president and director of the Jet Propulsion Laboratory, assured his listeners that planetary exploration would remain the principal activity at the lab. William J. Karzas was president of the Alumni Association in 1982-83, succeeded by Arne Kalm, who holds the position for 1983-84.

The Associates, the Caltech support group founded in 1926 by a group of distinguished Californians led by Henry Huntington, set a new record by passing the 1,000-member mark in late 1983. Robert L. Zurbach was president of the organization in 1983, with Berneice Anglea succeeding him in 1984.

Several new professorships have been established at Caltech through the generosity of both individual and institutional donors.

A grant from the W. M. Keck Foundation endowed the W. M. Keck Foundation Professorship for Resource Geology, focusing on the exploration and recovery of energy resources. Professor of Geology Leon T. Silver was appointed to fill the new chair.

The Edie and Lew Wasserman Professorship in the Division of the Humanities and Social Sciences was established by a gift from the Wassermans. Wasserman, a Caltech trustee, is chairman of the board and chief executive officer of MCA, Inc. Professor of Philosophy Brian Barry, formerly of the University of Chicago, is the chair's first occupant.

The Theodore von Kármán Professorship of Aeronautics was funded by aerospace and other corporations, foundations, and private donors in honor of the man who contributed more to the understanding of flight than any other person of our age. The first occupant is Hans Liepmann, formerly Charles Lee Powell Professor of Fluid Mechanics and Thermodynamics.

New Construction

A $700,000 grant from the Carl F Braun Trust and the Braun Foundation has been used to construct a new swimming pool, a women's locker room, and a weight training room. The completed project gives Caltech a regulation water polo pool with the required safe depth for three-meter diving. The pool is also expected to relieve crowding in the adjacent Alumni Swimming Pool.

Caltech's new swimming, diving, and water polo pool is part of a program to expand the Institute's athletic facilities.

Parsons-Gates Hall of Administration, constructed in 1917, damaged by earthquake in 1971, and renovated in 1982-83 through gifts of $1 million each from The Ralph M. Parsons Foundation and The James Irvine Foundation, reopened in May 1983. The oldest building on the Caltech campus and formerly known as the Gates Laboratory of Chemistry, Parsons-Gates now provides quarters for the offices of the president, provost, and vice presidents, along with the student affairs staff.

Caltech is taking an important step toward curbing energy costs. The first phase of a cogeneration program, which uses steam produced by campus boilers to operate a turbine-generator providing energy for electricity, heating, and cooling, has gone into operation. The cogeneration plant now produces approximately 20 percent of the entire campus's electrical supply. The second phase—a gas/oil-fired combustion turbine to supply additional power—is in the works; it should yield another 60 percent of the projected energy demand on campus for 1985.

Currently under construction on Catalina Avenue, a new graduate student housing complex is slated for completion by the fall of 1984. The complex will include six apartment buildings and a recreation building, with a total area of 42,000 square feet at an estimated cost of $3.6 million. It will house 156 graduate students.

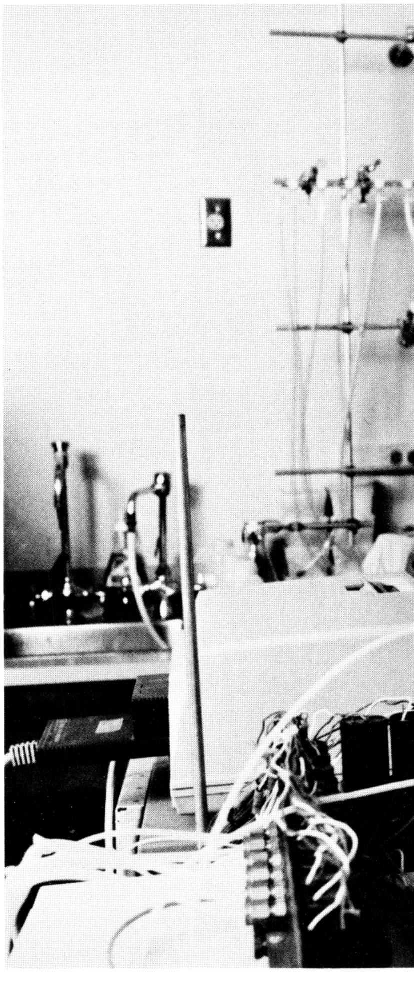
Research Highlights

Biology

The 1980s are proving to be the decade of biotechnology, which holds immense promise for exploring fundamental problems in developmental biology, neurobiology, and medicine. Caltech is a world leader in developing and further refining one set of tools for biotechnology—specifically microchemical instrumentation that exploits and extends recombinant DNA techniques.

