CALIFORNIA INSTITUTE OF TECHNOLOGY

1986-87 Annual Report

Maintaining the highest possible standards of excellence while fostering change and growth is a way of life at Caltech. One of the most important of our changes in the last year has been at the top level of administration. After nine years as president, Marvin L. Goldberger reached the age 65 and retired in the summer of 1987, accepting the position of director of the Institute for Advanced Study at Princeton. Dr. Goldberger left behind an institution that had been both broadened and strengthened under his stewardship—as it had under each of his predecessors.

Seeking a new president who would continue that tradition, the Trustee Selection Committee and the Faculty Advisory Committee unanimously chose Thomas E. Everhart, chancellor of the University of Illinois at Urbana-Champaign, as his replacement. Dr. Everhart is known in educational circles for enlightened and creative administration and has as well a distinguished record of achievement in his academic fields of electrical engineering and applied physics. The Trustees look forward to working with him as he leads Caltech in new endeavors and new accomplishments.

Caltech's ability to maintain values while pioneering in research and education is enhanced by the dedication and experience of the Board of Trustees, which is responsible for the general governance of the Institute. I wish to take this opportunity to thank the Trustees for their active participation in the affairs of Caltech. During this past year, a committee of Trustees, working with a Faculty Committee, selected a new president. Members of the Board serve on committees that oversee a wide range of specific Caltech activities. They personally provide significant financial resources. They review and approve operating and capital budgets and construction plans. They monitor the Institute's investments in accordance with a financial policy designed to assure the sound financial environment necessary to maintaining and building one of the finest student bodies, faculties, and research and education facilities in the world.

During the year there were a number of changes in the composition of the Board as we welcomed three new members—Eli S. Jacobs, Partner, E. S. Jacobs & Co., L.P.; James E. Olson, Chairman and Chief Executive Officer, American Telephone & Telegraph; and Albert D. Wheelon, Chairman of the Board and Chief Executive Officer, Hughes Aircraft Company. Trustees Gilbert W. Fitzhugh and Charles H. Townes, and Senior Trustee Lew R. Wasserman were elected Life Trustees. We regretfully accepted the resignation of Edgar F. Kaiser, Jr.

Augustus B. Kinzel died on October 23 after a long illness. He was 87. Dr. Kinzel was one of the nation's leading research metallurgists and the founding president of the National Academy of Engineering. He had been a member of Caltech's Board of Trustees since 1963, and all of us will miss his wise counsel.

The $40 million pledge of the Beckman Foundation for the establishment of the Beckman Institute was contingent on Caltech raising $10 million in capital funds from private sources. That $10 million has been raised, and the $40 million has been turned over to Caltech. The foundation also promised to provide an additional $10 million for the Beckman Institute if Caltech's Board of Trustees contributed an equal amount for the general endowment. This challenge is well on the way to being met, and ground is being cleared for construction of this exciting new facility. Completion of the Beckman Institute is expected by fall 1989.

The opportunities for the Caltech community are immense—brighter students, distinguished faculty, expanding horizons for research and teaching, and a rising recognition of the vital role of science and engineering in all manner of human affairs. The challenge to the Caltech community is to maintain our traditional focus on excellence, while pushing forward into exciting new endeavors.

Ruben F. Mettler
Chairman

In my brief time here, I have learned a great deal about the California Institute of Technology, an institution recently described by *Time* magazine as a "national treasure." Foremost, I have learned that Caltech stands, above all, for quality. As a consequence, it is a "selective" institution. It is selective about the fields in which it chooses to excel in teaching and research. It is equally selective about those whom it chooses to admit as students, and about those whom it chooses to invite to be on its faculty, administration, and staff. Such selectivity has kept the Institute's quality high yesterday and today, and will continue to keep it high tomorrow. Caltech is also blessed with a wise and prestigious Board of Trustees, whose thoughtful counsel and support have been essential in helping us achieve our goals in research and education.

Small size has contributed to Caltech's high quality, by providing an environment in which faculty members can know each other well and can freely share ideas and broaden each other's fields of interest. Similarly, all students have an opportunity to make lasting friendships, participate in a wide variety of extracurricular activities, and provide peer support unusual in higher education today. The high quality of faculty and their research programs have attracted a complement of superb postdoctoral fellows who, while continuing their education here, provide intellectual stimulation as well as help to our faculty members. This period of study prepares our postdocs to make very significant contributions when they embark on their own careers. Caltech has also been successful in attracting an outstanding technical and administrative staff, which supports the research and education enterprise and whose dedication and loyalty are the envy of other institutions.

High-quality faculty deserve, and help procure, exceptional facilities for research and education. For example, construction has begun on the Keck Observatory and Telescope in Hawaii, with first light due early in the 1990s. On campus, the Beckman Institute is scheduled to open its doors in 1989; and the Earth and Space Sciences Laboratory, the Microdevices Laboratory, and the Engineering Support Building are soon to be occupied at the Jet Propulsion Laboratory (JPL).

The new Beckman Institute reflects much more than simply the addition of laboratory space and the increased availability of advanced scientific instrumentation. It also emphasizes the importance of private funding of research and facilities, funding that provides leverage to enhance faculty competitiveness for government support, and seed money for pioneer efforts that—at first glance—might seem too risky to most outside funding organizations. The development of the Beckman Institute also recognizes that two or more disciplines are needed to attack some of the most important scientific problems today, and that instruments too expensive for a single faculty member can be shared among many if proper organization is provided. We are delighted that Professor Harry Gray, recently named "California Scientist of the Year," has accepted the position of director of this important new endeavor.

The buildings under construction at JPL will provide a setting for research that will enhance our ability to serve the nation. Indeed, the recently completed Central Engineering Building was funded by Caltech using a reimbursement plan, which demonstrates a new way that NASA and Caltech can cooperate to the nation's advantage. Facilities in the Microdevices Laboratory are expected to improve already good cooperation between campus and JPL.

Facilities, while important in allowing faculty, students, and other Institute personnel to accomplish their goals effectively, and equally important in attracting new colleagues, cannot substitute for the power of the human mind fully engaged in the purposeful pursuit of knowledge. The people of Caltech are excellent, I have found, in interactions ranging from Freshman Camp to question-and-answer sessions following formal talks. We need to continue to find the best and the brightest, and attract them to join us. The intellectual climate of Caltech—found in lectures and lunchtime discussions, research seminars and private conversations—continually needs new insights, new initiatives, and new visions. This we will get, in part, by inviting visitors who share knowledge with us, and by carefully selecting

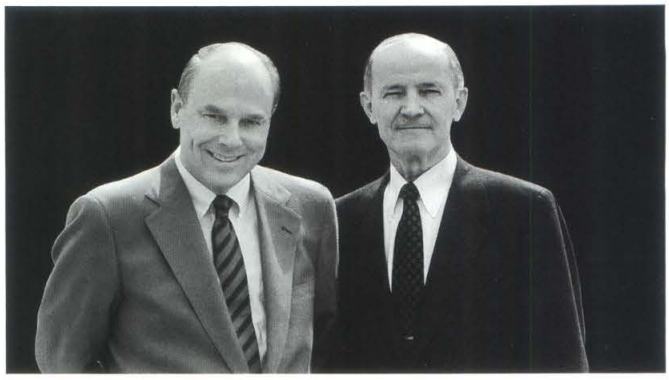
new students and faculty who join us for longer periods. This climate of camaraderie and community is often given by faculty and staff as a chief benefit of being associated with Caltech.

Caltech's alumni, although small in number, are strong in their commitment to the Institute's goals and traditions. Many are major donors to our programs. We are proud of their accomplishments and contributions to society. We trust they will be equally proud of the graduates we will be adding to their ranks in the years to come.

