California Institute of Technology

1983-84 Annual Report

An artist's rendering of the Arnold and Mabel Beckman Laboratory of Chemical Synthesis, now under construction. This renovation of two existing buildings will provide modern laboratories, offices, and instrumentation for synthesis-oriented researchers. As shown, the project also will feature a familiar Caltech landmark in a congenial new setting—the Calder arches, preserved from the demolition of old Throop Hall.

California Institute of Technology

1983-84 Annual Report

Pasadena, California

President's Message

Ruben Mettler (left), new chairman of Caltech's Board of Trustees, and retiring chairman Stanton Avery (right), with President Marvin Goldberger.

The year 1983-1984 was a rewarding one for Caltech, in research and educational achievements and in financial support from our friends. By the end of 1983-84, the Institute had received a record $27.7 million in gifts of cash and equipment—compared with $21.7 million in 1982-83.

A $5 million gift from the Arnold and Mabel Beckman Foundation was a highlight in the achievement of that record. Another example of Dr. and Mrs. Beckman's generosity to the Institute, this gift will enable Caltech to create a laboratory devoted to research in chemical synthesis. It will be called the Arnold and Mabel Beckman Laboratory of Chemical Synthesis.

Caltech is fortunate to have some of the finest synthetic chemists on its faculty at a time when a renaissance in this field is under way. The Beckman's gift will enable our synthetic chemists to apply themselves even more productively to furthering this renaissance. We expect the new laboratory to be completed in the spring of 1985.

Another exciting gift was announced early in January 1985. The W. M. Keck Foundation of Los Angeles announced a proposed grant to the Institute of $70 million to construct the world's largest optical telescope. The grant would be the largest private gift ever made for a scientific project. The W. M. Keck Observatory will house a 10-meter instrument that will be four times more powerful than the 5-meter telescope on Palomar Mountain in California. It will be located on Mauna Kea, an extinct volcano on the island of Hawaii. Construction of the observatory will begin in 1986.

A substantial number of gifts to the Institute in 1983-84 came in the form of critically needed laboratory equipment. Caltech shares in a major problem confronting colleges and universities across the country—aging and increasingly obsolescent laboratory equipment.

To help address this problem, the Institute established a discretionary equipment fund, initiated by a $1 million grant from the W. M. Keck Foundation in 1983. Called the Renewal Fund for Scientific Equipment, it will be used to fund a broad range of equipment and instrumentation for research and education.

We are pleased with progress we made in implementing a multimillion-dollar educational computing program begun during the previous year. By the end of 1984, more than 400 computing workstations were available on campus for educational computing. Within the next few years, the number of microcomputers available to students will increase to about 800.

In 1983-84 we confronted and resolved some important issues concerning the future of the Institute. One such issue and its resolution, involving Caltech's Palomar Observatory, took place in San Diego. After concerted efforts by Caltech and its friends, the San Diego City Council voted to convert the city's street lighting system to low-pressure sodium lights. These emit light in only one line of the spectrum, which can be filtered out of astronomical observations. San Diego County authorities took similar action in terms of street lighting and also adopted an ordinance controlling selected private outdoor lighting uses. These actions ensure that Palomar Observatory will not be blinded by light from neighboring communities.

A second important issue, the establishment of an Army analysis center under JPL cognizance, became the subject of extensive discussion among faculty members and the administration. Substantial faculty concern centered around the fact that the Arroyo Center would undertake policy studies involving discipline areas in which neither JPL nor the campus has extensive expertise. Faculty members noted that this would make it necessary to hire personnel in areas not connected with the lab's mainstream activities, and would create difficulties in supervision and review. A faculty vote recommended that the Arroyo Center not become a permanent part of the Institute. After its initial start-up phase at JPL, the analysis center activity was transferred to the Rand Corporation late in 1984.

Important new construction is under way at JPL. Ground was broken during 1984 for a frequency standards laboratory, and work is scheduled to begin during spring 1985 on an earth and space sciences laboratory and a central engineering building.

A major change during the year was the retirement of R. Stanton Avery after 10 years as chairman of the Institute's Board of Trustees. Under his guidance, Caltech flourished, both as an educational institution and as a center for scientific research. We will continue to have his service as chairman emeritus and life trustee. The entire Caltech community is grateful for his outstanding leadership.

We are fortunate to have Ruben F. Mettler as our new chairman. Mettler, a Caltech graduate who is chairman of the board of TRW Inc., assumed the position of chairman on January 1, 1985. We look forward to working with him.

We also welcomed two new members to the board—John F. Akers, who is president of IBM, and Roger B. Smith, who is chairman of the board of General Motors Corporation. Thomas J. Watson, Jr., and John G Braun retired from active service on the board and were elected life trustees. Frederick G. Larkin, Jr., a member of the Board of Trustees since 1969, died in December 1984. He was the retired chairman of the executive committee of Security Pacific National Bank. Larkin brought a special interest and expertise to the board, and we will miss him.

Caltech continues to be a strong and vital institution, highly respected throughout the world. When we look back on 1983-1984, we are pleased with our accomplishments. And as we enter 1985, we are enthusiastic about what lies ahead.

