California Institute of Technology

1984-85 Annual Report

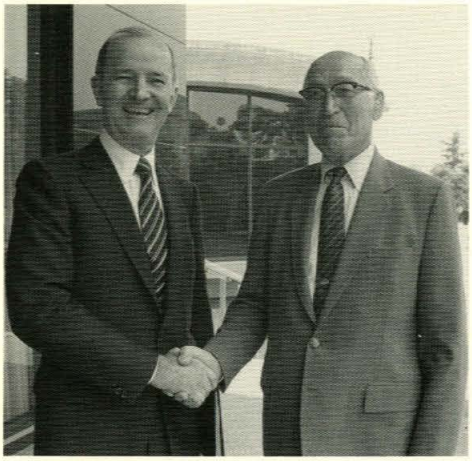
Jet Propulsion Laboratory's scientific ambassador to distant worlds, Voyager 2, took this image of the Uranian moon Miranda shortly before the spacecraft's closest approach. Miranda is only about 300 miles in diameter, but it displays a bewildering array of fractures that go in all directions, grooves up to several miles deep, and craters of many different densities. Clearly, the now dormant satellite must have undergone a long, complex geologic evolution.

California Institute of Technology

1984-85 Annual Report

Pasadena, California

Chairman's Message



Mutual congratulations were in order for Ruben F. Mettler, chairman of Caltech's Board of Trustees, and Arnold O. Beckman, chairman emeritus. Mettler had just presided for the first time at commencement, where Beckman was awarded the Robert A. Millikan Medal for distinguished service to the Institute.

What an exciting time to become chairman of the Caltech Board of Trustees. Many of the research and teaching activities in progress or in planning stages, and outlined by Dr. Goldberger in his portion of this report, are moving us toward technological and scientific capabilities previously far beyond our reach. At a time when rapid change also presents special opportunities, Caltech continues to do what it has always done so superbly. It is a small, dynamic, and flexible institution dedicated to excellence and creativity, and its work ranks at the top in those fields where it has chosen to excel.

Caltech has been an important part of my life since I enrolled in 1942 as part of a Navy unit for work in electrical engineering. As an undergraduate and graduate student, an alumnus, and as a Trustee, my appreciation for the Caltech community has continued to grow. The importance of Caltech's research and teaching to society at large has never been greater. To maintain our country's vitality in science and technology is a national priority. Clearly, Caltech must continue to play a critical role in this endeavor.

We are fortunate in having the support of a strong, diverse, and gifted Board of Trustees, each member with special expertise to offer. One of my priorities as chairman will be to support them in finding the most productive way to use their varied talents for the benefit of the Institute. Strong and committed Trustees are essential, and we intend to make skillful use of their abilities.

Central to Caltech's distinction are an unsurpassed faculty and exceptional students. These individuals represent our greatest strength, the source of our past successes, the key to our future. Their contributions are essential not only to Caltech, but to our country. They have my full support.

During the past year we welcomed four new members to the Board: Harold Brown, former president of Caltech and former U.S. secretary of defense, who is now chairman of the Foreign Policy Institute of Johns Hopkins University and a consultant to private corporations and investment banks; Harry M. Conger, chairman, president, and chief executive officer of Homestake Mining Company in San Francisco; Pamela Pesenti, who represents the third generation of the Braun family to serve on our Board, and Howard Keck, Jr., the third Keck family member to serve.

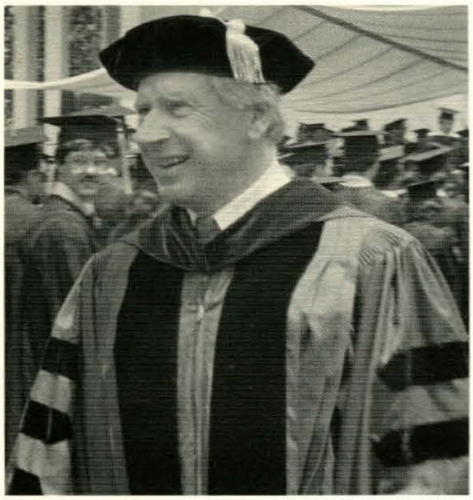
Six members were elected Life Trustees during 1985. They are John G Braun, Earle M. Jorgensen, Dean A. McGee, Rudolph A. Peterson, Simon Ramo, and Lew R. Wasserman. All of these individuals brought much to our Board, and we continue to look to them for guidance.

This is a memorable time for Caltech and its friends. We face the challenges of the years ahead with keen anticipation, and it is an honor for me to serve as the chairman of its Trustees.

Ruben F. Mettler

Chairman

President's Message



In June, President Marvin L. Goldberger welcomed 468 new alumni to Caltech. This was the Institute's ninety-first commencement.

Groundbreaking ceremonies for the new W. M. Keck Observatory—the future home of the world's largest telescope—were held September 12 on Mauna Kea in Hawaii. I pointed out on that occasion that we were taking a step to insure Caltech's historical preeminence in optical astronomy. This step was made possible by the enormous generosity of the W. M. Keck Foundation, which in January 1985 awarded us a gift of $70 million to construct a telescope that would be twice as large as Caltech's Hale Telescope on Palomar Mountain. Since then, in association with the University of California, which will provide the operating funds, we have formed the California Association for Research in Astronomy—a non-profit corporation to oversee construction and operation of the observatory. Site preparation is complete, and actual construction will start this April. The 10-meter telescope is expected to become operational in 1991, and that event will usher in a new era in astronomy.

The Keck Observatory is only one of a number of major academic and research projects currently under way. Some of the others are: the Arnold and Mabel Beckman Laboratory of Chemical Synthesis, the Program in Advanced Technologies, an advanced parallel processing computer project, the Infrared Processing and Analysis Center, the submillimeter observatory on Mauna Kea, an expanded materials research group, a new library information system, an educational computing program, a full engineering study for a large-scale gravitational wave detector facility, and an expanded program in developmental biology made possible by a major grant from the Markey Foundation.

Creating an environment that fosters the innovation and risk-taking represented by these projects is what Caltech is all about. Currently we are searching for ways to increase our endowment significantly. We need the flexibility to respond to opportunities as they arise. We must always be in a position to establish a new research direction, to amplify and diversify an existing research activity as it takes on new dimensions, and to assist our faculty in capitalizing upon unusual opportunities. We are also dedicated to strengthening our student aid program so we can continue to attract the very best students to the Institute irrespective of their financial means, to developing curricula that will enable their unusual abilities to flourish, and to providing a stimulating student social environment.

The Institute is small, and we wish to maintain the advantages that being small gives us. Our small size, the simplicity of our administrative procedures, and our ability to generate financial support for teaching and research are the critical ingredients for our maintaining an atmosphere of and expectation for excellence, which has been the hallmark of Caltech since its inception. Our plan for the future is the same as always—to be the very best!

Marvin L. Goldberger

President

The Year in Review

The year 1984-85 was filled with both large and small happenings at Caltech. Some of them are noted here.

Milestones

With the ground-breaking ceremonies for the W. M. Keck Observatory, held September 12 at the site on Mauna Kea in Hawaii, an important step was taken toward realization of an astronomical dream of an optical telescope four times as powerful as any now in existence. The project office for overseeing the construction and operation of the observatory was dedicated in Pasadena in August. The office consists of two Caltech-owned houses that were remodeled using money from a fund earlier established by trustee Gilbert Fitzhugh.