Every cell in an organism contains all the genetic information necessary to make it what it is, encoded in the DNA, which directs the synthesis of proteins that are the building blocks for living organisms. The human organism has enough DNA to code for approximately three million proteins. A sequence of DNA governing the expression of a particular trait is called a gene. Recombinant DNA techniques permit scientists to isolate a single gene and place it in a test tube to be analyzed. New genes, including experimentally altered ones, can be introduced into cells as well.

Caltech's Division of Biology has pioneered the creation of instruments for manipulating genes and proteins in increasingly sophisticated ways. The protein sequenator, developed here a few years ago, determines the order of amino acids in a protein; and a new, ultrasensitive mass spectrometer analyzes these amino acids at levels far lower than ever before. A more refined version of the protein sequenator is under development. The recently developed DNA synthesizer (the so-called gene machine) has the capacity to synthesize genes or fragments of genes; it too is undergoing further refinement.



Leroy Hood, Bowles Professor of Biology and chairman of the Division of Biology, works with the DNA synthesizer—a "gene machine," which creates customized DNA sequences for use in genetic engineering. Co-designed by Hood, this instrument has the capacity to manufacture small genes in one or two days.

Using the protein sequenator and the DNA synthesizer in tandem will open the way to the routine cloning of biomedically interesting genes such as the interferons. Thus a task that in the past took two or three years to achieve, in the near future will be accomplished in weeks.

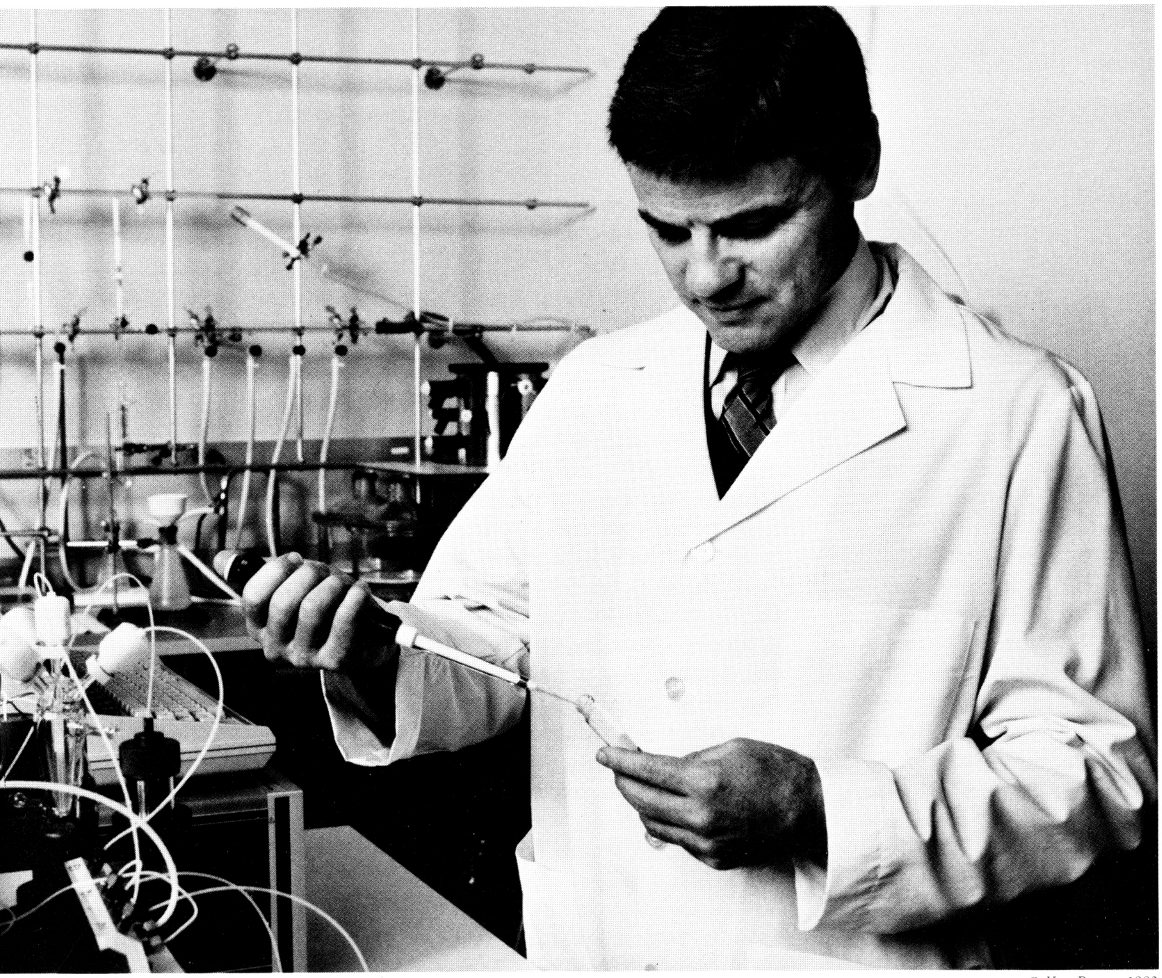
Among the next generation of devices under development at Caltech are automated machines for rapidly synthesizing proteins and sequencing the building blocks of DNA molecules. The microchemical instrumentation, in concert with recombinant DNA techniques, enormously extends the range of basic research into important clinical problems such as cancer, autoimmune disorders, and aging and degenerative diseases.