At Caltech, we seek to work in the most important fields, and to make lasting contributions that will improve the human condition. The most important areas may be somewhat different in 1988 than they were when the Institute was founded. But, like our predecessors, we need the courage to emphasize new fields, and the wisdom to choose wisely among our many options. We also need to be persistent in pursuing knowledge in old fields that continue to be important. Using the best advice available, we shall continue Caltech's long tradition of enhancing significant work already under way, while moving aggressively into emerging areas of scientific discovery. In this way, we can maintain our focus on important areas where we can make major contributions.

Thomas E. Everhart

Thomas E. Everhart
President



Thomas E. Everhart and Ruben F. Mettler

Events, appointments, honors, and changes and achievements in education, research, and support make up each year at Caltech. This annual report reviews some of them for the year 1986-87.

Milestones

The most newsworthy events of this year were the departure in the summer of 1987 of Marvin L. Goldberger as president of Caltech and the arrival of Thomas E. Everhart on September 1 to replace him. Dr. Everhart did his undergraduate work in physics at Harvard, earned an MS in applied physics at UCLA, and received his PhD in engineering at Cambridge. From 1958 to 1968 he was in the department of electrical engineering at UC Berkeley, serving as its chairman from 1972 to 1977. From there he went to Cornell as dean of its College of Engineering, and he became chancellor of the University of Illinois at Urbana-Champaign in 1984. He has gained international recognition for his work in the development of electron microscopy and is also known for his research on electron beams as applied to the analysis and fabrication of semiconductors. His inauguration took place in the spring of 1988, but he has already participated in many other kinds of inaugurations.

One of the most far-reaching is implementation of the first stages of Caltech's long-range master plan for the campus, which is the result of extensive consultation and review by both the Institute and the City of Pasadena. The plan outlines Caltech's strategy for anticipated growth during the next 15 to 30 years, and allows the city to plan in advance for expansion and building in the area.

All new construction continues Caltech's traditional concern for safety and efficiency, combined with aesthetic appeal, and the landscaping of completed new facilities will do the same. The Caltech campus, in fact, frequently garners awards for beauty, the latest being a Pasadena Beautiful Foundation award for the Throop Hall site, which is now a parklike area in the middle of the campus.

Astronomers at Caltech's Palomar Observatory have begun a mammoth five-year project to map the entire northern sky—the first time this has been done since the 1950s. They will use sensitive new photographic techniques available on the 48-inch Oschin Telescope, which can record celestial objects several million times fainter than can be detected with the naked eye. The resulting atlas of the heavens, contained on 2,682 glass plates, will serve as the basic astronomical guide to the skies for decades to come and will complement a similar survey of the southern sky now being completed using the Oschin's twin, the United Kingdom Schmidt Telescope in Australia.

A decidedly terrestrial event was the October 1 earthquake, whose epicenter was just seven miles southeast of Caltech. Its magnitude was 5.9, and it was followed four days later by an aftershock of magnitude 5.3 whose epicenter was three miles closer to campus. Together, the two shook down bricks and cracked plaster in a number of campus structures, heavily damaged the 10-foot wind tunnel, caused a serious but brief gas leak in one lab, and knocked books off shelves on the top floors of Millikan Library. It also upset all previous plans for Caltech seismologists, earthquake engineers, and media relations staff, who found themselves occupied once more with dispensing accurate seismological information for the press, television, radio, and the general public.

Appointments

Several administrative appointments were made during the year: Barclay Kamb, professor of geology and geophysics, became vice president and provost; David L. Goodstein, professor of physics and applied physics, became vice provost; and Gerald J. Wasserburg, John D. MacArthur Professor of Geology and Geophysics, was appointed chairman of the Division of Geological and Planetary Sciences. Robert Oliver, professor of economics, became the new Master of Student Houses; and Hans Hornung was appointed director of the Graduate Aeronautical Laboratories, known as GALCIT. He was also appointed Clarence L. Johnson Professor of Aeronautics.

A number of other faculty members were also appointed to named professorships. John F. Benton became the Doris and Henry Dreyfuss Professor of History shortly before his death; Daniel J. Kevles became the J. O. and Juliette Koepfli Professor of the Humanities; James J. Morgan, the Marvin L. Goldberger Professor of Environmental Engineering Science. Charles Plott became the Edward S. Harkness Professor of Economics and Political Science; Maarten Schmidt, the Francis L. Moseley Professor of Astronomy; Ronald F. Scott, the Dotty and Dick Hayman Professor of Engineering; Eleanor

Searle, the Edie and Lew Wasserman Professor of History; and Melvin I. Simon, the Anne P. and Benjamin F. Biaggini Professor of Biological Sciences.

Honors

Among the many honors awarded Caltech faculty in 1986-87, a large number went to Leroy Hood, Ethel Wilson Bowles and Robert Bowles Professor of Biology and chairman of the biology division. He received the 1987 Albert Lasker Basic Medical Research Award for "imaginative studies of the somatic recombination of genes of the immune system, which makes possible an infinite diversity of antibodies." For similar reasons, he also received this year the Isco Award of Isco, Inc., a major biotechnology firm; the Golden Plate Award of the American Academy of Achievement; an honorary Doctor of Science degree from Mount Sinai School of Medicine of the City University of New York; the 1987 Man of Science Award from the ARCS (Achievement Rewards for College Scientists) Foundation, Inc.; and the 1987-88 Dickson Prize from the University of Pittsburgh.

Awards to younger faculty members included two Presidential Young Investigator Awards from the National Science Foundation, to Kenneth Libbrecht, assistant professor of astrophysics, and John Doyle, associate professor of electrical engineering. Doyle was also named Office of Naval Research Young Investigator, as were Christof Koch, assistant professor of computation and neural systems; and Kerry Vahala, assistant professor of applied physics. David Anderson, assistant professor of biology, was selected the 1987 Searle Scholar by the Chicago Community Trust; and Alan L. Goldin, senior research fellow in biology, received the Markey Scholar Award in Biomedical Science from the Lucille P. Markey Charitable Trust.

Gary Leal, Chevron Professor of Chemical Engineering, was elected to membership in the National Academy of Engineering, as was James E. Broadwell, member of the professional staff in aeronautics and applied science. Broadwell was also named a Fellow of the American Institute of Aeronautics and Astronautics.

John Schwarz, professor of theoretical physics, received a MacArthur Foundation Fellowship, becoming the third MacArthur Fellow in residence on campus. Schwarz also was elected a Fellow of the American Physical Society, along with David Hitlin, professor of physics.

Caltech conferred its highest honor—the Distinguished Alumni Award—on five graduates. Those recognized were James E. Lu Valle (PhD '40), director for many years of the Stanford undergraduate chemistry teaching program; Morris Muskat (PhD '29), retired technical adviser for the Gulf Oil Corporation and highly regarded for his technical contributions to the petroleum industry; Stanley C. Pace (MS '49), chairman and chief executive officer of General Dynamics Corporation; Alvin W. Trivelpiece (MS '55, PhD '58), executive officer of the American Association for the Advancement of Science and former director of the Office of Energy Research, U.S. Department of Energy; and John Waugh (PhD '53), the Arthur Amos Noyes Professor of Chemistry at MIT, noted for his pioneering nuclear magnetic resonance techniques.

Four undergraduates applied for Thomas J. Watson fellowships for a year of independent study and travel abroad, and all four were selected, a first-time-ever record for Caltech. Mark Carlin, Joseph Francis, Rosemary Macedo, and Andrew Tikofsky were among 80 graduating seniors from 45 small colleges and universities to be chosen in the national competition.