Phase one of the conversion of parts of the Crellin and Church laboratories into the Arnold and Mabel Beckman Laboratory of Chemical Synthesis was completed, and the refurbished space was occupied by researchers. Phase two is well under way, with occupation scheduled for summer 1986. The Calder arches are installed on the facade of the bridge that connects the two wings of the new lab, and dedication is planned for April 1986.

The submillimeter telescope and observatory dome—a second astronomy project now in progress—were constructed on the campus, dismantled in May, and shipped to Hawaii where they are being reassembled on Mauna Kea. The space they had occupied was immediately preempted for construction of the Infrared Processing and Analysis Center, a building in which the data gathered by the Infrared Astronomical Satellite is now being analyzed.

Farther from campus, at the Owens Valley Radio Observatory, an array of three millimeter-wavelength radio telescopes was dedicated in May, completing a third large telescope project. The dishes, which can be combined to act as a single large telescope, are expected to make important contributions to our understanding of the birth of stars.

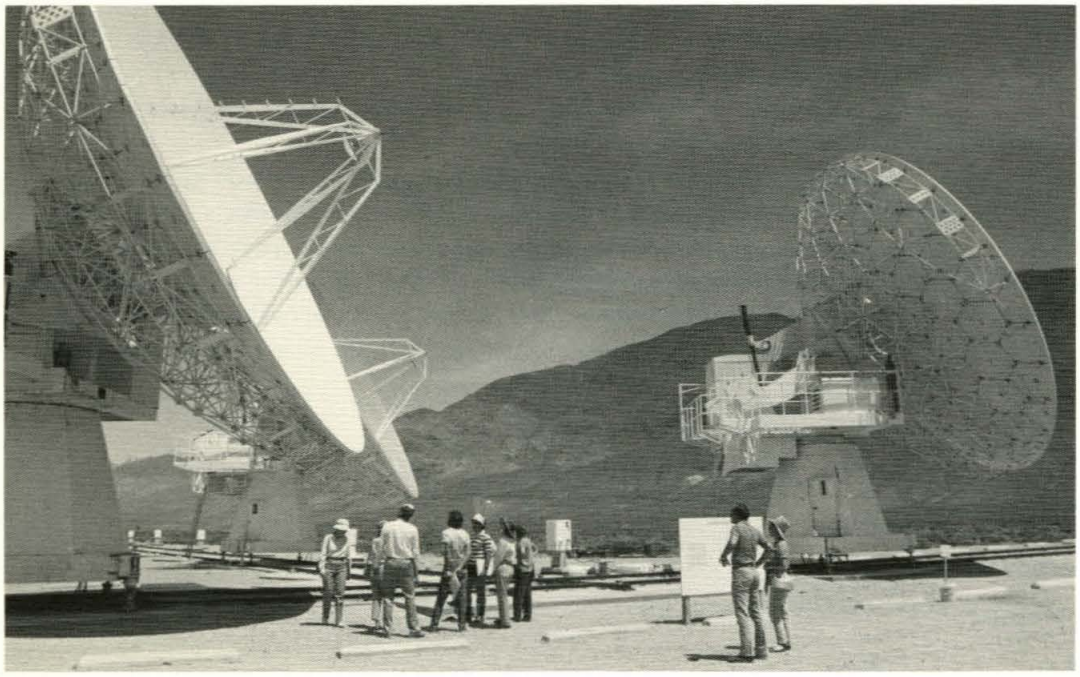
Ground was broken at JPL in May for a new central engineering building, the first major facility to be built at the lab in more than nine years. The four-story structure, which will provide extensive lab, office, and conference space for 800 to 900 JPL employees, is expected to be completed by summer 1986.

A new approach to landscaping brightened the appearance of the campus with numerous beds and planters full of blooming annuals. The result was so striking that it earned for the Institute the top award in the country in the category of colleges, universities, and schools from the Professional Grounds Management Society.

The new graduate student housing complex on Catalina Avenue was also commended, receiving the 1984 Pasadena Beautiful Foundation Award in the Institutional Buildings category. This complex is soon to be joined by nearby additional graduate apartments and the Institute's first parking structure, which will have space for almost 500 cars.

A unique aspect of the new buildings is that they are the first in Caltech's history to be financed by the sale of bonds. Proceeds from the sale will also be used for phase two of the Institute's plan to produce its own energy through the cogeneration process and eventually for other projects as well.

It would take a single radio telescope with a diameter of about a fifth of a mile to match the resolution that can be obtained with Caltech's new millimeter-wavelength interferometer at Owens Valley Radio Observatory. Each of these dishes is 34 feet in diameter.



Automation of the campus library operations and services has begun, and some stages of the system—including acquisitions and accounting—are already in operation. An online catalog is being implemented that will be capable of searching for books by author, title, series title, subject, or call number.

Baxter Art Gallery's final show—"25 Years of Space Photography: Jet Propulsion Laboratory, California Institute of Technology"—was a stunning display of some 150 black-and-white and color images documenting JPL's contribution to unmanned photographic space missions. After its campus showing, the exhibition, which was funded by a grant from IBM, traveled to the IBM Gallery of Art and Science in New York City for a show that opened in November.

One of a number of books published last year by Caltech professors was *Surely You're Joking, Mr. Feynman* by Nobel prize winner Richard Feynman and Ralph Leighton. It appeared in bookstores in January 1985 and became so popular that it spent several weeks on the *New York Times* best seller list.

Another faculty book received national attention and a nomination for the American Book Award. *In the Name of Eugenics: Genetics and the Uses of Human Heredity*, by historian of science Dan Kevles, was serialized in substantial part in the *New Yorker* before appearing in book form in May.

And finally, in a stunning upset of their own record, Caltech's battling Beavers achieved their first undefeated football season in more than 40 years. The team, an eclectic mix of students (undergraduate and graduate), staff members, and one faculty member, is probably no more unusual than it was in its last undefeated season. That was in 1944, when the gridders were mostly Stanford players who signed up for the Navy V-12 program and were shipped off to Caltech.

Appointments

Theodore P. Hurwitz, associate vice president for development at the University of Chicago, became Caltech's vice president for Institute Relations on August 1. This is a return to the Institute for Hurwitz, who was director of estate planning on the campus from 1969 to 1974.

Geoffrey Fox, professor of theoretical physics, has been appointed to the newly created position of associate provost for computing.

Five endowed chairs received new occupants. Guiseppe Attardi became the Grace C. Steele Professor of Molecular Biology, and John Bercaw is now the Shell Distinguished Professor of Chemistry. Anatol Roshko was appointed Theodore von Kármán Professor of Aeronautics, Felix Boehm became the William L. Valentine Professor of Physics, and Thomas McGill is the new Fletcher Jones Professor of Applied Physics.

Honors

Among the many honors awarded Caltech faculty in 1984-85 was election to the National Academy of Sciences for four biologists—Professors John Abelson and Mel Simon; Eric Davidson, Chandler Professor of Cell Biology; and Mark Konishi, Bing Professor of Behavioral Biology.