Chemistry and Chemical Engineering

A revolution is under way in the field of chemistry. Recent advances in the understanding of chemical reaction processes coupled with impressive strides in synthetic organic and inorganic chemistry have made it possible for researchers to undertake the design and construction of highly complex molecules that promise to have unique chemical and physical properties.

Caltech's Division of Chemistry and Chemical Engineering is uniquely situated to take the lead in this endeavor. Six different groups comprising organic, inorganic, and organometallic chemists are linked by their common research interest in chemical synthesis. Within the decade, they will be able to design and prepare organic and inorganic materials with very useful properties. Highly novel semiconductors, superconductors, microelectronic devices, catalysts, drugs, magnetic materials, molecular metals, superstrong polymers, and ultrapowerful light-generating devices are some of the possible applications.

Synthetic chemists probe the structure of existing molecules and conduct basic research into the precise mechanisms by which chemical processes (such as catalysis, for example) are carried out. They learn to manipulate these mechanisms to serve other specific ends—or to incorporate them into new systems of their own. Computer modeling techniques aid in the design of the new molecules, built to atomic specifications. And computer-assisted chemical instrumentation is used to speed up the purification and structural analysis of these "molecular machines." Ultimately, synthetic chemists will be able to reproduce the capabilities of existing chemical and biochemical systems, then construct equally complex systems not found in nature at all.



Engineering and Applied Science

All around the world, communications systems are changing from one mode of sending messages to another—from electricity flowing through wires to light beams pulsing through thin glass fibers. The signals carried by these fibers are created by lasers. When current is applied to a laser crystal, it produces a beam of light that can be switched on and off billions of times a second—with each on/off cycle transmitting an individual "bit" of information. Someday, light signals may replace electrical signals inside computers as well.

Light is being used only in transmission, not in processing information. The latter requires converting the light signals into electricity and back again at several points. For fiber-optics systems to come into their own, especially in computer applications, there must be a full integration of optical and electronic devices.

In Caltech's Division of Engineering and Applied Science, pioneers in the field of optoelectronics are working to achieve exactly this integration. Several years ago, they developed a chip with the capacity to detect a light signal, amplify the resulting electrical signal, and convert it back to light. In this prototype, a self-contained laser and microelectronic circuits for monitoring, stabilizing, and amplifying the signals are all housed together on a crystal of gallium arsenide. Such chips have recently proved able to modulate the laser light at rates exceeding 12 billion bits per second.

Geology graduate student Eme Burt observes soils exposed in the 1-1/2-meter-high fault scarp formed during the 1983 Idaho earthquake. The quake measured 7.1 on the Richter scale.

More recently, the group has been doing basic research on phase conjugate optics, which can be used to correct distortions in laser beams, and so has a direct bearing on the optoelectronics field. Light beams traveling through fibers could use phase conjugate optics to overcome distortions by the medium. And in optical computers of the future, phase conjugate optics could be used to amplify tiny information-carrying laser beams while conserving their information content, and to heal imperfections caused by flaws in the system. Such computers would be thousands of times faster than the current electronic ones.