Marvin L. Goldberger

President

The Year in Review

In the year 1983-84, the Institute continued its traditional high level of achievement in education and research, and recognition of this fact was reflected in both honors for its faculty and students and support for its programs.

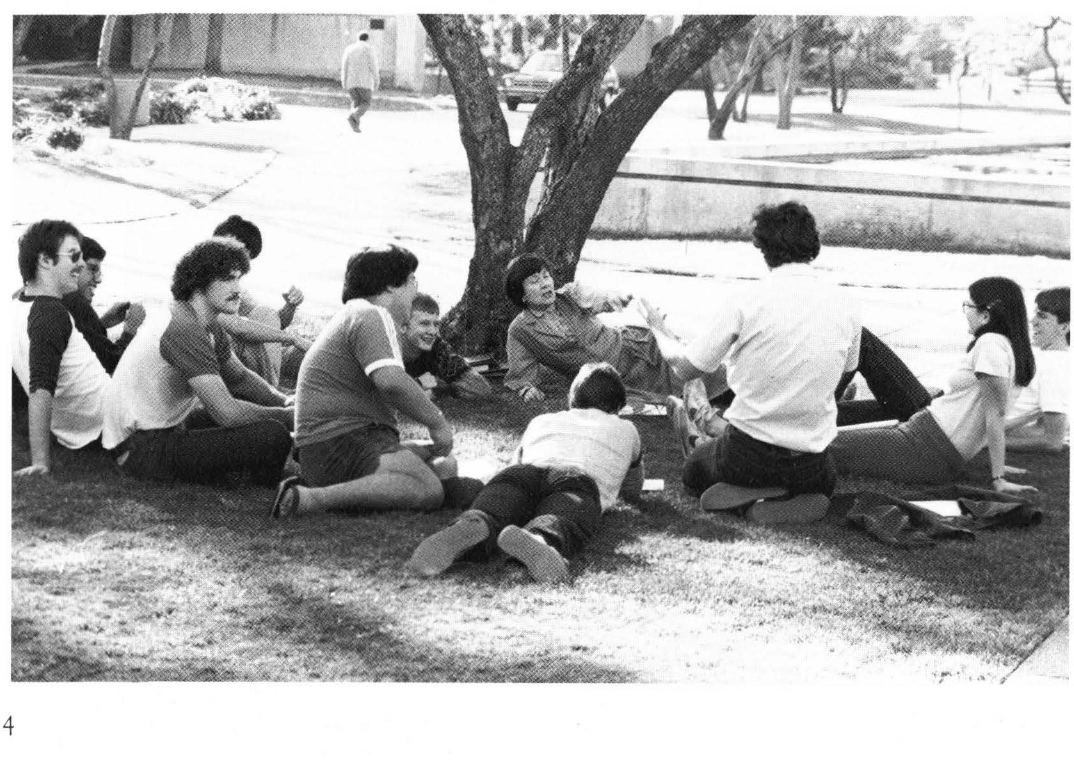
Education

In 1983-84 the Institute received applications from 1,267 high school students, which was 9 percent fewer than last year. From this group, 171 men and 23 women made up a freshman class numbering 194, an increase of 5 percent over last year. Total undergraduate enrollment dropped from 829 in the fall of 1983 to 817 for the first term of 1984. Graduate enrollment, however, reached an all-time high of 999, 156 of whom found housing in the newly completed graduate apartments.

Caltech's Financial Aid Office continued to be faced with a shortfall between available funds and number of eligible students, amounting to some $300,000 for 1983-84 and an estimated $500,000 in 1984-85. Projected changes in federal financial aid programs have been postponed temporarily, but substantial cuts are possible in 1986-87.

As an apparent consequence of the tightening in financial aid funds, there was a decline in the number of students coming to Caltech from low- and middle-income California families. This indicates valid concerns on the part of students and their families since the aid package today contains a larger percentage of loan and part-time job income, and a smaller percentage of direct aid, than in the past. About 85 percent of the Caltech student body hold part-time jobs, and while many students carry heavy loans, the default rate, which has always been one of the nation's lowest, declined in the last fiscal year from 3.96 percent to 2.83 percent.

Mild weather and small class size make it possible for Professor of History Eleanor Searle to conduct a session of her course outdoors.



As always, Caltech students graduating in June 1984 did well in terms of both job offers and salaries. The average annual salary offer for BS degree recipients was $28,700, which was 7 percent higher than the national average. For MS degrees, the average offer was $31,800. By August, 39 percent of the 213 BS recipients had accepted full-time positions, 47 percent planned to enter graduate school, and the rest had other plans. Of the 147 MS recipients, 27 percent took jobs, and 60 percent planned to continue in graduate school. Of the 123 PhDs, 61 percent accepted academic positions, and 34 percent went into industry.

One reason for this excellent record is, no doubt, Caltech's commitment to students' early and regular participation in actual research. The SURF (Summer Undergraduate Research Fellowships) program, for example, has provided funds for selected undergraduates to remain on campus during the summer and pursue student-designed research projects under the guidance of a faculty sponsor. A record number — 107 — were able to participate during the summer of 1984.