Lee Hood, Bowles Professor of Biology and chairman of the biology division, became the ninth faculty member since 1958 to be named California Scientist of the Year by the California Museum of Science and Industry. The award recognized Hood's "outstanding contributions to the understanding of the immune system and the role of genes in cancer."

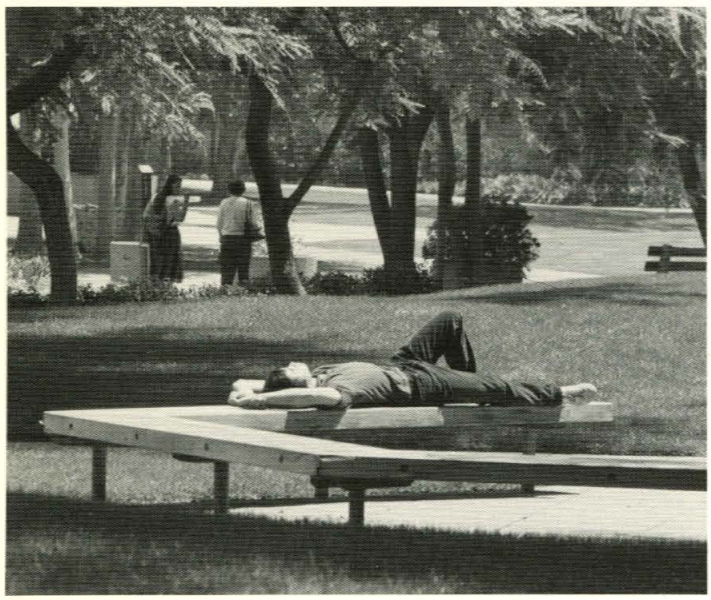
In addition, four members of the faculty were named recipients of Presidential Young Investigator Awards. Three are assistant professors, biologist Scott Emr, theoretical astrophysicist Sterl Phinney, and Ares Rosakis of aeronautics and applied mechanics. Hugh Woodin, professor of mathematics, also received one of the awards.

Rudolph Marcus, Noyes Professor of Chemistry, received the Wolf Foundation Prize in Chemistry for his contributions to chemical kinetics, and John Benton, professor of history, became the fourth faculty member to be named a MacArthur Prize Fellow.

ASCIT (Associated Students of the California Institute of Technology) also honored several members of the faculty. Yaser Abu-Mostafa, assistant professor of electrical engineering and computer science; Glen Cass, associate professor of environmental engineering; Eugene Cowan and Jerome Pine, professors of physics; and Fred Culick, professor of applied physics and jet propulsion, were chosen to receive ASCIT Teaching Excellence Awards.

Caltech also honored several of its graduates. At commencement, Arnold O. Beckman (PhD '28), chairman emeritus of the Caltech Board of Trustees, was awarded the Robert A. Millikan Medal for distinguished service to the Institute.

Life in the academic fast lane sometimes slows down long enough for appreciation of the sunshine.



The Distinguished Alumni Award was conferred on five graduates on Alumni Seminar Day. They were Richard DeLauer (Eng '50, PhD '53), who is president of the Orion Group, Ltd., and who served as undersecretary of defense from March 1981 to December 1984; Harold Johnston (PhD '48), professor of chemistry at UC Berkeley, who alerted the world to the possible dangers of destruction of the stratosphere's ozone layer; Dallas Peck (BS '51, MS '53), head of the U.S. Geological Survey; Ivan Sutherland (MS '60), a founder of the computer graphics field; and Chou Pei-Yuan (PhD '28), theoretical physicist and president of the Chinese Association for Science and Technology and of Peking University.

Education

The largest group of freshmen in the history of Caltech—200 men and 30 women—entered the Institute in the fall of 1985. They were chosen from 1,188 applicants. This represented a decrease of 6 percent in applications, but an increase of 19 percent in acceptances. In addition to the freshmen, 22 students transferred to the Institute from other schools. Total undergraduate enrollment was 845, an increase of 28 over 1984. Graduate enrollment totalled 994, a decrease of 5 for the same period.

Caltech is continuing to meet the full financial need of all qualified students, but it has increased its own aid contribution substantially over the past five years to compensate for a growing gap between students needing assistance and traditional government funding. This year, for example, the Institute is contributing more than twice as much scholarship and fellowship aid as it was five years ago. Increases in federal and state aid are substantially less.

Caltech students graduating in June continued to do well in terms of both job offers and salaries. By late summer, 92 of 186 students with BS degrees reported they were planning to enter graduate school, 70 had accepted jobs, 5 were still seeking positions, and the rest had other plans. Their average salary offer was $29,500. Of the 153 receiving MS degrees, 88 chose to continue for a PhD. Of those seeking jobs, 44 had accepted offers, 6 were still deciding or seeking, and 9 international students had returned to their home countries. The average salary offer for M.S. graduates was $32,000. Of the 129 PhD degrees awarded, 63 accepted academic positions, and 55 took jobs in industry. The rest were undecided. Salary offers ranged from $37,000 to $50,000.

Accreditation through a periodic peer review system is an important factor in maintaining quality in American higher education, and 1985 was Caltech's year for examination. The Institute submitted a 160-page self-study report, which was followed by a four-day visit from a team representing the accrediting agency—the Western Association of Schools and Colleges. Accreditation was granted in June and reaffirmed in December.

Caltech's 26-part college-level introduction to the history, laws, and applications of classical mechanics, "The Mechanical Universe," made its debut on broadcast and cable television in September. The series, which was funded by a grant from the Annenberg/CPB Project, immediately began garnering honors, among them the Gold Medal in the Scientific Themes category from the International Film and Television Festival of New York and the Golden Plaque at the Chicago Film Festival. A grant from the National Science Foundation has made possible adaptation and taping of some segments for use in both regular and advanced placement high school physics classes. An additional 26 programs titled "Beyond the Mechanical Universe" are currently in production on campus and will be aired beginning in January 1987.

The Summer Undergraduate Research Fellowships (SURF) program at Caltech began in 1979 with 18 students. In the summer of 1985, 128 students participated. This interaction between individual students and faculty members on research problems of mutual interest gives a valuable new dimension to undergraduate education, and there have also been concrete results in the form of some 40 publications in scientific journals. A 1983 SURFer, the late Tak Leuk Kwok (BS'84), received the Apker Award of the American Physical Society for the most promising physics research done by an American undergraduate.

The Summer Secondary School Science Project enrolled 400 high school students this year. The classes, which are taught by undergraduate student instructors, offer highly motivated secondary school students three levels of molecular biology, three of physics with trigonometry, three of chemistry, and two of physics with calculus.

Support Groups

Membership in the Caltech Alumni Association numbers 6,800, or 45 percent of the alumni, but the Association serves the Institute as a whole and all of its approximately 15,500 living graduates.

Major programs for the year included Seminar Day in May, when 1,200 alumni and guests visited the campus for faculty lectures and exhibits; the annual Rose Parade program; two wine-tastings in March; 12 class reunions; and various chapter activities around the country. Travel programs to Mount St. Helens and central Pennsylvania were conducted during the year, and a new program in Undergraduate Admissions Support was begun. This involves a network of alumni prepared to visit high school counselors and attend college nights to assist in recruiting qualified students for Caltech.