Geological and Planetary Sciences

Great excitement in geology and geophysics is being generated by current research relating seismology to plate tectonics and dynamic processes in the interior of the earth. In Caltech's Division of Geological and Planetary Sciences, scientists combine seismology and computer modeling techniques to get a quantitative grasp of these relationships.

The earth's crust is made up of moving plates, the motion of which is accompanied by the constant creation of new seafloor at spreading ridges where molten rock emerges from the mantle, and the destruction of old seafloor at deep-sea trenches in a process called subduction. But this is part of the larger circulatory mechanism of mantle convection, in which the hot material that rises close to the surface cools and after millennia sinks back down into the earth again.

Caltech scientists think that a clue to the convection mechanism comes from variations in the velocity of seismic waves as they travel through the earth. The variations, which can be mapped by tomographic methods similar to those used in medical imaging, indicate anomalous structures in the mantle. These are probably representative of temperature variations in the convecting mantle. For example, detailed studies using seismic wave travel times measured by Caltech's southern California array indicate that a high velocity zone lies directly beneath this region of California. This zone probably represents cold material sinking in the mantle in a small convection cell, causing the compressive stresses supporting the mountain ranges and tending to lock the Big Bend of the San Andreas Fault. Tomographic investigation of the entire mantle of the earth reveals seismic velocity anomalies related to a much broader scale of convection. Seismically slow regions of the lower mantle are associated with hotspots at the earth's surface, while seismically fast regions are associated with areas of ancient subduction.

Other investigators have developed a theory of the effects of convection on the earth's gravity field. Computer models based on this new theory and using the seismic tomographic results for the lower mantle corroborate the interpretation that both seismic anomalies and variations in gravity are the result of mantle convection.

Humanities and Social Sciences

Caltech's Division of the Humanities and Social Sciences continues to win recognition for its research contributions in many disciplines.

A concern for the historical context of literary texts has opened up a new field for research in the humanities. Dissatisfied with the formalist literary criticism dominant in the twentieth century, which focuses on the text in isolation from its context, Caltech scholars seek to bring biographical, historical, and sociological questions to bear on literature. Inspired by eighteenth and nineteenth century traditions of textual scholarship, they have also drawn on Marxist and women's studies perspectives in developing their historical theory and methodology. They pay special attention to the sociology of literature and literary institutions—who was reading what, and why, at a given point in time. The goal is to reconstruct the culture of the past through understanding the literary texts that transmit it, while always respecting the vital differences between the past and the present.

Economics is not usually considered a laboratory science. In the past decade, however, a group of economists at Caltech has led in developing another approach by conducting experiments. The idea is to set up market situations in a simple setting where conditions can be controlled and varied. As few as ten participants can conduct a working market, with actual sums of money exchanged to provide participants with incentives. Such experiments give economists an opportunity to examine their theoretical models in action and to see how they work—if they work at all. In addition, experiments allow researchers to vary the institutional environment in which trading takes place. One can examine the effects on volume and prices of such practices as using brand names, prohibiting discounting, requiring advance notice of price changes, forming trade associations, collusion, and so on. In recent years, experimental economics has become increasingly accepted, and experimental results have provided the basis for a number of government policy decisions.

Physics, Mathematics and Astronomy

Studying the fundamental forces and the ultimate constituents of matter is the business of physicists. Their work often takes the form of a dialogue, with experimentalists trying to prove or disprove the theoreticians' predictions through laboratory research.

In the Division of Physics, Mathematics and Astronomy, scientists are conducting a search for free quarks, which, if they exist, would be expected to show up as fractionally charged particles. Quarks, postulated as the basic building blocks of matter, have been sought long and hard by particle physicists since the 1960s. Current theory holds that quarks may not exist free in nature, but rather are bound tightly within protons and neutrons in the atom. Negative results from the present experiment would tend to corroborate this theory, while positive evidence of fractionally charged particles would have revolutionary implications.

The locus of the search is the Kellogg Radiation Laboratory, in the news recently because it is the same laboratory where William Fowler, winner of the 1983 Nobel Prize, also carried out his research. The quark hunters use a beam of argon ions to "sputter," or break down, a sample of material into individual atoms. Charged ions resulting from the process are then accelerated in Kellogg's new high-current, high-stability electrostatic accelerator. After the ion beam has been accelerated, it passes through an apparatus to determine the charges of the particles.