Once more Caltech students honored their teachers with awards for teaching excellence. The ASCIT (Associated Students of the California Institute of Technology) Board of Directors announced that 1987's awards were given to Donald S. Cohen, professor of applied mathematics; Dennis A. Dougherty, associate professor of chemistry; Valentina A. Lindholm, lecturer in Russian; Thomas A. Prince, associate professor of physics; Jean-Paul Revel, Albert Billings Ruddock Professor of Biology; and Thomas A. Tombrello, professor of physics.

A total of 219 students, including 35 women, composed the 1987 freshman class. They were chosen from 1,589 applicants, an increase of 18 percent over the number of applicants last year, and an increase of 34 percent in the last two years. Eight regular transfers arrived from other colleges, and 17 students transferred into the third year of the engineering option from liberal arts colleges. New graduate students totaled 203.

As always, Caltech students graduating in June did well in terms of both job offers and the salaries that accompanied them. Even before graduation, 52 of 176 students graduating with BS degrees had accepted full-time employment. Salaries offered ranged from just under $20,000 to $45,000. The nation's top graduate schools were accepting Caltech's BS applicants. Average salary offers to MS degree recipients were $36,325—up almost 8 percent over 1986. Of the 128 students who received MS degrees, 79 went on to graduate school for a PhD. Of 147 PhD degree recipients, 59 accepted postdoctoral research positions; 15, tenure-track academic positions; and 49, industrial positions. Industrial salary offers ranged from $30,000 to $60,000, tenure-track academic salaries (adjusted for the academic year) ranged from $34,000 to $57,000, and offers to postdoctoral fellows ranged from $12,000 to $36,000.

Graduate student Christine Wilson received a different kind of reward. Checking a photographic plate taken as part of the Palomar Sky Survey, she discovered a new comet that may rival Halley's Comet in brightness, and it was officially named Comet Wilson in her honor.

An innovative course developed by Steven Koonin, professor of theoretical physics, teaches juniors and seniors to use computers to solve highly complex physics problems far beyond the reach of the analytical pencil-and-paper approach. Called "Computational Physics," the course has been so successful that roughly a third of Caltech's undergraduate physics majors take it, and it has been adopted by a number of other universities.

At another educational level, two members of the Caltech faculty—biologist James M. Bower and physicist Jerome Pine—have become partners in improving the teaching of science in the elementary schools. Using a two-part approach, the two men are developing hands-on scientific experiments and the kits to carry them out. In addition, there will be a computer simulation program that will let kindergartners through fifth-graders use computers to do science exercises that are direct extensions of the experiments they have been doing in the classroom. The computer part of the program is a year or so down the road, but the summer of 1987 saw brainstorming sessions with classroom teachers concerning the possibilities of computer simulation. There was also training to help them teach the hands-on part of the program. The objective of the program is not to turn out young scientists, but to reinforce the natural tendencies of children to explore, while building a sense of order and direction into the process.

Gifts to Caltech

Fiscal 1986-87 was an all-time record year for gifts to Caltech, which received approximately $80 million from trustees, alumni, Associates, other individuals, corporations, and foundations. Included in this total were payments of $30.74 million from the W. M. Keck Foundation for the W. M. Keck Observatory and $3.4 million from the estate of Liliore G. Rains. The gift total also included a record $4.8 million in life income trusts and annuities and $4.67 million in unrestricted support, which was provided primarily by The Associates, the Alumni Fund, and the Industrial Associates.

Fund-raising activity focused, in part, on the challenge provided by Arnold and Mabel Beckman for the Beckman Institute. The terms of the first phase of the challenge required that Caltech raise $10 million for the Beckman Institute. That first phase was successfully completed in October 1987, thereby qualifying Caltech for a payment of $40 million from the Beckman Foundation. Activity is now directed toward the second phase of the challenge: to raise $10 million from the trustees for Caltech's general endowment.

Pledges of $1 million each by Du Pont, Eastman Kodak, Shell Oil, and 3M will make possible the implementation of a new four-year program—the Caltech Consortium in Chemistry and Chemical Engineering. The goal of the Consortium is to create a significant source of funds to support novel research initiatives in biochemistry, materials science, and advanced chemical techniques and to obtain the perspective of industrial partners in selecting among possible research projects.

Other notable fund-raising activities included a $1.5 million challenge grant from the A. W. Mellon Foundation for an instructorship program in the humanities. The Laboratory for Experimental Economics was funded by gifts and pledges totaling $1.25 million from the Lynde and Harry Bradley Foundation, General Motors, Pacific Telesis, and the Sloan Foundation. The Kenneth T. and Eileen L. Norris Foundation and Mr. and Mrs. Samuel Oschin provided gifts and pledges totaling $2.2 million for two major initiatives in astronomy. Substantial support from the AT&T Foundation, the Parsons Foundation, the Sloan Foundation, and the System Development Foundation was obtained for the new academic option in computation and neural systems.

Under the direction of Chairman Harry J. Moore (BS '48), more than 700 volunteers led the Alumni Fund to another successful year. A total of $1.85 million was contributed by 6,647 donors, which represents a participation rate of 44 percent. Through the years, a loyal group of alumni donors and volunteers has continued to provide a stable base of important unrestricted support to the Institute.

Contributions from The Associates have been a major source of unrestricted support for the Institute since the founding of the organization in 1926. In calendar 1987, under the leadership of Associates president Robert Henigson, this group provided Caltech with $1.7 million in unrestricted contributions and $2.2 million in restricted contributions for a total of $3.9 million. Current total membership is 1,143, thirty percent being alumni of Caltech. The President's Circle, a group of Associates who make especially generous annual donations, numbers 220, an all-time high.

Associates participated in more than 38 popular events including luncheons and dinners with faculty speakers, tours, and a five-day trip to Yosemite led by geologist Kerry Sieh. Two other geologists also led trips—Clarence Allen to Death Valley and Brad Hager to Santa Cruz. Physicist David Hitlin conducted a tour of the Stanford Linear Accelerator facility in Palo Alto. At the annual President's Circle Garden Party in June, Associates *bid farewell* to Marvin and Mildred Goldberger, who will maintain their ties to Caltech as life members of The Associates and members of the President's Circle.

The Industrial Associates program encourages technical exchange between corporations and Caltech and also provides unrestricted support to the Institute. In 1986-87, 42 member companies donated a total of $1.1 million in unrestricted support. The Office for Industrial Associates sponsored three conferences attended by over 300 corporate personnel, and arranged for over 200 campus visits and seminar days. In addition, Caltech faculty made 56 visits to industrial laboratories, and member companies actively utilized the library, publication, and technical information services available through the program.