Annual 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 year 1985 this group provided Caltech with $1.9 million in unrestricted contributions.

Current total membership is 1,067, and the President's Circle, a group of Associates who make especially generous regular donations, numbers 157, an all-time high. The combined total of unrestricted and restricted gifts from Associates was $4.8 million for 1985. Richard L. Hayman was president this year, and he will continue as president through 1986.

Caltech offered Associates participation in more than 20 very popular events during 1985. Some were held on campus with faculty speakers at luncheons and dinners; others were off-campus activities, ranging from a late-afternoon tour of JPL to a five-day trip to Glacier Park led by geologist Robert Sharp.

Under the leadership of Robert Sharp, Sharp Professor of Geology, Emeritus, 40 members of the President's Circle had a four-day geological tour of Glacier Park in August.

Among Caltech's most highly valued corporate friends are the Industrial Associates, whose membership fees provide over $1 million annually in unrestricted funds, and whose total contributions to Caltech for fiscal 1984-85 exceeded $9 million. The approximately 40 member companies of the Industrial Associates maintain close contact with Caltech. In 1984-85, more than 100 campus visits were made by IA company personnel, including over 230 appointments with faculty in all six divisions. Four technical conferences, attended by nearly 500 individuals were also held. Other IA activities included faculty visits to industry, and library and publications services.

Gifts

In fiscal year 1985, Caltech received a total of $38.6 million in gifts of cash and equipment from foundations, corporations, and individuals. This total was an all-time record and a 30 percent increase over last year. Included in the total was the first payment of $7.6 million on the $70 million pledge for the Keck Observatory.

Of this amount, more than $12 million came from corporations, $16 million from foundations, and $10 million from individuals. There were notable new gifts in all categories, among them several major corporate pledges, including one of $500,000 from Chevron Corporation to establish the Chevron Research Fund for purchase of equipment for the Division of Chemistry and Chemical Engineering and the Division of Geological and Planetary Sciences. The Boeing Company pledged $250,000 for faculty development, particularly for start-up funds for new faculty, and the Texaco Philanthropic Foundation has pledged $400,000 for fellowships in the Division of Geological and Planetary Sciences.

The Program in Advanced Technologies, made possible by five-year pledges last year of $1 million each by Aerojet General, GTE, General Motors, and TRW, is now in operation and is providing funds for research, equipment, and fellowships. In its first two years, PAT funds totaling $800,000 supported 23 research proposals, $200,000 was granted for equipment purchases, and eight graduate students were given assistance as PAT fellows.

The Flintridge Foundation, a Moseley family foundation, has endowed a new professorship in the Division of Physics, Mathematics and Astronomy in honor of the late Francis L. Moseley, who was a life member of The Associates. Two other long-time friends of Caltech have also recently endowed professorships, trustee Benjamin F. Biaggini and Joseph Koepfli, senior associate in chemistry, emeritus.

Caltech alumnus and trustee Benjamin Rosen (BS '54) gave a total of $700,000 to the Institute for its educational computing program, bringing total contributions to that program (mostly from corporations) to over $9 million. Mr. Rosen's gift is being used to purchase personal computers for student use, as well as for software support, maintenance, and student fellowships.

Biologist Elliot Meyerowitz believes the weed Arabidopsis thaliana, *like yeast, mice, and* Drosophila, *may be an organism for which combined genetic and molecular research will lead to both fundamental and practical scientific advances.*

The 1984-85 Alumni Fund exceeded its goal and earned $440,000, the maximum grant possible from the Irvine Foundation through the three-year Irvine Challenge Campaign. The Fund reported gifts of $1,987,000, an increase of more than $300,000 over the previous record year. (Gifts made to The Associates by alumni are credited to the Alumni Fund.) More than 50 percent of the alumni responded, and contributions from those who graduated within the last 15 years increased by 50 percent. Alumni who made contributions of $1,000 or more were considered members of the Golden Beaver Club, while those who made gifts of $200 or more were designated members of the Second Century Club.

Another important group are the Torchbearers of Caltech, those individuals who have established life income arrangements or included the Institute in their estate plans. They continue to increase in number, now totaling nearly 300.

Research Highlights

Biology

The ease with which modern recombinant DNA work can be done with any organism depends in part on the size of the organism's genetic material—the nuclear genome; the smaller the genome, the less work is required to isolate any particular gene. The harmless weed of the mustard family, *Arabidopsis thaliana*, now appears to have not only a small genome, but also to have the advantages of rapid growth, small size, and high fertility.

Molecular biologists at Caltech have performed several detailed analyses of the *Arabidopsis* genome to verify its small size and to determine the fraction and nature of repetitive DNA sequences present. Their initial study was a reassociation analysis of DNA extracted from whole plants, and later they used recombinant DNA techniques to examine random segments of genomic DNA. The results of these two sets of experiments demonstrate that *Arabidopsis* has a remarkably small and simple genome. This fact, together with the results of some 40 years of classical genetic experiments on this plant, indicate that it is a very good model system for modern research in plant molecular biology.

The Caltech group has now started studies on individual genes from *Arabidopsis* to determine mechanisms by which gene expression is regulated by both developmental and environmental stimuli. They report that these individual genes are similar to those of other flowering plants, and they predict that genes of interest can be easily located in *Arabidopsis's* small genome, which can then be used to pick out the corresponding genes in more complex plants of economic interest.

For *Arabidopsis* to be truly useful as a tool for molecular genetic research, two additional techniques must be developed. First, it must become possible to clone genes about which no more is known than their mutant phenotype. Second, it must become possible to take cloned genes that have been modified in vitro and introduce them back into the plant to assay their in vivo function. This ability will make possible the type of detailed analysis of these genes that is now being performed with the genes of yeast, *Drosophila*, and mice. The hope is that *Arabidopsis* will soon join the other organisms for which a combined genetic and molecular approach has led to both fundamental and practical scientific advances.

Chemistry and Chemical Engineering

The living cell is a tiny, highly efficient chemical factory where enzymes—proteins that act as catalysts in biochemical reactions—are synthesized. These enzymes and the microorganisms that produce them are vital to the food, pharmaceutical, chemical, and waste treatment industries. By changing a cell's DNA—the blueprint that tells it which proteins to produce—scientists have genetically engineered organisms to treat wastewater, "eat" oil slicks, and produce vaccines and other medicines in large amounts.

Recent developments in engineering, computer technology, and biology have engendered an exciting new branch of biochemical engineering—biocatalysis. The Caltech biocatalysis group is interested in tapping the catalytic potential of biological systems. One way they do this is by experimenting with cells in the "unnatural" environments that are encountered in process conditions. These process environments profoundly alter biocatalyst properties, such as activity and useful lifetime, relative to their properties in their native biological surroundings.

These researchers also experiment with the enzymes and antibodies produced by living cells. In enzyme immobilization, for instance, enzymes are bound to a solid surface to maximize their use in catalytic processes. Protein spectroscopies are then applied to investigate conformational change caused by immobilization and to understand the relationship between overall catalytic activity and the molecular state of the catalyst.