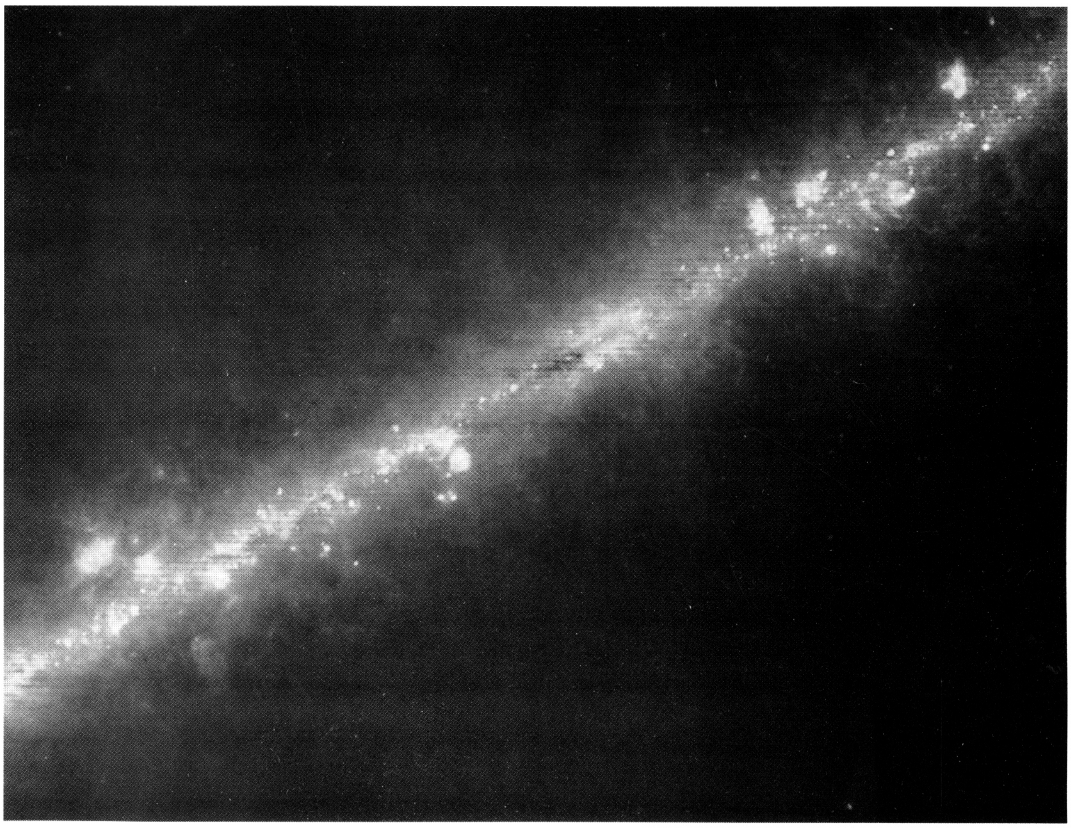
Searches for fractional charges are being conducted or planned by a number of other institutions. But the Caltech experiment is unique because it can analyze almost any sort of material, not just one or two substances. It is also an extremely sensitive test, which will be able to detect one fractionally charged particle in one billion billion particles of normal matter—if such a thing as a free quark turns out to exist after all.

Jet Propulsion Laboratory

The Jet Propulsion Laboratory is staffed and managed by Caltech under contracts with NASA. Currently, JPL is acting as the U.S. management center for an international project that has revolutionized our vision of the universe in the course of the past year.

The Infrared Astronomical Satellite (IRAS), a joint venture of the United States, the United Kingdom, and the Netherlands, was orbited in January 1983. IRAS carried a highly sensitive, cryogenically cooled, infrared astronomical telescope that conducted an all-sky survey of objects in the universe radiating even the faintest emanations of heat, or infrared energy. Before the flight mission ended in November, the satellite relayed to earth an abundance of astronomical information, enough to keep scientists busy interpreting it for years to come.

This image of the center of our galaxy was produced from observations made by IRAS, the Infrared Astronomical Satellite developed at Caltech's Jet Propulsion Laboratory. The bulge in the band is the center of the Milky Way, while the discrete clumps of material scattered along the band are giant clouds of interstellar gas and dust heated by nearby stars.