Current students are also reaping the benefits of an educational computing effort begun over the last year. The Caltech approach constitutes a sharply different path, in both scope and aims, than at many other universities using computers to help educate their students.

Students will use several different brands of computers and equally varied programming languages. The aim of this approach is to enable students to make fully informed decisions about the best hardware and software for any given task. Also students will be able to learn the basics of computer programming in courses at several different levels of sophistication, or perhaps in informal tutorials. Four sections of an introductory computational physics course, for example, offer four different computer languages. The emphasis in this course is not on learning the basics of the language but on immediate programming applications.

While the pioneers in educational computing at Caltech are the faculty in computer science, it is expected that courses in which computer programming is "flavored" with a given discipline will spread far beyond the traditional computerized disciplines.

Caltech's telecourse in physics, "The Mechanical Universe," will be extended from its original 26 programs to 60 by a $2.9 million increase in funding for the Annenberg/CPB Project.

Management education has long been available at Caltech through its Industrial Relations Center, which this year established a new program to help high-technology entrepreneurs learn how to operate in the competitive world of business. Modeled after a six-year-old program developed by alumni of the Massachusetts Institute of Technology, the Caltech/MIT Enterprise Forum is held monthly during the academic year.

At each meeting the chief executive of a growth-oriented firm presents critical aspects of their corporate business plan and demonstrates the company's primary products. A panel of business leaders then analyzes the strengths and weaknesses of the plan. The audience, which numbers about 200 for each meeting, is also offered an opportunity to question and comment on the company's plan.

Appointments

A number of administrative posts were filled during 1983-84. The new vice provost is Charles Babcock, professor of aeronautics and applied mechanics. Arden Albee, professor of geology, was appointed dean of graduate studies; and Gary Lorden, professor of mathematics, became dean of students. Fred Anson, professor of chemistry, took over chairmanship of the Division of Chemistry and Chemical Engineering; and Paul Jennings, professor of civil engineering and applied mechanics, is the new chairman of the Division of Engineering and Applied Science.

Endowed professorships are an important source of funds for the Institute and of recognition for distinguished members of the faculty. During the last year, several eminent professors were named as the first occupants of chairs. Samuel Epstein became the first William E. Leonhard Professor of Geology, Robert Leighton was named William L. Valentine Professor of Physics, William Goddard became the Charles and Mary Ferkel Professor of Chemistry and Applied Physics, and Gerry Neugebauer now holds the Howard Hughes Professorship, recently established by the Hughes Aircraft Company.

In addition, three already established chairs received new occupants: The Carl F Braun Professorship of Engineering was awarded to William Bridges, Gerald Whitham was named Charles Lee Powell Professor of Applied Mathematics, and Barry Simon became IBM Professor of Mathematics and Theoretical Physics.

Honors

Honors come to Caltech faculty in numbers that make it impractical to list all of them here. The year 1983-84 was no exception to this pattern, but one highlight was the election of five faculty members to the National Academy of Sciences. These five bring Caltech's total current membership to 56, an all-time high. This year's new members include two professors of biology, Giuseppe Attardi and Howard Berg; Marshall Cohen, professor of radio astronomy; William Goddard, the Charles and Mary Ferkel Professor of Chemistry and Applied Physics; and Edward Stone, professor of physics.

The National Academy of Engineering also elected two Caltech faculty members, Donald Coles, professor of aeronautics, and Carver Mead, the Gordon and Betty Moore Professor of Computer Science. This brings faculty membership in NAE to 28, another high point.

On a visit to the campus, George Keyworth II (left), science advisor to President Reagan and director of the Office of Science and Technology Policy, met two Institute recipients of Presidential Young Investigator Awards, David Rutledge (center) and Gregory Stephanopoulos.

Eight Caltech faculty were among 200 scientists and engineers named by the U. S. Office of Science and Technology Policy as recipients of the first Presidential Young Investigator Awards. They are geologists Robert Clayton and Joseph Kirschvink; physicists Robert McKeown, John Preskill, and Thomas Prince; chemical engineers Manfred Morari and Gregory Stephanopoulos; and electrical engineer David Rutledge.

Caltech, which does not award honorary degrees, nevertheless tries to recognize its distinguished graduates. The Institute's highest honor is the Distinguished Alumnus Award, and in May it was bestowed on four graduates at Alumni Seminar Day—Arnold Beckman (PhD '28), founder and chairman of Beckman Instruments and chairman emeritus of the Caltech Board of Trustees; Carel Otte (MS '50, PhD '54), president of the geothermal division of UNOCAL Corporation; Eberhardt Rechtin (BS '46, PhD '50), president and chief executive officer of Aerospace Corporation; and George Zweig (PhD '64), a physicist at the Los Alamos National Laboratory.

A three-member student team did its share for the honor-gathering tradition by winning the 44th annual Putnam Mathematics Competition. They vied with 1,900 other talented students from all over the United States and Canada, and senior Alan Murray was one of the top ten individual scorers. Since the first Putnam competition in 1938, Caltech teams have taken first place nine times.

The students awarded honors as well as winning them. ASCIT (Associated Students of the California Institute of Technology) bestowed Teaching Excellence Awards on James Knowles, professor of applied mechanics; Eric Herbolzheimer, assistant professor of chemical engineering; Robert McEliece, professor of electrical engineering; Richard Wilson, professor of mathematics; and P. P. Vaidyanathan, assistant professor of electrical engineering.