Biochemical engineers at Caltech also employ laser flow cytometry, which provides single cell measurements in less than one millisecond and enables detailed studies to be made of genetic stability in recombinant cells. Yeast and bacteria, which are used in industrial processes, have already been investigated using this approach.

The biochemical engineering group at Caltech is a world leader in fundamental biocatalysis research. Here, advanced engineering methods, instrumentation, microprocessor technology, molecular genetics, enzyme and antibody biophysics, polymer science, control engineering, and applied mathematics unite to address the central questions in process biocatalysis.

Graduate student Sally Rigden and Professors Edward Stolper and Thomas Ahrens examine the cannon-like apparatus with which they discovered that molten silicates under high pressure may be more dense than the solids with which they are in equilibrium.

Engineering and Applied Science

A better understanding of the nature of materials can lead to everything from stronger skyscrapers to improved computer chips.

To further that understanding, research groups from engineering, chemistry, and physics have formed the Caltech Materials Group (CMG)—a unique alliance of scientists that employs both experimental techniques and theoretical insights from the three disciplines. CMG will focus on crucial issues facing materials science by emphasizing the real-time interplay of experiment, theory, and modeling.

The CMG has already secured a $2.3 million, three-year grant from the National Science Foundation. This amount, coupled with $400,000 in matching funds from the Institute, will allow the group to support its research efforts and to purchase major items of equipment, including a scanning transmission electron microscope, a new computing facility, and an ultra-high-vacuum facility for the preparation of thin film samples.

Even before the formation of the CMG, individual materials research groups at the Institute had made significant discoveries. A breakthrough in materials science over a year ago led to a new approach to the synthesis of amorphous metals—those with glasslike, rather than crystalline, structures—in bulk form. Amorphous metals can be stronger and more wear- and corrosion-resistant than their crystalline counterparts. They also have superior electrical and magnetic properties, and their use in electrical transformers could save hundreds of millions of dollars per year in electrical costs.

Research on materials is also critical to the development of the computer industry. Novel semiconducting materials, for example, are the potential basis of a new generation of computer devices. Computer circuits made of such new semiconducting materials could send information faster and more efficiently.

Other groups are experimenting with using ion erosion and ion-beam mixing to enhance adhesion and modify the surfaces of materials. They are also exploring the characterization of materials and how thermodynamics and kinetics determine their microstructure.

As CMG scientists and engineers discover more about the chemical, mechanical, and electrical properties of materials, they will learn to manipulate and adapt new materials to suit the needs of many industries—automotive, aerospace, and manufacturing, for example, as well as computers and electronics.

Geological and Planetary Sciences

A geophysicist, a geologist, and a graduate student in geology have recently combined their research at Caltech, with results that may require adjustment of current theories about the earth's formation. Using a cannon-like apparatus, they fired aluminum or tungsten projectiles into samples of molten silicates heated to temperatures of 1,400 degrees Centigrade. The compositions of the silicates were similar to those of terrestrial volcanic rocks.

The projectiles reached velocities up to 5,625 miles per hour as they struck the target, creating pressures equivalent to those about 700 kilometers deep in the earth. A high-speed camera measured the speed of the shock wave that passed through the molten sample when it was struck, making it possible to calculate the density of the sample and the pressure to which it was subjected. The pressures ranged up to 3.4 million pounds per square inch or 240,000 times atmospheric pressure.

The scientists discovered that, contrary to accepted assumptions, molten silicates under high pressure may be more dense than the solids with which they are in equilibrium. At such great pressures, then, these silicates will tend to sink deep into earth's mantle rather than rise. This in turn means that they might carry elements into the deep interior that have previously been thought to be concentrated near the surface—sodium, calcium, and aluminum, for example, as well as heat-producing radioactive elements such as potassium and uranium.

Enrichment of these elements at depth with liquid silicates could help explain the existence of "hot spots" in the mantle. Hot spots are thought to induce mantle plumes that give rise to volcanic activity associated with such deep-seated features as the Hawaiian Islands.

The Humanities and Social Sciences

Political scientists in Caltech's Division of the Humanities and Social Sciences have conducted the first major comparative study of California's Asian and Latino populations, the fastest-growing political constituencies in the state, and reached some surprising conclusions about the impact these groups are likely to have on the future direction of state policy. The researchers found that Asians and Latinos diverge on a variety of key issues, including political affiliation, and that a majority within both groups hold views that in many cases differ from those of black respondents.

The researchers obtained their results from a sample of 1,646 respondents, including 305 Asians, 586 Latinos, 355 blacks, and 400 whites. The Asian and Latino sample was limited to immigrants who had arrived since 1965, reflecting the experience of these groups and permitting an assessment of government efforts to help recent immigrants enter America's cultural and economic mainstream. The respondents were questioned about political views and voting behavior, perceptions of racial and social relations, economic standing and expectations, and experience of discrimination in both economic and social settings.

A major finding of the study was that, contrary to the assumptions of some politicians and policy-makers, there appears to be no simple community of interests uniting California's non-white population, either as minorities or as recent immigrants. Asian voters, for example, were found to be more politically conservative than either blacks or Latinos and to resemble white voters in their strong support of such issues as capital punishment and defense spending, positions supported by fewer Latinos, and opposed by a majority of black voters.

The study also identified several areas in which the experience of black Americans departs significantly from that of minorities composed primarily of immigrants. While blacks reported encountering far more job-related than social discrimination, Asians and Latinos said precisely the opposite, reflecting, the researchers conjecture, the traditional immigrant view of America as a land of unlimited economic opportunity but often bewildering cultural diversity. Their findings also indicated that the entrepreneurial success of Asians and Latinos is substantially influenced by the financial and moral support both cultures enjoy from "extended families," an asset less available to urban black Americans.

In interpreting their data, the researchers suggest that California's candidates for public office need to pay greater attention to the individual interests of minority groups, and that government programs to assist minority businesses must become more sensitive to how family structure and cultural traditions differ among minorities.

Physics, Mathematics and Astronomy

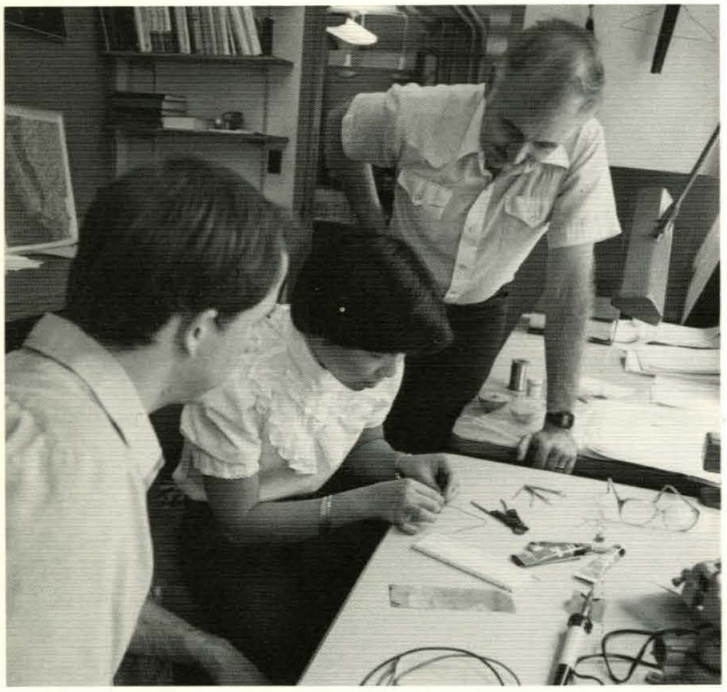
Contemplation of the cosmos and its meaning is as old as humanity. The ancient Greeks conceived of a universe governed by the "music of the spheres"; more than 2,000 years later, the theory of quantum mechanics (which describes how subatomic particles behave) and Einstein's general theory of relativity (which describes gravity) transformed mankind's view of the physical world and set modern physics on its current path. Today, that path is dominated by one overriding goal: the development of a unified field theory that accounts for the four known forces of nature—electromagnetism, the strong force, the weak force, and gravity—and for all the known laws of physics.