The early results are impressive. IRAS has discovered five new comets and another comet-like object, which appears to be the source of orbiting debris that falls to earth annually as the Geminid meteor shower. IRAS has also found rings of dust within the solar system, possibly the result of asteroid collisions in the main belt between Mars and Jupiter. In fact, much of interstellar space turns out to be strewn with wispy clouds of dust, probably composed of graphite particles and called "infrared cirrus" by the science team because of their resemblance to the earth's high-altitude clouds.

In some of the most significant findings, IRAS has located many small clouds of molecular gas and dust where stars resembling our sun are forming. And in studying the bright stars Vega and Fomalhaut, IRAS scientists have discovered evidence of a system of cool, solid material orbiting the stars—the first places outside our solar system where scientists will now have the opportunity to study the phenomena that lead to the formation of planetary systems around stars.

Environmental Quality Laboratory

The Environmental Quality Laboratory studies environmental and resource problems with both local and national policy implications. A multidisciplinary group of professors, graduate students, and postdoctoral research staff carries out EQL's current research on air, water, energy, and risk assessment of hazardous substances.

Advances in understanding the air we breathe have come through EQL's development of computer models and control strategies for aerosol nitrates and nitric acid in the atmosphere—research sponsored by the California Air Resources Board. Aerosol nitrates contribute to visibility problems, and nitric acid is one of the major constituents of acid rain and acid fog. EQL's computer models connect the many sources of pollutants with atmospheric chemistry and circulation patterns to predict the air quality in different places, and at different times of the day. With such computer models, it becomes possible to predict to what degree air quality could be improved by implementing alternative emission control strategies.

Looking out to sea, EQL has collaborated with the Orange County Sanitation Districts and the National Oceanic and Atmospheric Administration to develop a research plan for the experimental deep-ocean discharge of sewage sludge. According to EQL predictions, processed sewage sludge could be deposited at the unprecedented depth of 1,300 feet off the Orange County coast with very little impact on the environment. The disposal pattern would cause the minute sludge particles to settle in deep basins miles offshore, having next to no effect on the overlying ocean waters. Orange County is currently seeking permission from the federal government to proceed with this research and development experiment.

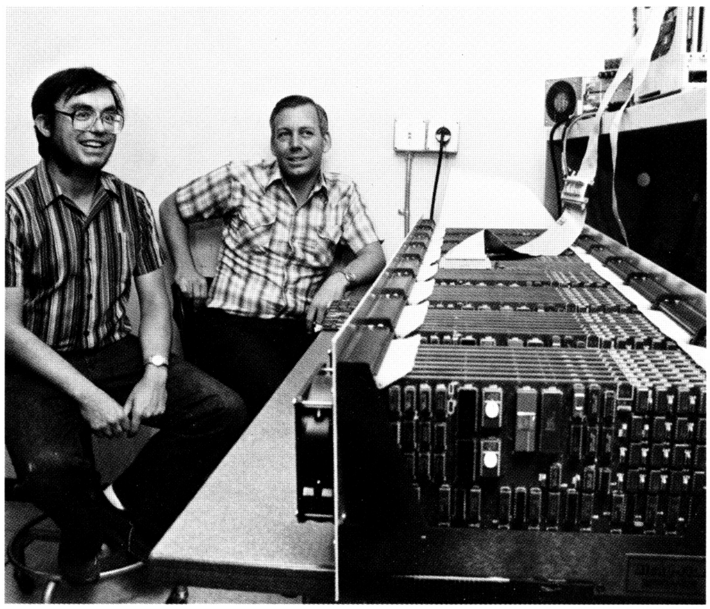
The Supercomputer Project

As powerful as computers are, they are far from equal to many computationally difficult problems in engineering and science. The largest, fastest machines—such as the Cray-1 supercomputer, which can do 20 to 80 million operations a second—are so expensive that few scientists have access to them.

A new class of supercomputers, capable of outperforming the largest computers in use today, but at a much lower cost, is under development at Caltech. The Cosmic Cube, an experimental prototype, is up and running now. In a few years, a computer sized to fit a desktop could match the computational power of 50 Cray-1 computers, while costing a fraction of one Cray-1. Investigators from the Division of Engineering and Applied Science and the Division of Physics, Mathematics and Astronomy, as well as the Jet Propulsion Laboratory, are collaborating on the project, with scientists from virtually every academic division exploring its applications to their own research. The project is supported by the Defense Advanced Research Projects Agency, Department of Energy, System Development Foundation, The Ralph M. Parsons Foundation, Intel Corporation, and Digital Equipment Corporation.