Gifts

Fiscal 1983-84 was a banner year for gifts to Caltech, which received a total of $27.71 million in cash and equipment from foundations, corporations, and individuals. The total was an all-time record and a 28 percent increase over last year.

Among the notable new gifts from foundations was a $1 million grant from the W. M. Keck Foundation in December 1983 to establish the Institute's Renewal Fund for Scientific Equipment. In addition, a pledge of $1 million for the equipment renewal fund was made by The James Irvine Foundation. The William and Flora Hewlett Foundation made a grant of $210,000 for the Environmental Quality Laboratory. As mentioned in the President's Message, the Beckman Foundation gift of $5 million has made possible the Arnold and Mabel Beckman Laboratory of Chemical Synthesis.

Corporate gifts of equipment represent a particularly valuable acquisition, much of it donated by Data General, Digital Equipment Corporation, Evans & Sutherland, Hewlett-Packard, IBM, Lotus, Microsoft, and Tektronix in the form of computers and software for the educational computing program. The Atlantic Richfield Foundation provided a gift of $500,000 to meet crucial equipment needs in geological and planetary sciences.

Pledges of $1 million each by Aerojet General, GTE, General Motors Corporation, and TRW make possible the implementation of a new five-year Program in Advanced Technologies, the purpose of which is to enhance research at Caltech in the areas of solid-state materials, fluid dynamics, and electronics, and to facilitate the rapid industrial development of the research results. The sponsoring companies will participate in discussions leading to the selection of research projects and may send representatives to take part in the work. One more corporation will eventually be included in the program.

Many individuals have also been extremely generous, and a group—the Torchbearers—has been organized to recognize them for either their direct personal gifts or gifts made by will.

More than a thousand volunteers under the national chairmanship of Lee Carleton (BS '33) made sure that the Alumni Fund continued to do well, with 50 percent of the alumni (7,249) contributing more than $1.65 million. One reason for the Alumni Fund's success has been the challenge grant provided by the Irvine Foundation. The grant, which is tied to new and increased support from alumni, now totals $239,011.

Support Groups

The Caltech Alumni Association serves the Institute and its 15,000 graduates. Carole L. Hamilton (PhD '63) was elected president of the association in June, succeeding Arne Kalm (BS '56, MS '57). The association currently numbers 6,672 members.

Programs were many and varied both off and on campus. In San Francisco, Seminar Day in the fall of 1983 launched the chapter's program for the year. In May 1984, Seminar Day on the campus attracted 1,200 alumni and friends. Three admissions receptions for high school students and their parents were held—in Washington, D. C., San Francisco, and Los Angeles. A new alumni chapter took form in Phoenix. Forty members of the class of 1934 gathered in June to commemorate their 50th reunion, and 11 more classes held reunions as well. The popular travel program continued with trips to Hawaii, Mount St. Helens, and Yellowstone National Park.

The Associates, under the direction of President Berneice Anglea, contributed crucial unrestricted funds to the Institute. These Caltech supporters, who numbered 100 at their inception in 1926, now count 1,057 members and have active groups in San Francisco, Santa Barbara, Newport Beach, and San Diego. Richard L. Hayman is the 1985 president.

Research Highlights

Biology

The body's immune system defends itself against infection by generating specialized proteins, called antibodies, which recognize and attack molecules present on foreign cells and substances. Antibodies have long been valuable tools of biologists and medical researchers because they provide a means of localizing and characterizing many different molecules of interest. The effectiveness of this approach has dramatically increased in recent years because of the development of a technique for making "monoclonal" antibodies, which are more homogeneous and are produced in much greater quantities than with standard techniques for generating antibodies.

Caltech has recently established a monoclonal antibody facility that will serve as a major communal resource for a number of investigators on campus who use these molecular probes in their research. This facility will be of particular importance for a group of neuroscientists in the Division of Biology who study the development and specificity of function of the brain. Each of the tens of billions of nerve cells within the brain is unique in terms of its size, shape, location, and pattern of connections with other nerve cells. This exquisite specificity is essential for proper brain function.

Three decades ago Roger Sperry, a Caltech Nobel laureate, hypothesized that the precision of neural connections resulted from highly specific chemical signatures that are associated with each cell in the brain and that allow cells to recognize their appropriate targets during development.

Because these chemical tags are thought to be present only in extremely small amounts, it has proved very difficult to determine the actual molecular basis of Sperry's "chemospecificity" theory. By taking advantage of the monoclonal antibody facility, Caltech scientists anticipate that they will be able to identify and characterize many brain-specific molecules in regions as diverse as the eye of the fly, the cells of the autonomic (visceral) nervous system, the learning centers of the rat, and the visual cortex of the monkey.

Chemistry and Chemical Engineering

Laser chemistry is both a tool and a goal with two basic problems: how to crack molecules selectively by laser energy and what happens when molecules are subjected to heavy doses of laser radiation. The solution of these problems requires the work of both experimentalists and theoreticians, each trying to determine the dynamics of the vibrational energy of a molecule.