While there has been substantial progress toward uniting the first three forces in quantum terms, gravity has remained the odd man out, with physicists continuing to search for a way to assimilate general relativity into the world of quantum mechanics. Now, theoretical physics research in the Division of Physics, Mathematics and Astronomy may have produced a decisive breakthrough, employing a framework the Greeks would have appreciated. The universe, it suggests, is composed of the harmonies of "superstrings."

Superstring theory has generated great interest in the physics community because it appears to point the way to a consistent quantum theory that unifies gravity with the other forces. The theory proposes that all the elementary particles, which have always been treated mathematically as points, are instead very tiny (10^{-33} cm) strings that exist in ten-dimensional spacetime—the familiar three dimensions of space and one of time, plus six more dimensions that are described as curled up or collapsed into a kind of ball. This model also offers a solution to the longstanding conundrum of why there are so many fundamental particles by depicting them all as variations of a single string vibrating to an infinite range of frequencies or energy levels, much as a stringed instrument can be tuned to produce an almost limitless variety of notes.

The ultimate test of any scientific theory is its ability to explain observed phenomena. Theoretical physicists across the country are now developing their understanding of superstrings in order to devise experimental means of testing it. Should their findings confirm the theory's validity, physics will have provided a unified view of natural phenomena ranging from the latest events in particle accelerators to the birth of the universe some 15 billion years ago.

Graduate student William Lyons and Fred Shair, professor of chemical engineering, oversee the assembling of a modified Hartley oscillator by senior Thientu T. Lam. The device, used to study heat transfer in freely floating objects, is of particular value in food sterilization. This project was done under a grant from Caltech's Summer Undergraduate Research Fellowships program.



Environmental Quality Laboratory

In recent years, under a project sponsored by the California Air Resources Board, researchers in Caltech's Environmental Quality Laboratory have been investigating how each of the different components of air pollution reduce visibility.

The effects of visibility reduction are dramatic. Imagine looking north from the top of Millikan Library on a smoggy day in Pasadena. The sky will be more gray than blue; the San Gabriel Mountains will not be visible, even though they are some 6,000 feet high and are only three miles away; and most buildings will be indistinct in the haze.

On a smoggy day, light is scattered and absorbed by particulate matter and gases in the atmosphere, reducing visibility, lowering contrast, and even altering the perceived colors of objects in the field of view. The EQL researchers have made detailed analyses of air samples taken on smoggy days. They have also taken photographs to record the actual visual appearance of each experiment day.

Light-scattering theory and the measured physical and chemical characteristics of the aerosol are then used in the development of a model that accurately predicts visibility under specified air pollution conditions. A computer-generated color photograph representing a scene under those conditions illustrates the results of the model. The expertise of the JPL Image Processing Laboratory enables EQL scientists to produce the synthetic photographs.

Researchers are using the photographs and the visibility model to analyze the substances that degrade visibility in the Los Angeles area. Once that aspect of the project is completed, the group will evaluate air quality controls that might be used to solve the problem—a practical outcome of research that started with imagining a smoggy day.

Jet Propulsion Laboratory

The Jet Propulsion Laboratory acts as NASA's lead center for exploration of the solar system. The Laboratory's Voyager 2 spacecraft began its encounter with Uranus in November and at year-end was nearing the date of closest approach to the planet, January 24, 1986. Uranus presented a number of puzzling phenomena from the beginning of the encounter, including a featureless atmosphere and no sign of an intrinsic planetary magnetic field.

The Laboratory continued preparations throughout the year for the launch of the Galileo spacecraft to Jupiter. Galileo was shipped to the Kennedy Space Center in late December to prepare for launch in May 1986. The Ulysses Project, a joint flight mission with the European Space Agency to explore the Sun's polar regions, also was preparing for launch in May 1986. All launch plans for 1986 were delayed, however, when the shuttle Challenger was destroyed shortly after lift-off from KSC on January 28, 1986.

In April 1985, JPL research scientist Taylor Wang flew as a payload specialist with the Drop Dynamics Module experiment in Spacelab 3 aboard the shuttle Challenger.

Other JPL experiments that flew on space shuttles in 1985 were the Atmospheric Trace Molecules Spectroscopy (ATMOS) experiment, and the Superfluid Helium Experiment.

The Hypercube Research Project, a close collaboration between campus and JPL's Advanced Microelectronics Program, made good progress during the year. Programming the hypercube has turned out to be less complicated than expected. To date, 26 applications programs have been implemented. One 128-node and four 32-node hypercubes have been completed. Ametek has become the first commercial company to join the core sponsor group and a licensing agreement is in negotiation for Ametek to manufacture Mark III hypercube computers.

Analysis of data from the Infrared Astronomical Satellite (IRAS) continued throughout 1985 with very interesting results: Some galaxies and quasars detected by IRAS have turned out to be among the most luminous objects in the universe, emitting the energy of hundreds of Milky Ways, all at infrared wavelengths. In many cases, bursts of star formation are thought to power the emission from these exotic objects.

Within our own galaxy dozens of lower luminosity protostars—stars like the Sun in the process of formation—have been identified forming in nearby molecular clouds. The protostars are among the youngest objects in the Milky Way, less than 100,000 years old.

Financial Report

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, 1985, 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 the inside back cover 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 $493.3 million to $541.7 million, consisting primarily of an increase of $18.6 million in campus equipment, buildings, and land and an increase in investments of $27.2 million.

The *Statement of Changes in Fund Balances* reflects the impact of revenue, expenditures, and transfers in the fund balances, thus portraying the sources and uses of funds by major category. The increase of $8.9 million in gifts and grants from private sources for fiscal year 1985 included $7.6 million representing the first installment on the $70 million grant from the W. M. Keck Foundation to construct a 10-meter telescope in Hawaii. Approximately $21 million is expected to be received for this purpose in fiscal year 1986. A significant increase of $10.7 million was also realized in the net gain from disposal of investments.

The *Statement of Operating Expenditures* provides the detail of current fund expenditures for educational and related purposes. Total expenditures for fiscal year 1985 for the campus increased $16.5 million or 14.1 percent over fiscal year 1984. Expenditures for direct costs of sponsored research at the Jet Propulsion Laboratory increased $151.1 million or 29.9 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.