The Caltech supercomputers are based on the principle of concurrent processing; they basically consist of a linked system of identical processors called nodes. Thus, a scientific problem must be broken down into segments, so that each node has charge of part of the problem. In the Cosmic Cube, each of 64 nodes executes programs concurrently, while each one communicates with six other nodes. Being able to do many things at once is what makes these machines faster than conventional computers, which operate on a problem sequentially.

Professor of Theoretical Physics Geoffrey Fox (left) and Associate Professor of Computer Science Charles Seitz display their innovative 64-node Cosmic Cube. Seitz and his students designed this concurrent computer, while Fox and his students have programmed it to solve significant problems in physics.



The supercomputer project aims to advance research in concurrent computation and to provide scientists in a wide range of fields—including astrophysics, high-energy physics, geophysics, chemistry, computer science, and applied mechanics—with powerful computing capabilities. Besides aiding pure research, the supercomputers will permit advances in such applied areas as aircraft design, oil exploration, microcircuit design, and meteorology.

Financial Review

As with other sectors of the economy, higher education experienced a degree of recovery in 1983 after coping with high inflation and shrinking student financial aid in the previous three years. Caltech's recovery was most evident in net assets, which increased from $411 million to $460 million, or 12 percent. The Institute experienced an improvement in funding of sponsored research at the same time inflation was decreasing. Federal sponsorship of research at Caltech increased 9.9 percent, from $39.9 million in fiscal year 1982 to $43.8 million in 1983.

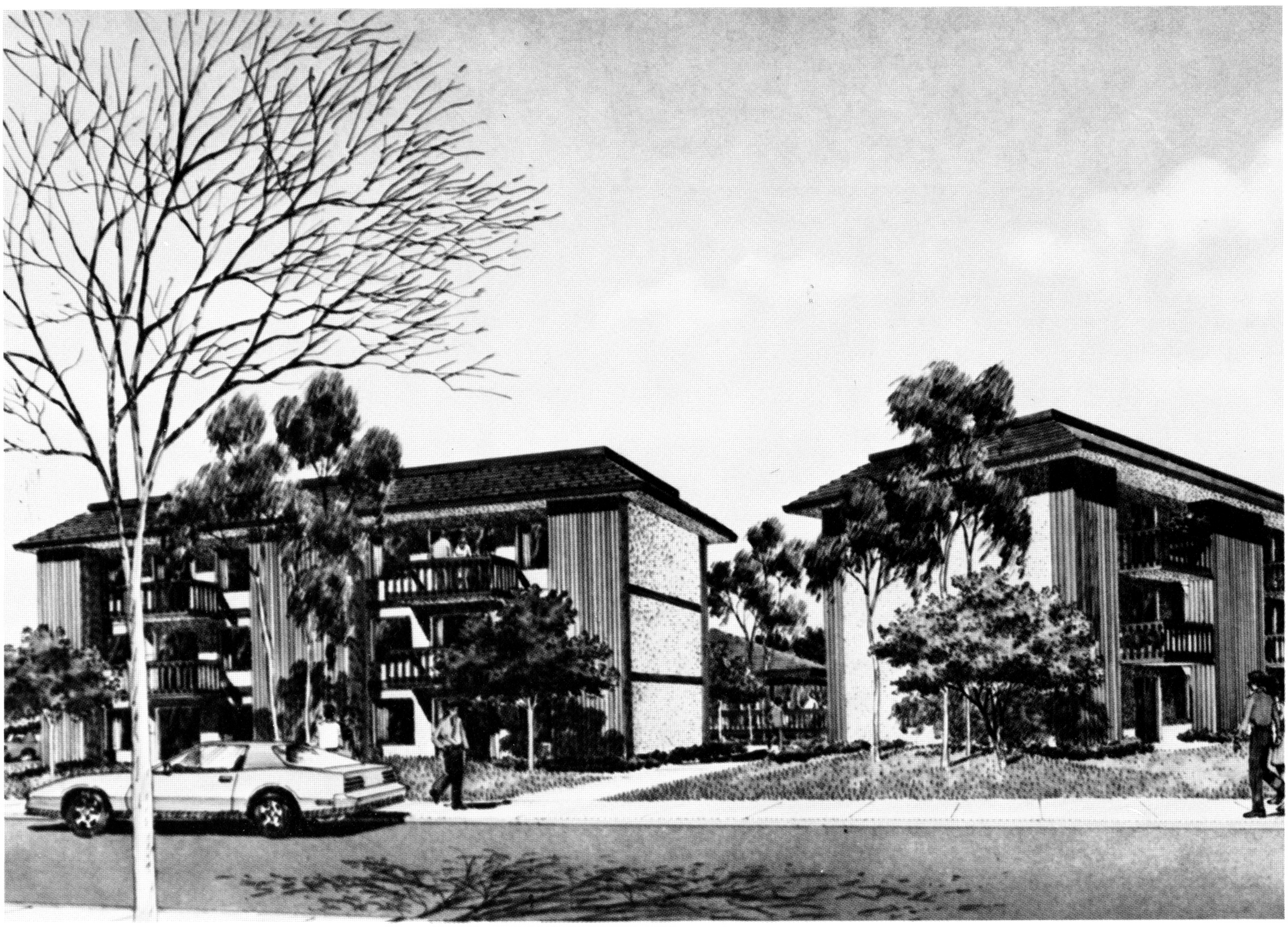
Caltech's Jet Propulsion Laboratory experienced a moderately strong recovery, with renewed activity in unmanned space exploration. Total JPL expenditures increased from $385 million in fiscal year 1982 to $425 million in 1983. NASA continues to provide the primary support for JPL's activities.