Molecules are made of atoms held together by chemical bonds. When these molecules take on energy, by heating for example, the bonds vibrate according to well-known rules of physical chemistry. When the bonds break, chemical reaction may proceed.

The advantage of the laser is that it can, in principle, heat certain bonds in the molecule and leave all others cold, enabling chemists to direct a chemical reaction by causing certain bonds to break. To find out how to go about such selective heating, the chemists must understand how the bonds "communicate" with each other and how fast the heat (or energy) spreads among the bonds—and why certain frequencies do the job while others cannot.

Some years ago, theoreticians described the reactivity of a uniformly heated large molecule in which equilibrium was reached among all vibrations in accordance with the laws of statistical thermodynamics. Now laser chemists hope to deviate from the limits of this theory—or determine its accuracy—and achieve a highly non-statistical bond cracking. One way to do this would be to slow down the communication among certain vibrations; another would be to break the bond so fast that there would be no time for communication among the different vibration bonds of the molecule.

Experimentalists at Caltech are working to apply the laser technique to the study of the behavior of these energetic molecules, trying to accomplish experiments on much faster time scales—in the picoseconds (10^{-12}) range if possible. They want to understand the distribution of the selectively deposited energy and whether the observed spectrum in the high-energy region reflects the locality of energy in bonds.

These are challenging problems for both theoreticians and experimentalists, and Caltech scientists have worked jointly to understand the nature of the energy communication between bonds. While solving the problems would give them great intellectual satisfaction, such collaborative effort might eventually also be useful in various areas of applied chemistry.

Engineering and Applied Science

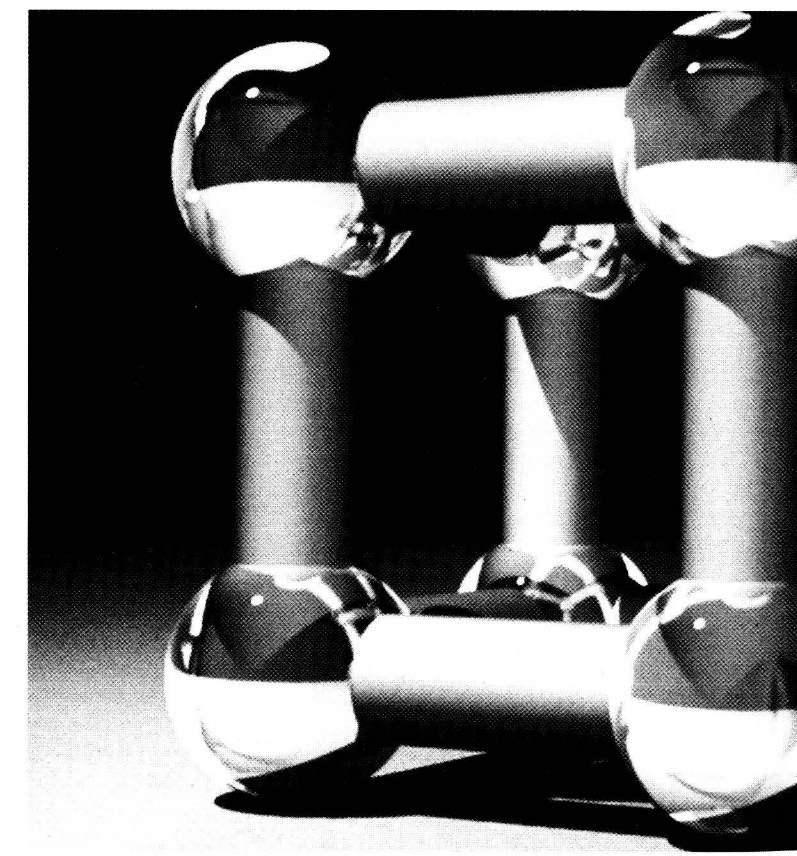
Computer graphics is much more than just making pretty pictures. Activity in the field began at Caltech only a few years ago, but already the computer graphics group is establishing a reputation for mathematical sophistication—creating a unified mathematical formalism for representing the shape and the behavior of objects, connecting computer graphics principles to the basic equations of electromagnetism that govern the behavior of light, and doing work in surface modeling and texture mapping.

To show that his mathematics for representing shapes and behavior worked, for example, one of the researchers made computer graphics movies of hypothetical sperm cells swimming and then verified that the representation matched real sperm swimming under a microscope. This work led to a general interest in shapes, and it is now possible to generate a whole family of round, square, and solid shapes called superquadrics with "just a few sines, cosines, and exponents," and put a hole through the middle by adding a constant to one of the cosine terms.

Fractals are mathematical shapes generated out of a process of constrained randomness, and they are used at Caltech for modeling a wide variety of natural phenomena, such as trees, mountains, and clouds. Work is also being done on developing mathematical methods for the simulation of hair, fire, fabric, and splashing water, as well as the shapes and appearance of plants and animals. An unsolved problem is how to present anisotropic reflection, that is, reflection from surfaces such as cloth, hair, or fur.