Five Years in Review

	1981	1982	1983	1984	1985
Current funds expenditures (in thousands)					
Instruction and research (including libraries)	$62,259	$64,938	$ 74,535	$ 80,516	$ 93,019
Scholarships and fellowships	3,540	4,494	5,095	6,198	6,839
Institutional and student support	11,399	12,836	14,314	15,692	17,260
Plant operation, maintenance, and utilities	6,587	8,116	9,586	10,013	11,084
Total operating expenses	83,785	90,384	103,530	112,419	128,202
Auxiliary enterprises	3,870	4,219	4,435	4,796	5,543
Total	87,655	94,603	107,965	117,215	133,745
Capital expenditures, campus (in thousands)	19,967	10,526	12,459	21,679	18,551
Jet Propulsion Laboratory, direct expenditures (in millions)	396.6	384.8	425.2	505.2	656.4
Total gifts and nongovernment grants (in thousands)	22,271	25,652	24,747	29,697	38,578
Endowment and similar funds at market value (in millions)	184.3	208.3	248.3	247.0	274.6
Investment income (in millions)	19.8	20.4	19.6	22.5	22.8
Student enrollment (first term)—Undergraduate	844	866	874	829	817
Student enrollment (first term)—Graduate	865	888	936	936	999

Summary of Changes in Fund Balances
Year Ended September 30, 1985

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

United States Government Grants and Contracts. Reimbursement from various government agencies for direct costs of research, instruction, and student support.	$43,900
Gifts and Nongovernment Grants. Includes gifts and grants from private sources for education and research.	$38,578
Indirect Costs and Management Allowance. Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	$29,733
Investment Income. Endowment income and investment income of other funds, including earnings from short term investments.	$22,758
Plant Acquisitions. Additions to campus plant for land, buildings, and equipment.	$19,781
Realized Gains. Net realized gains on investments sold.	$17,918
Tuition and Fees. Includes tuition and fees assessed students.	$16,336
Auxiliary Enterprises. Revenues from sales by food services, student housing, and bookstore.	$5,483
Other. Income from sales and services, and other miscellaneous revenue.	$1,778

Total Additions
(Excluding Reimbursement of Direct Costs at the Jet Propulsion Laboratory) $196,265

Deductions

(Excluding Jet Propulsion Laboratory Direct Costs)
(in thousands)

Research. Activities specifically organized to produce research outcomes supported by federal and private sponsors.	$48,590
Instruction. Expenditures for activities that are part of the instructional program, including departmental research.	$44,429
Institutional and Student Support. Includes Business and Financial Affairs, Student Services, Institute Relations, and general administration.	$17,260
Plant Fund. Includes plant fund expenditures for buildings, equipment, renewals, payments on interfund advances for plant purposes, as well as retirement of plant assets.	$11,921
Plant Operations. Represents utilities and other expenditures for the operation and maintenance of the campus grounds and facilities.	$11,084
Scholarships and Fellowships. Awards made to students enrolled in formal course work with no requirement that they perform services or repay the awards.	$6,839
Auxiliary Enterprises. Expenditures, including maintenance, of auxiliary enterprises.	$5,543
Other. Includes payments to life beneficiaries with life income and annuity agreements and miscellaneous other charges.	$2,203

Total Deductions (Excluding Direct Costs at the Jet Propulsion Laboratory)	$147,869
Increase in Fund Balances	$48,396
Total	$196,265

Loan Funds are provided by gifts and participation in the government's National Direct Student 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.

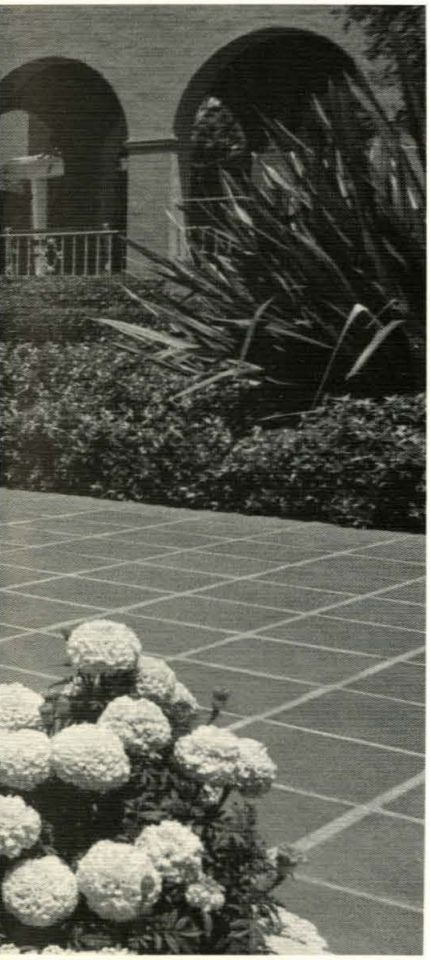
Investment objectives for Caltech's endowment funds focus on three principles: 1. preservation of capital, 2. ability to meet current income targets, and 3. appreciation of capital to foster future income growth. In this way, the Institute endeavors to provide a stream of investment return, after considering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

The 12 months ended September 30, 1985, 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, 1985, was $274.6 million, compared to $247.0 million at September 30, 1984. The annual compound total rate of return (income plus market appreciation) on the Institute's endowment for the five years ended September 30, 1985, was 11.78 percent—approximately twice average annual inflation, as compared with the consumer price and GNP deflator indexes.

Blooming annuals have recently brightened the looks of the campus—and helped earn the Institute the top award in the country in its category from the Professional Grounds Management Society.

Life Income and Annuity Funds consist of gifts received subject to 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 agreements 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 non-taxable 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, 1985, the market value of the life income and annuity funds was $29.7 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 Institute sold $20 million of tax-exempt revenue bonds on December 26, 1985, after receiving ratings of AAA by Moody's Investors Service and Standard and Poor's Corporation. The bonds were sold at par with an average coupon yield of 8.47 percent. The proceeds will be used to finance construction of graduate student housing, cogeneration equipment to provide a major portion of campus power requirements, parking facilities, and rehabilitation of the undergraduate student complex.

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 sale of revenue bonds.

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

	September 30, 1984
	Total All Funds
Assets	
Cash (demand deposits)	$ 941
Accounts receivable:	
United States government (note B)	65,341
Other	3,603
Student accounts and notes receivable	8,746
Investments (notes A and C)	282,407
Interfund advances	
Prepaid expenses and other assets	3,078
Campus properties (note A):	
Equipment	98,282
Buildings	102,990
Land	12,365
	$577,753
Liabilities and Fund Balances	
Accounts payable and accrued expenses (note B)	$ 72,850
Deferred student revenue	4,884
Funds held in custody for others	5,748
Annuities payable (note A)	970
Fund balances	493,301
	$577,753
Fund balances comprise (Exhibit 2):	
United States government grants refundable	$ 3,238
Institute funds—	
Unrestricted	4,053
Discretionary endowment:	
Unrestricted	48,470
Restricted	27,242
Endowment principal	153,091
Other restricted funds	52,301
Invested in plant	204,906
	$493,301

See accompanying notes to financial statements

Balance Sheet
(in thousands)