These outstanding results continue to represent the committed involvement of volunteers, friends, faculty, and administration. Caltech trustees, in particular, have played an important role in terms of

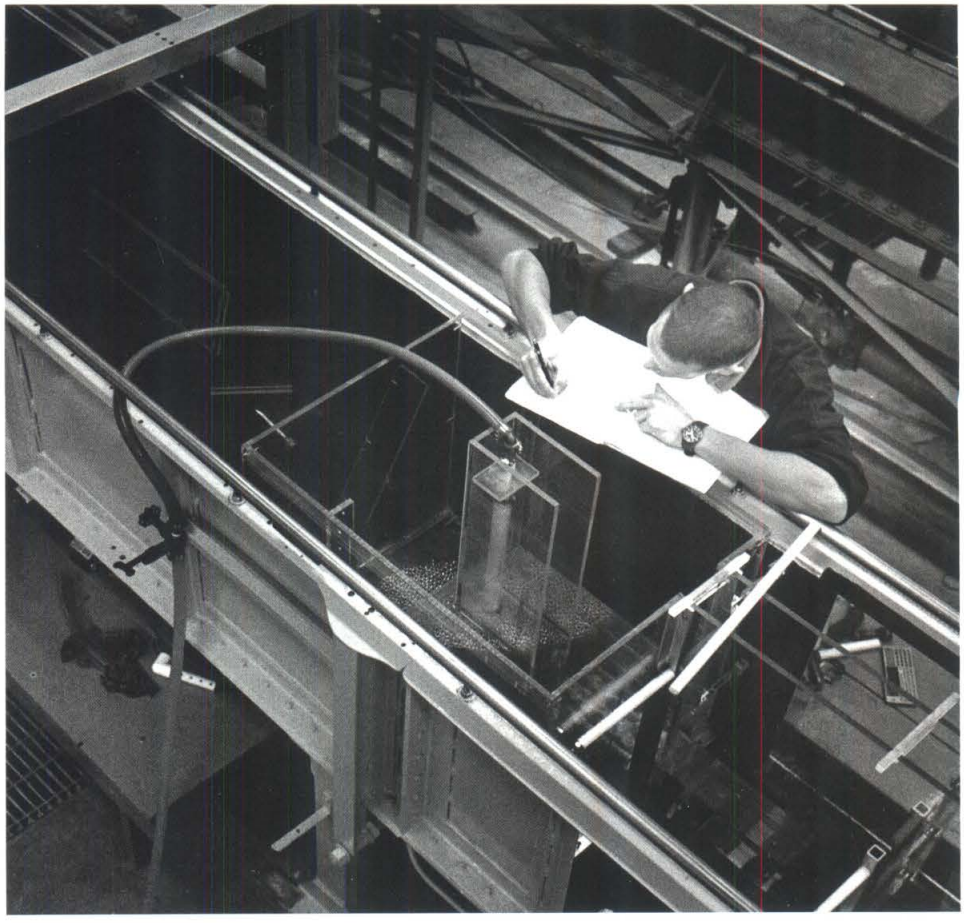
the wisdom, guidance, and help they provide for major initiatives, and in 1986-87 many more trustees were directly involved in fund raising. Though the uncertainties of the stock market decline and the 1986 Tax Reform Act may have some impact on future results, the Institute remains confident that it has the potential for continued success in its fund-raising programs.

Alumni Association

Membership in the Caltech Alumni Association numbers 7,219, or 45 percent of the alumni; but the association serves the Institute as a whole and all of its approximately 16,000 living graduates.

Major programs for the year included Seminar Day in May, when 1,400 alumni and guests visited the campus for faculty lectures and exhibits and heard a keynote speech by Dr. Francis H. Clauser, Clark Blanchard Millikan Professor of Engineering, Emeritus; the annual Rose Parade program; two wine tastings in March; class reunions; and many chapter activities around the country. Travel programs to Alaska and New England were conducted during the year, and work began on the production of a new alumni directory to be released in the fall of 1988. The Undergraduate Admissions Support Program has expanded to approximately 120 volunteers across the country. These alumni visit high school counselors and attend college nights to assist in recruiting qualified students.

Seven new chapters are headed by Craig Marks, Cleveland; Gilbert Peppin, Seattle; John P. Andelin, Washington, D.C.; William L. Martin III, San Francisco; Spicer V. Conant, Phoenix; Frank Davis and Albert L. Kellner, San Diego; and Peter V. Serrell, Portland.



Biology

If genetic engineering technology is ever to reach its full potential as a therapeutic tool in human medicine, a number of intermediate milestones must be passed. At a news conference on February 26, 1987, researchers in Caltech's biology division announced that such a milestone had been reached. They revealed that, for the first time, genetic surgery had been used to cure a genetic, neurological disease of mice.

The disease is called the shivering disease, since mice who are afflicted with it begin shivering uncontrollably several weeks after birth and, at several months of age, have convulsions that lead to premature death. Shiverer mice lack a key gene needed for the construction of the myelin sheaths that insulate nerve fibers in the brain.

The researchers cured the shivering disease by injecting functional copies of the gene for myelin basic protein into fertilized mouse eggs. In a small percentage of the cases, a copy of the gene became incorporated into the egg's chromosomes and was expressed normally. The mice that developed from these eggs never developed the shivering disease and lived a normal life span.

Although this marks an important milestone in genetic engineering, the achievement will have no direct consequences for the medical treatment of human genetic or neurological diseases. For one thing, there is no corresponding human disease. More importantly, the technique of genetic surgery on fertilized eggs is inappropriate for technical and ethical reasons for use in treating humans.

In addition to learning how to perform this delicate genetic surgery, the research provides a powerful new way to study the myelination process. Problems with myelin are characteristic of a number of human diseases—multiple sclerosis, for example—and the researchers are now able to produce mice with different levels of myelin around their nerve cells. Mice with a very low level of myelin have the shivering disease, mice with slightly more myelin begin to live longer, those with a bit more myelin no longer convulse, and those with still more lose their shivering difficulties entirely.

Chemistry and Chemical Engineering

For the first time ever, scientists are watching the birth of molecules. A Caltech group using ultrashort laser pulses can follow molecules as they approach each other, collide, stick together momentarily in the so-called "transition state," and finally split apart into new combinations of atoms. While transition-state theory has been accepted for decades, the state itself is so fleeting it had never been observed directly.

The group records the molecular encounter in a series of "snapshots" a few femtoseconds apart. A femtosecond is a quadrillionth of a second—a hairsbreadth of time. Light zips from the earth to the moon in about 1¼ seconds, but in one femtosecond light travels only one percent of the width of a human hair.

The group developed their techniques at the Noyes Laboratory of Chemical Physics, where a state-of-the-art laser facility has recently been established. The technique uses two laser pulses. The first pulse initiates the reaction and starts the clock. The second one takes the molecular "photograph." Repetitions using different pulse delays and different laser frequencies build up a complete "movie" of the reaction, showing bonds breaking and new bonds forming in real time.

So far, the scientists have examined two reactions: the bimolecular reaction of hydrogen and carbon dioxide to form carbon monoxide and a hydroxyl molecule, and the unimolecular decay of cyanogen iodide into iodine and cyanide. The hydrogen-carbon dioxide reaction clocked in at five picoseconds (five trillionths of a second), while cyanogen iodide decomposed in a mere 200 femtoseconds.

Studying reaction dynamics on the molecular level is fundamental to the entire field of chemistry. The 1986 Nobel Prize in Chemistry went to two Americans and a Canadian for their work in chemical dynamics, which concentrated on molecular states "before" and "after" a reaction. This new work permits viewing the dynamics of the event itself, and opens up a new era in chemistry.

Engineering and Applied Science

As our industrial society becomes increasingly complex, and we use more and more natural resources, the quality of the environment—our air, waters, and land—must be managed more skillfully. Caltech supports this goal by conducting a broad spectrum of environmental teaching and research, ranging from basic science to engineering to policy studies. This work is centered in the Environmental Engineering Science academic program, and the Environmental Quality Laboratory,

a multidisciplinary research unit for focusing on complex, large-scale problems.

Groundwater contamination is not visible but threatens drinking water supplies over long time periods—often from careless disposal of toxic wastes years ago. For example, tricholoroethylene (TCE), a chemical widely used by industry as a degreaser, was commonly dumped into seepage pits decades ago, and is now being detected in some local groundwater aquifers at concentrations above the allowable safe limit for drinking water. A bacterium already exists naturally that works as a tiny chemical factory, converting TCE into harmless by-products. Basic researchers are exploring the biochemistry and genetics of this organism to provide environmental engineers with information that will help them develop more efficient techniques for TCE clean-up, both in situ and in industrial wastewater.