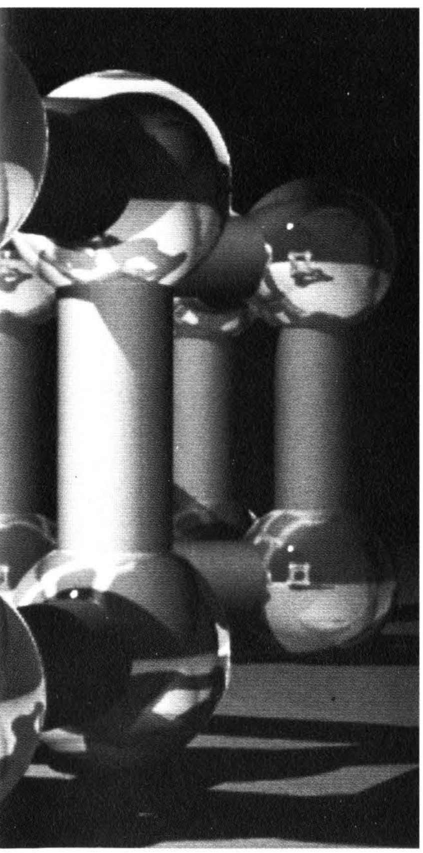
Realism, which is one of the major goals of the Caltech group, has evolved in stages over the history of computer graphics, beginning with defining and making pictures of surfaces in the first place. New methods had to be invented to simulate specular reflection. Using highlights and shading has made it possible to picture realistic-looking objects like goblets and teapots, although at first they all looked as if they were made of plastic.

A new model, incorporating Fresnel's laws of reflection from conductors, renders different surface properties—different kinds of metals and so on. Eventually, a sophisticated, time-consuming set of algorithms called ray tracing incorporated refraction, multiple reflections, and shadows. Ray tracing basically follows the path of each photon as it bounces off surfaces, and recently startling advances have been made by applying Monte Carlo techniques to graphics. "In fact," said a graduate student, "computer graphics is just applied electricity and magnetism."



This representation of cylinders and glass spheres created by computer scientist Alan Barr shows how accurately computer graphics can represent realistic surface properties—in this case those of refractive objects.

It's more than that, too. Computer graphics also offers a new medium to artists and industry. Members of the Caltech group have worked with students from Pasadena's Art Center College of Design, generally writing the software to implement the students' artistic objectives. Some of this work has led to computer-generated films and to awards for computer animation. And a number of industrial firms have shown a strong interest in their work on specialized hardware to perform large-scale computation in graphics, which may be particularly suited for VLSI (Very Large Scale Integration) technology.



Geological and Planetary Sciences

Because glaciers play a large role in altering the earth and modifying its climate, geologists find them an important subject for research. At Caltech, current glacier studies are focused on the tectonic aspects of glacial flow, and for the last 12 years this has led Institute geologists to the Alaska coast north of Juneau to monitor the movements of the surge-type Variegated Glacier.

During most of its life, this kind of glacier flows along at about the same majestic pace as other glaciers—a few inches a day. But at regular intervals it grinds forward as much as 100 times faster than normal, a phenomenon first observed at Variegated Glacier in 1906. This glacier's surge recurrence interval is about 20 years, and a surge was expected about 1984.

It actually began in 1982, when the upper half of the glacier reached a speed of 30 feet a day. In 1983, the surge motion propagated down the lower half, reaching flow speeds of as much as 200 feet a day. By drilling boreholes to the bed of this glacier, the scientists found that more than 95 percent of the motion during surge came from the glacier sliding over its bed.

The key to the rapid sliding, they think, is the behavior of water at the glacier bed. The water (from surface melting) normally flows along the bed in one or two large ice tunnels. But during surge the tunnels appear to be destroyed, so the water has to find its way along the bed through a network of many small cavities and narrow passageways. This makes water pressure rise sufficiently to lift the ice off its bed, reducing frictional drag and causing basal sliding to increase greatly.

Every five or six days the 1982-83 surging motion of Variegated Glacier abruptly slowed down, and a flood of water issued from the glacier's snout. The researchers reasoned that in these events the cavities close, releasing their water to generate a flood and allowing the ice to recontact its bed, which causes the sliding to slow down. The abrupt termination of the surge on July 4-5, 1983, was accompanied by a spectacular flood.

On the basis of their observations, the research team thinks that they now understand in a general way how a surge works, but how and why the necessary condition develops remains elusive. It needs to be understood, however, for practical as well as scientific reasons. Of the hundred-odd surge-type glaciers in Alaska and the Yukon, three are poised along the Alaskan oil pipeline. Understanding the surge mechanism may ultimately make it possible to predict when surges will occur and how far they will go.

The Humanities and Social Sciences

Application of the methods of economics, statistics, and data processing to the study of history is bringing a new dimension to scholars' understanding of mankind's past. In Caltech's Division of the Humanities and Social Sciences a number of faculty members are focusing on studies of the statistical characteristics of populations around the world and over long periods of time. Their hope is that mathematical analysis of these data will lead to better insights into the causes and effects of social movements.

A recently completed project, for example, involved looking at a small region in France from 1500 to 1789. It was a time of religious reform and turmoil. The research problem was to find out who supported or opposed the various reform movements, and how the religious ferment affected society.