Exhibit 1

Total All Funds	Current Funds	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
		September 30, 1985			
$ 889	$ 569	$ 29	$ 8	$ 283	
97,841	97,841				
3,674	3,674				
9,496	4,051	5,445			
309,619	19,715	1,003	247,547	27,022	$ 14,332
	2,719		4,184		(6,903)
3,518	3,518				
111,272					111,272
108,312					108,312
12,604					12,604
$657,225	$132,087	$6,477	$251,739	$27,305	$239,617
$104,606	$102,387			$ 269	$ 1,950
4,702	4,702				
5,196	3,839		$ 1,357		
1,024				1,024	
541,697	21,159	$6,477	250,382	26,012	237,667
$657,225	$132,087	$6,477	$251,739	$27,305	$239,617
$ 3,495		$3,495			
5,049	$ 651				$ 4,398
49,116			$ 49,116		
34,494			34,494		
166,772			166,772		
59,436	20,508	2,982		$26,012	9,934
223,335					223,335
$541,697	$ 21,159	$6,477	$250,382	$26,012	$237,667

Year Ended September 30, 1984

	Total All Funds
Fund balance at beginning of year (Exhibit 1)	$460,624
Revenues and other additions (notes A, D and G):	
Student tuition and fees	14,999
Investment income	22,533
Net gain on disposal of investments—	
Unrestricted	2,437
Restricted	4,789
Gifts and nongovernment grants	29,697
United States government grants and contracts—	
Reimbursement of direct costs	36,117
Recovery of indirect costs and management allowance	26,486
Auxiliary enterprises revenues	4,952
United States government advances	184
Plant acquisitions, etc. (including $12,148 included in campus operating expenditures and $7,633 included in plant acquisitions, payments on interfund advances and renewals)	20,961
Other	2,079
Total revenues and other additions	165,234
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(117,215)
Plant acquisitions, payments on interfund advances and renewals	(10,918)
Retirement and disposal of campus properties	(2,150)
Interest on advances for plant purposes	(233)
Payment to life beneficiaries	(1,844)
Other	(197)
Total expenditures and other deductions	(132,557)
Transfers among funds:	
Gifts allocated	
Discretionary endowment transfers to (from) current funds	
Allocations for plant purposes	
Terminated trust and annuity agreements	
Other	
Total transfers among funds	
Increase (decrease) for the year	32,677
Fund balance at end of year (Exhibit 1)	$493,301

See accompanying notes to financial statements

Statement of Changes in Fund Balances
(in thousands)

Exhibit 2

Year Ended September 30, 1985

Total All Funds	Current Funds Unrestricted	Current Funds Restricted	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
$493,301	$ 701	$21,392	$5,873	$228,803	$24,999	$211,533
16,336	16,336					
22,758	6,782	13,198	158		1,934	686
4,296				4,296		
13,622				13,090	532	
38,578	4,127	20,112	150	4,003	408	9,778
43,900		42,850				1,050
29,733	29,733					
5,483	5,483					
319			319			
19,781						19,781
1,459	521	29	94		113	702
196,265	62,982	76,189	721	21,389	2,987	31,997
(133,745)	(60,214)	(73,531)				
(9,819)						(9,819)
(1,558)						(1,558)
(544)						(544)
(1,934)					(1,934)	
(269)		(138)	(131)			
(147,869)	(60,214)	(73,669)	(131)		(1,934)	(11,921)
	(43)	(785)		828		
	942	(2,502)		1,560		
	(3,029)	(605)		(2,424)		6,058
				40	(40)	
	(688)	488	14	186		
	(2,818)	(3,404)	14	190	(40)	6,058
48,396	(50)	(884)	604	21,579	1,013	26,134
$541,697	$ 651	$20,508	$6,477	$250,382	$26,012	$237,667

California Institute of Technology
Statement of Operating Expenditures
(in thousands)

Exhibit 3

	Year Ended September 30,	
	1984	1985
Educational and general:		
Instruction, including departmental research	$ 41,350	$ 44,429
Organized research	39,166	48,590
Scholarships and fellowships	6,198	6,839
Institutional and student support	15,692	17,260
Plant operation, maintenance and utilities	10,013	11,084
Total educational and general	112,419	128,202
Auxiliary enterprises	4,796	5,543
Total campus expenditures	$117,215	$133,745
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government)	$505,245	$656,353

See accompanying notes to financial statements

Notes to Financial Statements
September 30, 1985

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 objectives.

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, 1985 and 1984, 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, 1984	September 30, 1985
Marketable securities—		
Debt securities (approximate market value of $78,114,000 in 1984 and $72,558,000 in 1985)	$ 81,665,000	$ 71,906,000
Equity securities (approximate market value of $152,418,000 in 1984 and $165,410,000 in 1985)	132,906,000	142,215,000
	214,571,000	214,121,000
Short-term commercial obligations	36,488,000	61,612,000
Settlements in process—		
Receivables for securities sold	2,529,000	258,000
Payables for securities purchased	(2,251,000)	(2,208,000)
Real estate, less amortization and accumulated depreciation of $2,786,000 in 1984 and $2,307,000 in 1985	21,312,000	22,510,000
Mortgages, notes and other securities	9,758,000	13,326,000
	$282,407,000	$309,619,000

Investments shown above include the investment pool as follows:

	September 30, 1984	September 30, 1985
Investment pool assets at year end—		
At carrying value	$198,108,000	$216,174,000
At approximate market value	$209,070,000	$236,363,000
Pool share value at market	$ 12.42	$ 13.67
Annualized income earned per pool share	$ .86	$ .87

Note D—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 $11,500,000 and $11,000,000 at September 30, 1985 and 1984, respectively. The income derived from these funds amounted to $756,000 and $711,000 for the years ended September 30, 1985 and 1984, 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 $3,550,000 and $3,340,000 at September 30, 1985 and 1984, respectively, have been excluded from the financial statements due to their revocable nature.

Note E—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, 1985 and 1984, totaled $3,595,000 and $3,388,000, respectively for the Campus; $10,948,000 and $11,228,000, 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 funded amount and balance sheet accruals 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, 1984) is presented below:

	September 30, 1984	
	Campus	JPL
Actuarial present value of accumulated plan benefits:		
Vested	$20,877,000	$ 95,286,000
Non-vested	1,249,000	5,746,000
	$22,126,000	$101,032,000
Plan assets	$22,750,000	$106,151,000

In determining the actuarial present value of accumulated plan benefits as of September 30, 1984, the rates of return used were 7.25% for fixed dollar annuities and 3.75% for variable annuities. This represents a weighted rate of 5.31%.

Note F—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 $10,075,000 and $6,276,000 at September 30, 1985 and 1984, 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 G—Pledges

The Institute does not record pledges in its financial statements. At September 30, 1985, the Institute had pledges on hand (principally for restricted purposes) totaling approximately $88,000,000, of which $30,900,000 is expected to be collected in 1986. It is not practicable to estimate the net realizable value of such pledges.

Note H—Subsequent Events

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 1986 through 1990 are approximately:

1986	$ 962,000
1987	1,650,000
1988	1,650,000
1989	2,042,000
1990	2,040,000

Price Waterhouse

West Los Angeles, California
December 27, 1985

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, 1985, 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.

We have previously examined and reported upon the September 30, 1984, financial statements which are included in summary form for comparative purposes.

Price Waterhouse

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