Disposal of processed sewage sludge in the ocean is another vexing problem, being studied as a component of marine pollution control. If the science and engineering is properly done, the deep ocean can be safely used. EQL prepared an extensive research plan for a large experiment for Orange County Sanitation Districts to discharge sludge via a small pipeline to 400-meter depth at 12 kilometers off the Orange County coast. There is good likelihood that this experiment will proceed with EPA permission because Congress specifically approved this experiment in 1987. Caltech researchers have done a conceptual design and preliminary modeling of the behavior of the sludge plume which would be formed in the ocean far below the surface. In addition the settling velocity of the tiny digested sludge particles in salt water has been measured with a novel system using high-magnification double-exposure holograms.

Geological and Planetary Sciences

The five damaging California earthquakes of 1986 and 1987 renewed public and scientific interest in these both fascinating and terrifying geological phenomena. Since 1978, over 100,000 earthquakes were located throughout southern California by the seismic network operated by Caltech and the U.S. Geological Survey. All but a few of these were too small to cause damage; nevertheless, their geographic patterns and other characteristics are providing important clues about earthquake processes, crustal plate motions, and seismic hazards. Efforts to modernize the seismic observatory at the Kresge Laboratory are beginning to provide us with the world's most versatile seismograph system to study earthquakes in great detail.

The Whittier Narrows earthquake (October 1, 1987) was the most recent of the six damaging earthquakes to strike the Los Angeles metropolitan region since 1930. The quake resulted in property losses of about a half billion dollars. Like most of its predecessors, the earthquake was generated by slip along the near-horizontal fault that accommodates North-to-South shortening of the region, not by a vertical-strike slip fault like the famous San Andreas. The fault belongs to a system that extends beneath downtown Los Angeles and along the Santa Monica mountains, toward the coast. This earthquake is a sobering indication that similar, and perhaps larger, shocks may be generated on faults within the metropolitan region.

The earthquakes of June 1986 and November 1987 near Palm Springs were produced by strike-slip faults near the end of a 100-kilometer segment of the San Andreas fault. These earthquakes have contributed to the growing perception that this large portion of the San Andreas fault is the prime candidate for generating the next major earthquake. Caltech geologists have found that, although no major earthquakes have occurred along this reach in about 300 years, at least four occurred between A.D. 1000 and A.D. 1700.

Nearer Los Angeles, very precise dates of the latest 10 great earthquakes on the fault have recently been determined. New analytical methods have reduced the error in radiocarbon dating to about 2 decades. The date of the latest "prehistoric" earthquake was recently determined to fall between the growing seasons of A.D. 1812 and A.D. 1813. This event, which is recorded as a disturbance in the annual rings of pine trees growing near the fault, is probably the heretofore mysterious large earthquake of December 8, 1812, mentioned in early mission records. The new, very precise dates present an intriguing pattern of great earthquakes—century-long bursts of earthquake activity, separated by 2 to 3 centuries of quiet.

The Humanities and Social Sciences

Caltech has established a program that will explore the extent to which political and economic theories can be examined in the laboratory. Research in the new Laboratory for Experimental Economics and Political Science is expected to have applications in industry, government, business and commerce, and the academic community.

The laboratory, which will be located in the basement of Baxter Hall, will feature expanded computing and video facilities and other equipment that can be manipulated to create a large variety of experimental situations.

Research will be based on experimental techniques developed by Caltech researchers over the last 15 years. The methodology enables researchers to create simple market processes and committee processes that involve highly motivated individuals. Students, for example, are given the opportunity to make money under special situations created in the laboratory. The decisions they make are useful in evaluating broad theories of decision-making and strategic behavior that are at the foundation of modern economics and political science.

One such study on how committees reach decisions was instrumental in modifying airline industry policy on the allocation of landing rights at four major national airports. Previously these rights had been decided and assigned by committees. The researchers recommended that the procedure be changed to one in which landing rights were bought and sold on the open market, a change that was implemented last year.

The recommendation was based on a study that evolved from earlier research on committee decision-making in which the Caltech researchers found that the person who has control of the committee's agenda can often determine the ultimate outcome of the committee's deliberations.

All these experiments have so far been carried out without the support of modern communications and computer technology. Using the expanded facilities of the new laboratory, the researchers will be able to set up more complex experiments, with larger numbers of subjects drawn from a larger pool, and to evaluate more complex models. Outside economists and political scientists will be invited to campus for short periods of time to collaborate in developing experiments to test their own ideas.

Physics, Mathematics and Astronomy

In recent years, physics and astronomy have often converged, with advances in one field greatly contributing to progress in the other. The physicist's discovery of methods for detecting light waves no larger than a fraction of a millimeter, for instance, can significantly enhance the astronomer's ability to discover what is happening in galaxies millions of light years from earth.

Such cross-fertilization bore fruit in November 1986, when Caltech physicists and astronomers dedicated the world's first submillimeter telescope, the Caltech Submillimeter Observatory. The 10.4-meter radio dish is located at the summit of 13,900-foot Mauna Kea in Hawaii because, at lower altitudes, water vapor in the earth's atmosphere attenuates submillimeter waves from space.

Through studies of these waves, astronomers expect to better understand how stars are born, age, and die; form a clearer picture of the center of the Milky Way, which may harbor a black hole; identify new organic molecules in space; and investigate whether "starburst galaxies"—in which millions of brilliant stars are apparently born simultaneously—are triggered by galactic collisions or near-collisions.

Like visible light waves, submillimeter (or shortwave radio) waves belong to the electromagnetic spectrum, but they exist at frequencies the eye cannot see and at energies too weak for detection by conventional instruments. They are also unlike visible light in their ability to pass through clouds of dust as if they were transparent, and it is this property that makes them so useful to astronomers. Interstellar dust permeates the Milky Way and other galaxies, preventing optical telescopes from observing, for example, how an interstellar gas cloud initially collapses to form a young star. But the gas molecules in the cloud emit submillimeter waves at distinct frequencies. By analyzing these emission lines, submillimeter astronomers can build up a picture of conditions in interstellar clouds, including their composition, temperature, density, and dynamics.

The submillimeter band of the spectrum has been one of the last to be opened to astronomy because of the technical demands of the instrumentation. The Caltech Submillimeter Observatory possesses both a radio dish with extremely high surface accuracy and receivers that have the unique sensitivity to make very fine distinctions among submillimeter wave frequencies from space. The telescope is also designed to operate at the long submillimeter wavelengths least affected by the earth's atmosphere. Thus research at the Caltech Submillimeter Observatory may one day enable astronomers to discover under what conditions a newborn star becomes a single or double stellar system, and under what conditions it acquires planets, an event known to have occurred at least once in cosmic history.

Jet Propulsion Laboratory

Preparation of the redesigned Galileo mission to Jupiter for its rescheduled 1989 launch was a major effort of the Laboratory in 1987. The new flight path, using gravity-assist encounters with Venus and twice with Earth, puts new requirements on the spacecraft design, while the encounters with asteroids Gaspra and Ida provide new opportunities in planetary science. Another major effort was the preparation for Voyager 2's 1989 encounter with Neptune, its fourth outer planet in ten years.

Laboratory scientists participated in studies of the Antarctic "ozone hole," including the demonstration of a mechanism for chlorine breakdown of ozone there, and pursued various instrumental approaches to ozone monitoring. They also studied other atmospheric and terrestrial phenomena using combinations of space-derived and conventional data. Similar studies enlarged our knowledge of other members of the solar system, and more distant reaches, including the Cygnus X-1 source and Supernova 1987A. The Deep Space Network continued work in radio and radar astronomy in addition to its primary mission of tracking and communicating with distant spacecraft.