Study of criminal court records and of individuals' wills yielded interesting data. Statistical techniques adopted from econometrics made it possible to unravel the separate effects of wealth, religious fervor, and other factors that weighed upon men and women when they drew up their wills. The statistical analysis of wills and of criminal court records revealed, for example, that reforms within the church drew strong and somewhat unexpected support from rural women and from literate urban men, but they provoked resistance from illiterate rural males. These results are important for social historians, and they help explain later political and religious divisions during the French Revolution.

Research in the demographic behavior of diverse historical populations is also being undertaken. Records from a set of villages in northeast China that detail births, deaths, marriages, and migrations of every individual and that were updated every three years between 1750 and 1910 are the basis of one of the first demographic studies of a historical Chinese population. Researchers will examine birth rates, for example, in relation to family planning or mortality. Fluctuations in the price of five kinds of grain and information on the amount of rainfall every ten days, moreover, provide an opportunity to reconstruct demographic behavior in relation to economic change over the 160-year period. The effects of weather, harvests, and grain prices on family planning, household structure, and marriage rates are of particular interest for future analysis.

One arm of Caltech's L-shaped prototype gravity wave detector stretches 40 meters away from graduate student Mark Hereld to the left, and the same distance but out of the photo on the right from Professor of Physics Ronald Drever. A pair of detectors with 5-kilometer-long arms is being planned.

A similar study of an American population in the late 19th century is also under way. Researchers, using church records and the U.S manuscript census, are reconstructing the fertility behavior of a rural Wisconsin population as it underwent a process of fertility decline. Out-migration, marriage behavior, and mortality as the region developed will also be examined.

These are only a few examples of research projects within the division in which the mathematical methods of social science are applied to subjects of historical interest. They represent a very different approach to the study of the past but may also offer an increased depth of understanding of the dynamics of human institutions.

Physics, Mathematics and Astronomy

The so-called dense regions of the Milky Way and companion galaxies have been identified by astronomers as especially fertile sites for observing the life cycle of the stars. These regions are populated by aging or massive stars returning a large proportion of their mass to the interstellar medium in the form of dark molecular clouds and immense spirals of matter dust, which then serve as the raw material for creating new stars. An innovative way to explore this activity is to analyze the clouds' molecular composition by identifying the distinctive emission frequencies associated with molecular rotations.

To study these phenomena, which cannot be accurately detected by optical or conventional radio telescopes, a group of Caltech astronomers and physicists recently completed design and construction of the millimeter-wave interferometer now in use at the Institute's Owens Valley Radio Observatory. Operating at wavelengths longer than visible and infrared light and shorter than radio waves, the interferometer can penetrate to the heart of dense galactic and extragalactic clouds to obtain high angular resolution images of the major star formation processes taking place there.

Considered the finest instrumentation of its kind, the Owens Valley interferometer consists of three electronically joined 10.4-meter radio telescope antennas whose configuration is realigned several times over a pre-designated period until an aperture resembling a single, very large telescope's mirror has been synthesized, and a specific area of sky mapped in its entirety.

Interferometric studies of emission lines emanating from the Orion nebula and other intragalactic neighbors a few thousand light-years away are providing unprecedented information about the density, velocity, and temperature of dense-region material, as well as new insights into stellar evolution and morphology and the physics of mass-loss in aging stars. The exciting data from a comprehensive study of a single cosmic region has shown over 500 emission lines representing 28 different molecules. Over the next year, the interferometry group also plans to begin a major study of the center of the Milky Way, where violent and enigmatic cosmic activity may signify the presence of a black hole or some equally singular phenomenon.

A recent, major achievement of the interferometry group has been the discovery that certain extragalactic nuclei that look like fuzzy orbs in optical telescopes have instead a totally different configuration. Carbon monoxide mapping of the nearby galaxy IC 342 has disclosed an intriguing and unexpected bar of gas running through its center, suggesting both the presence of an as yet undetermined and novel gravitational potential, and the existence of similar bars in other apparently spherical extragalactic regions.

Environmental Quality Laboratory

Ozone is one of the well-known components of smog that may act as a respiratory irritant. Now scientists at the Environmental Quality Laboratory are finding that ozone is probably also a threat to the preservation of works of art. Early tests of watercolor pigments and wood block prints by exposure to ozone indicate that many of the organic pigments used by artists are susceptible to fading in the presence of ozone at the concentrations found in the Los Angeles atmosphere. Moreover, while museums and galleries—and artists—are very sensitive to whether colors in paintings are "lightfast," few are aware of this lack of ozone-fastness, and so relatively few steps have been taken to protect artwork through control of indoor ozone levels.

On the basis of their early findings, EQL researchers have started a three-year study of the chemistry of the fading of artists' pigments. This understanding of the basic chemistry of the situation will be used to guide the formulation and selection of air-pollutant-resistant pigments. They will also measure the ozone concentration in environments in which art is exhibited, and will try to determine what steps can be taken to protect existing works of art from ozone damage.

With more awareness of the problem and with scientifically based knowledge of what to do about it, it may be possible for existing artworks to continue to show their true colors—and tomorrow's masterpieces may never be in danger.