On the opposite page is a five-year review of financial and other Institute statistics.

Current Fund Expenditures

Caltech's operating expenditures inclusive of auxiliary enterprises grew at an annual rate of 14.2 percent, from $94.6 million in fiscal year 1982 to $108 million in 1983. Utility costs in 1983 continued to outpace inflation and, after extensive conservation measures, still grew at an annual rate of 28.9 percent. The utility cost element is of major concern to Caltech's administration, and the Board of Trustees has approved funds to construct a second cogeneration facility. This facility will significantly reduce utility expenditures in 1985 and beyond.

New apartments for 156 Caltech graduate students are scheduled to be ready for occupancy in fall 1984.



Scholarship and fellowship expenditures for both undergraduate and graduate programs totaled $5.1 million, an increase of 13.4 percent over 1982. Income from gifts, endowment, and federal grants provides the major source of support for these programs. Non-student aid, institutional support, and student assistance expenditures increased $1.5 million, or 11.5 percent, a decline from the 12.6 percent increase of the prior year.

Expenditures for plant operation and maintenance, exclusive of utility expenditures, totaled $4.4 million— a 7.6 percent increase.

Expenditures for auxiliary enterprises rose in 1983 at a rate slightly higher than inflation, at 5.1 percent, from $4.2 million to $4.4 million.

Capital expenditures on the campus reflected the completion of major projects initiated in previous years and extensive rehabilitation of older facilities to accommodate the needs of today's research faculty.

In summary, Caltech's financial position remains healthy, and we are confident of continued growth.

David W. Morrisroe
Vice President for Business & Finance and Treasurer

Five Years in Review

Year ended September 30	1979	1980	1981	1982	1983
Current funds expenditures (in thousands)					
Instruction and research (including libraries)	$47,696	$56,920	$62,259	$64,938	$74,535
Scholarships and fellowships	2,827	3,232	3,540	4,494	5,095
Plant operation, maintenance and utilities	5,148	6,571	6,587	8,116	9,586
Administration, student services and general	8,657	9,608	11,399	12,836	14,314
Total operating expenses	64,328	76,331	83,785	90,384	103,530
Auxiliary enterprises	2,829	3,417	3,870	4,219	4,435
Total	67,157	79,748	87,655	94,603	107,965
Capital expenditures, campus (in thousands)	6,973	14,078	19,967	10,526	12,459
Jet Propulsion Laboratory, direct expenditures (in millions)	319.0	375.4	396.6	384.8	425.2
Total gifts and nongovernment grants (in thousands)	16,770	16,958	22,271	25,652	24,747
Endowment and similar funds at market value (in millions)	173.9	197.4	184.3	208.3	248.3
Investment income (in millions)	13.8	16.3	19.8	20.4	19.6
Student enrollment (first term) — Undergraduate	801	817	844	866	874
Student enrollment (first term) — Graduate	851	892	865	888	936

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