Notable progress was made in techniques of visualization, which by combining many data in computer imagery (for example, direct images, multispectral scans, and/or radar, with applicable point data) can bring out new information and understanding. A significant example was the preparation of motion pictures reflecting three-dimensional constructs from a single Landsat image and from a Voyager image of Uranus' satellite Miranda, each enhanced with U.S. Geological Survey altitude data.

The JPL/Caltech Hypercube project continued its progress in the study, development, and application of increasingly powerful parallel-processing computers, generating and benefitting from growing industrial interest and participation. A Center for Space Microelectronics Technology was organized during the year to focus the Laboratory's work in these vital areas. One such activity in 1987 was the demonstration of a laser/fiber optics rotation sensor, a new concept in spacecraft guidance platforms in which moving parts such as gyros are eliminated.

This financial report of the California Institute of Technology has been prepared from the Institute's accounting records and reflects the Institute's financial position as of September 30, 1987, and the results of its operations for the year then ended. These statements have been reviewed by the Board of Trustees Audit Committee, whose members are designated by an asterisk in the list of board members on page 28 of this annual report.

The *Balance Sheet* portrays the assets, liabilities, and fund balances for each major fund group as well as the total for the Institute. Total net assets increased from $658.5 million to $762.3 million, reflecting an increase of $52.1 million in campus properties and an increase of $44.8 million in investments.

The *Statement of Changes in Fund Balances* reflects the impact of revenues, expenditures, and transfers in the fund balances, thus portraying the sources and uses of funds by major category. Gifts and grants from private sources, totaling $79.4 million for fiscal year 1987, included $30.7 million representing additional installments on the $70 million grant from the W. M. Keck Foundation to construct a 10-meter telescope in Hawaii. A total of $59.8 million has been received through fiscal year 1987, with the balance of $10.2 million expected in fiscal year 1988. $31.7 million was realized as the net gain from disposal of investments in fiscal year 1987, compared with $36.7 million for fiscal year 1986.

The *Statement of Operating Expenditures* provides the detail of current fund expenditures for educational and related purposes. Total expenditures for fiscal year 1987 for the campus increased $13.7 million or 9.5 percent over fiscal year 1986. Expenditures for direct costs of sponsored research at the Jet Propulsion Laboratory increased $47.7 million or 5.7 percent.

Current Funds are those funds available for operating purposes. They are classified as unrestricted—available for any purpose; or restricted—to be used for purposes specified by the sponsor or donor. They include tuition and fees, investment income, gifts, and grants or contracts from federal and private sponsors.

Loan Funds for students are provided by gifts and participation in the government's Perkins Loan Program, and are subject to repayment with interest after graduation. As repayments are made, the principal and accumulated interest are lent again to new borrowers.

Endowment and Similar Funds include both the principal of funds set aside as endowment in accordance with the donors' wishes, which are invested to produce income and capital appreciation, and also the principal of discretionary and expendable funds, which are designated by the Board of Trustees to function as endowment.

Investment objectives for Caltech's endowment funds focus on three principles: 1) preservation of capital, 2) ability to meet current income targets, and 3) appreciation of capital to foster future income growth. In this way, the Institute endeavors to provide a stream of investment return that, after considering inflation, will strike a fair balance between current and future support of its instruction and research programs.

The year ended September 30, 1987 provided an excellent investment climate for this strategy. The Institute positioned its investment mix to participate in the stock and bond market rallies during this period. The market value of the Institute's endowment fund at September 30, 1987 was $418.2 million, compared to $347.9 million at September 30, 1986. Gifts, bequests, and favorable investment performance contributed to the $70.3 million growth in 1987. The annual compound total rate of return (income plus market appreciation) on the Institute's endowment for the five years ended September 30, 1987 was 18.9 percent. On October 19, 1987, the U.S. and most world equity markets declined sharply and continued to be volatile for several weeks. Investments in Caltech's portfolios are broadly diversified, and there has been no long-term impairment of the earning power of the endowment.

Life Income and Annuity Funds consist of gifts received to establish living trusts for which the Institute is trustee, or annuity agreements. Payments are made to beneficiaries and annuitants during their lifetimes in accordance with the terms of these agreements.

Life income and annuity agree-

	1983	*1984*	*1985*	*1986*	*1987*
Current funds expenditures *(in thousands)*					
Instruction and research (including libraries)	$ 74,535	$ 80,516	$ 93,019	$ 99,578	$109,611
Scholarships and fellowships	5,095	6,198	6,839	8,178	8,372
Institutional and student support	14,314	15,692	17,260	20,031	22,739
Plant operation, maintenance and utilities	9,586	10,013	11,084	10,988	11,263
Total operating expenses	103,530	112,419	128,202	138,775	151,985
Auxiliary enterprises	4,435	4,796	5,543	5,731	6,197
Total	$107,965	$117,215	$133,745	$144,506	$158,182
Capital expenditures, campus *(in thousands)*	$ 12,459	$ 21,679	$ 18,551	$ 44,579	$ 52,055
Jet Propulsion Laboratory, direct expenditures *(in millions)*	425.2	505.2	656.4	832.5	880.2
Total gifts and nongovernment grants *(in thousands)*	24,747	29,697	38,578	84,920	79,410
Endowment and similar funds at market value *(in millions)*	248.3	247.0	274.6	347.9	418.2
Investment income *(in millions)*	19.6	22.5	22.8	25.0	28.3
Tuition rate *(in thousands)*	7.5	8.7	9.4	9.9	10.4
Student enrollment (first term)–Undergraduate	874	829	817	845	833
Student enrollment (first term)–Graduate	936	936	999	994	981

Year Ended September 30, 1987
(in thousands)

ADDITIONS

(Excluding Reimbursement of Direct Costs at the Jet Propulsion Laboratory)

Gifts and Nongovernment Grants	
Includes gifts and grants from private sources for education and research and physical facilities.	$79,410
United States Government Grants and Contracts	53,817
Reimbursement from various government agencies for direct costs of research, instruction, and student support.	
Campus Property Acquisitions	
Additions to land, buildings, and equipment.	47,934
Indirect Costs and Management Allowance	
Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	37,533
Realized Gains	
Net realized gains on investments sold.	31,746
Investment Income	
Endowment income and investment income of other funds, including earnings from short-term investments.	28,314
Tuition and Fees	
Tuition and fees assessed students.	18,301
Auxiliary Enterprises	
Revenues from sales by food services, student housing, and bookstore.	7,178
Other	
Income from sales and services and other miscellaneous revenue.	2,043
Total Additions	$306,276

DEDUCTIONS

(Excluding Direct Costs at the Jet Propulsion Laboratory)

Research	
Expenditures for activities specifically organized to produce research outcomes supported by federal and private sponsors.	$59,836
Instruction	
Expenditures for activities that are part of the instructional program, including departmental research.	49,775
Plant Fund	
Consists of expenditures for buildings, equipment, renewals, payments on interfund advances for plant purposes, as well as retirement of plant assets.	42,070
Institutional and Student Support	
Expenditures for business and financial affairs, student services, institute relations, and general administration.	22,739
Plant Operations	
Expenditures, including utilities, for the operation and maintenance of the campus grounds and facilities.	11,263
Scholarships and Fellowships	
Awards made to students enrolled in formal course work, with no requirement that they perform services or repay the awards.	8,372
Auxiliary Enterprises	
Expenditures, including maintenance, of auxiliary enterprises.	6,197
Other	
Includes payments to life beneficiaries with life income and annuity agreements and miscellaneous other charges.	2,239
Total Deductions	202,491
Increase in Fund Balances	103,785
Total	$306,276

ments are a source of meaningful additions to the Institute's endowment and other funds. This form of deferred giving has proved attractive to many donors who wish to support the activities of the Institute and receive income on their gift during their lifetime while obtaining a charitable income tax deduction for their gift. Upon termination of beneficiary agreements, the principal is transferred to the endowment or other fund groups as designated by the donor.

The Institute's life income and annuity agreements consist of pooled income funds, annuities, and taxable and nontaxable unitrusts. Investment assets include cash equivalents, equities and fixed income securities (including tax-exempt municipal bonds, where appropriate), real estate, and various royalty interests. The Institute functions as trustee, with the majority of the marketable securities managed by a major institutional investment advisory firm. The Institute does not charge a trustee fee at present. At September 30, 1987, the market value of the life income and annuity funds was $38.4 million.

Plant Funds consist of funds that have been received for, or designated by the trustees for, facilities. The group is divided into two categories: unexpended plant funds and investment in plant. Unexpended plant funds are available for expenditure for land, buildings, and equipment. As these funds are used, they are transferred to funds invested in plant. This transfer records the original cost of the Institute's physical facilities.

The *Notes to Financial Statements* are an integral part of the financial statements and provide significant information on accounting policies, investments, funds held in trust, retirement and deferred compensation plans, pledges, and revenue bonds.

The California Institute of Technology maintains its accounts in accordance with the guidelines suggested by the American Institute of Certified Public Accountants and the National Association of College and University Business Officers.

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

Exhibit 1

BALANCE SHEET

California Institute of Technology

September 30, 1986

(in thousands)

	Total All Funds
Assets	
Cash	$ 1,066
Accounts receivable:	
United States government (note B)	118,444
Other	5,108
Student accounts and notes receivable	10,057
Investments (notes A, C and D)	404,160
Interfund advances	
Prepaid expenses and other assets	3,088
Campus properties (notes A and D):	
Equipment	131,314
Buildings	132,295
Land	13,158
	$818,690
Liabilities and Fund Balances	
Accounts payable and accrued expenses (note B)	$132,777
Deferred student revenue	4,399
Funds held in custody for others	1,671
Annuities payable (note A)	1,364
Revenue bonds payable (note I)	20,000
Fund balances	658,479
	$818,690
Fund balances (Exhibit 2):	
United States government grants refundable	$ 3,689
Institute funds–	
Unrestricted	5,026
Discretionary endowment:	
Unrestricted	56,610
Restricted	39,116
Endowment principal	213,045
Other restricted funds	81,675
Invested in plant	259,318
	$658,479

See accompanying notes to financial statements

September 30, 1987

Total All Funds	*Current Funds*	*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*
$ 1,074	$ 236	$ 308	$ 80	$ 450	
148,168	148,168				
3,318	2,981			37	$ 300
9,960	3,541	6,419			
448,919	25,336	789	351,254	32,246	39,294
	2,925		1,426		(4,351)
2,777	2,777				
146,034					146,034
166,419					166,419
16,369					16,369
$943,038	$185,964	$ 7,516	$352,760	$ 32,733	$364,065
$153,759	$150,781		$ 207	$ 506	$ 2,265
3,992	3,992				
1,811			1,811		
1,212				1,212	
20,000					20,000
762,264	31,191	$ 7,516	350,742	31,015	341,800
$943,038	$185,964	$ 7,516	$352,760	$ 32,733	$364,065
$ 3,993		$ 3,993			
5,386	$ 2,209				$ 3,177
62,956			$ 62,956		
45,338			45,338		
242,448			242,448		
98,339	28,982	3,523		$ 31,015	34,819
303,804					303,804
$762,264	$ 31,191	$ 7,516	$350,742	$ 31,015	$341,800

Exhibit 2

STATEMENT OF CHANGES IN FUND BALANCES

California Institute of Technology

Year Ended September 30, 1986

(in thousands)

	Total All Funds
Fund balances at beginning of year (Exhibit 1)	$541,697
Revenues and other additions (notes A, E and H):	
Student tuition and fees	17,576
Investment income	24,987
Net gain on disposal of investments	36,715
Gifts and nongovernment grants	84,920
United States government grants and contracts–	
Reimbursement of direct costs	47,847
Recovery of indirect costs and management allowance	33,389
Auxiliary enterprises revenues	6,342
United States government advances	247
Campus property acquisitions ($14,313 included in campus operating expenditures and $33,621 included in campus property acquisitions, payments on interfund advances and renewals)	30,893
Other	1,850
Total revenues and other additions	284,766
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(144,506)
Campus property acquisitions, payments on interfund advances and renewals	(19,393)
Retirement and disposal of campus properties	(273)
Interest on advances for plant purposes	(516)
Interest on revenue bonds payable	(848)
Payment to life beneficiaries	(2,055)
Other	(393)
Total expenditures and other deductions	(167,984)
Transfers among funds:	
Gifts allocated	
Discretionary endowment transfers to current funds	
Allocations for plant purposes	
Terminated trust and annuity agreements	
Other	
Total transfers among funds	
Increase for the year	116,782
Fund balances at end of year (Exhibit 1)	$658,479

See accompanying notes to financial statements

Year Ended
September 30, 1987

Total All Funds	*Current Funds*		*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*
	Unrestricted	*Restricted*				
$658,479	$ 1,379	$27,426	$6,979	$308,771	$25,276	$288,648
18,301	18,301					
28,314	9,333	14,176	169		1,902	2,734
31,746				30,382	1,364	
79,410	8,188	20,263	15	8,702	4,964	37,278
53,817		53,800				17
37,533	37,533					
7,178	7,178					
374			374			
47,934						47,934
1,669	571	412	113		213	360
306,276	81,104	88,651	671	39,084	8,443	88,323
(158,182)	(71,595)	(86,587)				
(36,433)						(36,433)
(3,479)						(3,479)
(508)						(508)
(1,650)						(1,650)
(1,902)					(1,902)	
(337)			(159)		(178)	
(202,491)	(71,595)	(86,587)	(159)		(2,080)	(42,070)
	(1,329)	(913)		2,242		
	1,258			(1,258)		
	(6,941)	27		15		6,899
				624	(624)	
	(1,667)	378	25	1,264		
	(8,679)	(508)	25	2,887	(624)	6,899
103,785	830	1,556	537	41,971	5,739	53,152
$762,264	$ 2,209	$28,982	$7,516	$350,742	$31,015	$341,800

STATEMENT OF OPERATING EXPENDITURES

California Institute of Technology

Exhibit 3

(in thousands)	*Year Ended September 30,*	
	1986	*1987*
Educational and general:		
Instruction, including departmental research	$ 46,458	$ 49,775
Organized research	53,120	59,836
Scholarships and fellowships	8,178	8,372
Institutional and student support	20,031	22,739
Plant operation, maintenance and utilities	10,988	11,263
Total educational and general	138,775	151,985
Auxiliary enterprises	5,731	6,197
Total campus expenditures	$144,506	$158,182
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government)	$832,517	$880,199

See accompanying notes to financial statements

NOTE A—Summary of Significant Accounting Policies

Basis of accounting and reporting
The financial statements of the Institute, a not-for-profit educational organization, have been prepared in accordance with the principles of accrual basis fund accounting for colleges and universities. Under these principles, Institute resources are accounted for by the use of separate funds so that visibility and control are maintained for the benefit of the Institute and its sponsors. Funds that have similar objectives and characteristics have been combined into fund groups. Within each fund group, fund balances restricted by outside sponsors for specific purposes are so indicated and are distinguished from unrestricted funds that are available for use in achieving any Institute objective.

The financial statements of the Institute reflect the volume of activity at the Jet Propulsion Laboratory, which is managed by the Institute, but owned and supported by the United States government through the National Aeronautics and Space Administration.

Investments
Institute investments are stated at their approximate market value at date of gift, or at cost if purchased by the Institute, less applicable amortization and depreciation of real estate, unless there has been an impairment of value not considered temporary.

All investments of endowment and similar funds are carried in an investment pool unless special considerations or donor stipulations require that they be held separately. Pool share values are computed periodically based upon the total market value of the investment pool and the total number of pool shares invested.

Income on investments of endowment and similar funds is recorded as current fund revenues for the purposes specified by the donor. Such income is supplemented, where necessary, by transfers of additional amounts so as to result in a total return from the investment pool equivalent to 5% of the average market value of the pool over a three-year period. This total return concept is authorized by the California Uniform Management of Institutional Funds Act, which allows the prudent use of realized appreciation on investments, thus permitting greater flexibility in investment strategy.

Campus properties and plant funds
Campus properties are recorded at cost of construction or acquisition, or at appraisal value at date of gift, and no depreciation or amortization is recorded. The Institute provides for the renewal and replacement of its campus properties from funds designated for this purpose. Expenditures for maintenance and repairs are generally charged to current funds as plant operation and maintenance expenditures.

Annuities
Annuities payable to certain donors of the Institute are recorded at the present value of the liability calculated under an actuarial method which takes into account the life expectancies of the recipients.

Tax-exempt status
The Institute is a tax-exempt educational organization under federal and state income, gift, estate, and inheritance tax laws.

NOTE B—United States Government Contracts

The Institute has many contracts with the United States government that provide for reimbursement of costs incurred for sponsored research at the Jet Propulsion Laboratory and at the campus. These contracts gave rise to a substantial portion of the accounts payable and accrued expenses in the current funds at September 30, 1987 and 1986, and in turn to accounts receivable from the United States government.

NOTE C—Investments

Institute investments, at carrying values (see Note A), comprise the following:

	September 30, 1986	1987
Marketable securities—		
Debt securities (approximate market value of $150,930,000 in 1986 and $146,630,000 in 1987)	$144,620,000	$151,537,000
Equity securities (approximate market value of $180,780,000 in 1986 and $260,520,000 in 1987)	144,821,000	182,603,000
	289,441,000	334,140,000
Short-term commercial obligations	64,501,000	60,204,000
Settlements in process—		
Receivables for securities sold	291,000	2,132,000
Payables for securities purchased	(1,072,000)	(2,516,000)
Real estate, less amortization and accumulated depreciation of $2,320,000 in 1986 and $2,323,000 in 1987	23,964,000	25,356,000
Mortgages, notes and other securities	27,035,000	29,603,000
	$404,160,000	$448,919,000

As of December 31, 1987, total market value of the Institute's marketable securities, as shown above, approximated their aggregate carrying values.

Investments shown above include the investment pool as follows:

	September 30, 1986	1987
Investment pool assets at year end—		
At carrying value	$276,754,000	$315,561,000
At approximate market value	$310,300,000	$376,240,000
Pool share value at market	$ 16.41	$ 19.23
Annualized income earned per pool share	$ .82	$ .95

NOTE D—Campus Properties

In January 1985, the W. M. Keck Foundation awarded the Institute $70 million to construct a 10-meter telescope in Hawaii. As of September 30, 1987, approximately $60 million had been received: $35 million had been expended and is included in Buildings and $25 million was unexpended and is included in investments of the Plant Funds. Gifts to Plant Funds for the year ended September 30, 1987 include $31 million of this award and Pledges (Note H) include approximately $10 million.

NOTE E—Funds Held in Trust

The Institute is the income beneficiary of certain funds, recorded at a nominal value, which are held in trust by others and which had current market values, estimated by the Institute, of approximately $15,600,000 and $11,500,000 at September 30, 1987 and 1986, respectively. The income derived from these funds amounted to $744,000 and $679,000 for the years ended September 30, 1987 and 1986, respectively. This income has been included as investment income in the Statement of Changes in Fund Balances.

In addition, the Institute is the trustee for several revocable trusts in which it has a remainder interest and for which it makes income payments for life to the grantors of the trusts. These trusts totaling $5,740,000 and $3,520,000 at September 30, 1987 and 1986, respectively, have been excluded from the financial statements due to their revocable nature.

NOTE F—Retirement Plans

The Institute has three retirement plans covering substantially all its employees that are funded by periodic transfers to the respective insurance companies. The provisions for these pension costs for the years ended September 30, 1987 and 1986, totaled $4,960,000 and $4,275,000, respectively for the Campus; $19,049,000 and $16,738,000, respectively for the Jet Propulsion Laboratory (included in direct costs of sponsored research). The Institute's policy is to fund pension costs accrued. At the most recent annual valuation the plan assets for retirement plans were sufficient to cover the actuarially computed value of vested benefits. A comparison of accumulated plan benefits and plan assets for the defined benefit plans at the most recent annual valuation date (September 30, 1986) is presented below:

	September 30, 1986	
	Campus	*JPL*
Actuarial present value of accumulated plan benefits:		
Vested	$30,280,000	$143,180,000
Non-Vested	1,470,000	6,790,000
	$31,750,000	$149,970,000
Plan assets	$32,210,000	$152,060,000

In determining the actuarial present value of accumulated plan benefits as of September 30, 1986, the rates of return used were 7.25% for fixed dollar annuities and 4.00% for variable annuities. This represents a weighted rate of 5.25%.

NOTE G—Deferred Compensation Plan

The Institute has established a deferred compensation plan whereunder eligible employees may elect to defer a portion of their normal salary, generally until retirement. The Institute's liability for future benefits payable to active employees under this plan, which approximated $19,260,000 and $15,000,000 at September 30, 1987 and 1986, respectively, is matched by Institute investments in an annuity contract with a major insurance company. It is expected that any payments by the Institute to employees would be matched by payments from the insurance company to the Institute. The amounts representing future benefits payable and the matching investments are not reflected in the financial statements.

NOTE H—Pledges

The Institute does not record pledges in its financial statements. At September 30, 1987, the Institute had pledges on hand (principally for restricted purposes) totaling approximately $90,000,000, of which $61,000,000 is expected to be collected in 1988. It is not practicable to estimate the net realizable value of such pledges.

NOTE I—Revenue Bonds

On December 26, 1985, the Institute borrowed $20,000,000 through the California Educational Facilities Authority for the purpose of constructing, acquiring and refinancing the cost of certain educational facilities. Funds were obtained through the sale of revenue bonds, repayable together with interest from the general revenues of the Institute over a 30-year period. Interest rate varies from 6.4% to 8.625%. Required principal and interest payments on the bonds for the fiscal years 1988 through 1992 are approximately:

1988	$1,650,000
1989	2,040,000
1990	2,040,000
1991	2,040,000
1992	2,040,000

Investments of the Plant Funds include $1,500,000 held by a trustee as a Bond Reserve Fund.

Price Waterhouse

Los Angeles, California
January 15, 1988

To the Board of Trustees of
California Institute of Technology

In our opinion, the accompanying balance sheet and the related statements of changes in fund balances and of operating expenditures (Exhibits 1 through 3) present fairly the financial position of California Institute of Technology at September 30, 1987, and the changes in fund balances and the operating expenditures for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year. Our examination of these statements was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Price Waterhouse

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