Jet Propulsion Laboratory

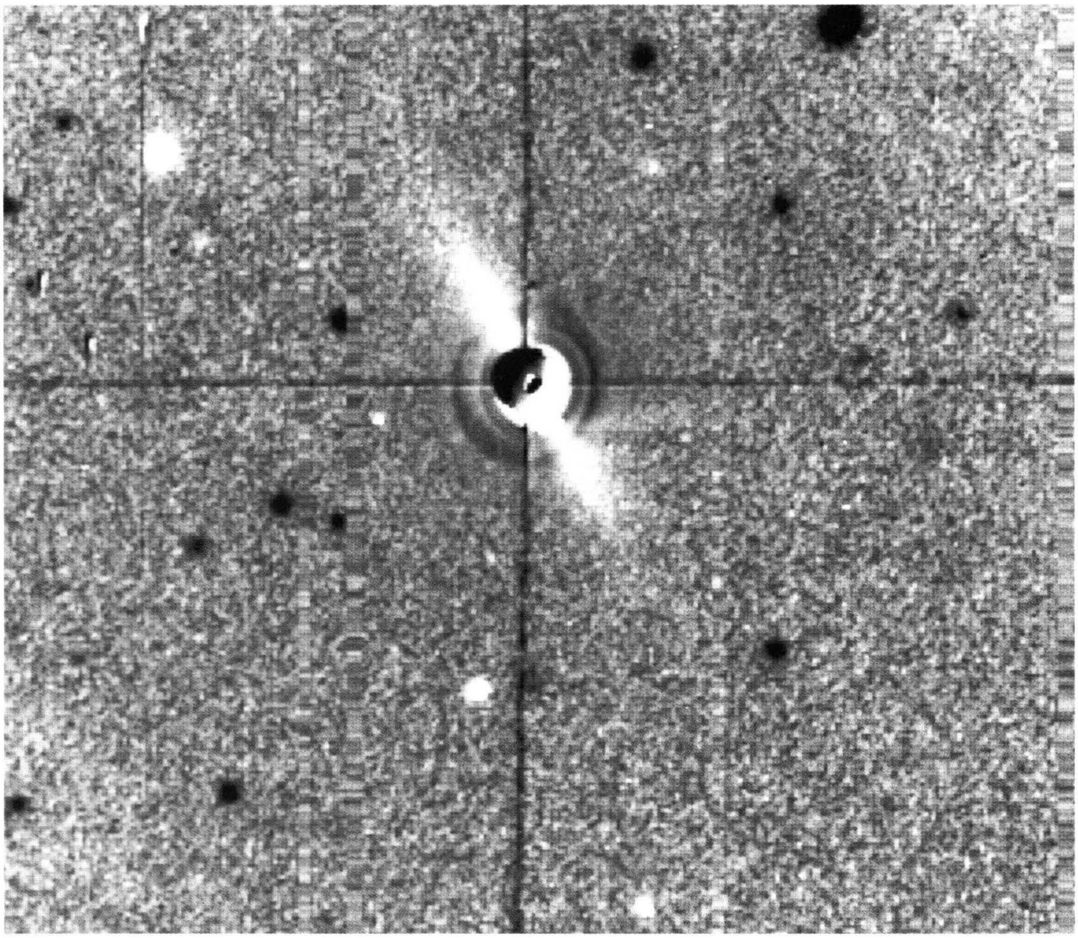
As NASA's lead center for exploration of the solar system, JPL continued preparations for a number of major launches and encounters scheduled over the next few years.

The Galileo orbiter and probe were subjected to critical system tests in preparation for a May 1986 launch to Jupiter, with arrival at the giant planet occurring in 1988. They will extend the study of the Jovian system begun by the earlier Voyager 1 and 2 spacecraft. Voyager 2 continued on its journey toward Uranus while preparations were under way for the first-ever flyby of that planet to occur in January of 1986. Other missions in various stages of planning and development will explore the Sun, Venus, Mars, comets, and asteroids.

One highlight in space science during the past year was the flight of the second Shuttle Imaging Radar (SIR-B). SIR-B, one of several JPL experiments designed for NASA's space shuttles, returned detailed radar images of selected regions of the Earth's surface, continuing to demonstrate the enormous potential of this type of remote sensing. JPL research scientist Taylor Wang continued training and preparations to fly on a 1985 shuttle flight with his drop dynamics basic research experiment.

Data processing continued in the wake of 1983's successful Infrared Astronomical Satellite (IRAS), as the science team completed its basic catalog of the night sky. IRAS star studies led two astronomers to their finding of the first visual evidence of a possible solar system around another star, Beta Pictoris.

Beta Pictoris, a star 50 light years from earth, has a circumstellar disk of material extending 40 billion miles outward. The disk is probably made up of particles of ices, carbonaceous organic substances, and silicates, the materials from which our own solar system formed, and thus may well be a solar system in formation.



The Keck Observatory

Progress in science has often come as a result of development of new instrumentation. The proposed grant of $70 million to Caltech from the W. M. Keck Foundation of Los Angeles for construction of the world's largest optical telescope offers a giant step forward in astronomy. It will be located atop the extinct Mauna Kea volcano in Hawaii.

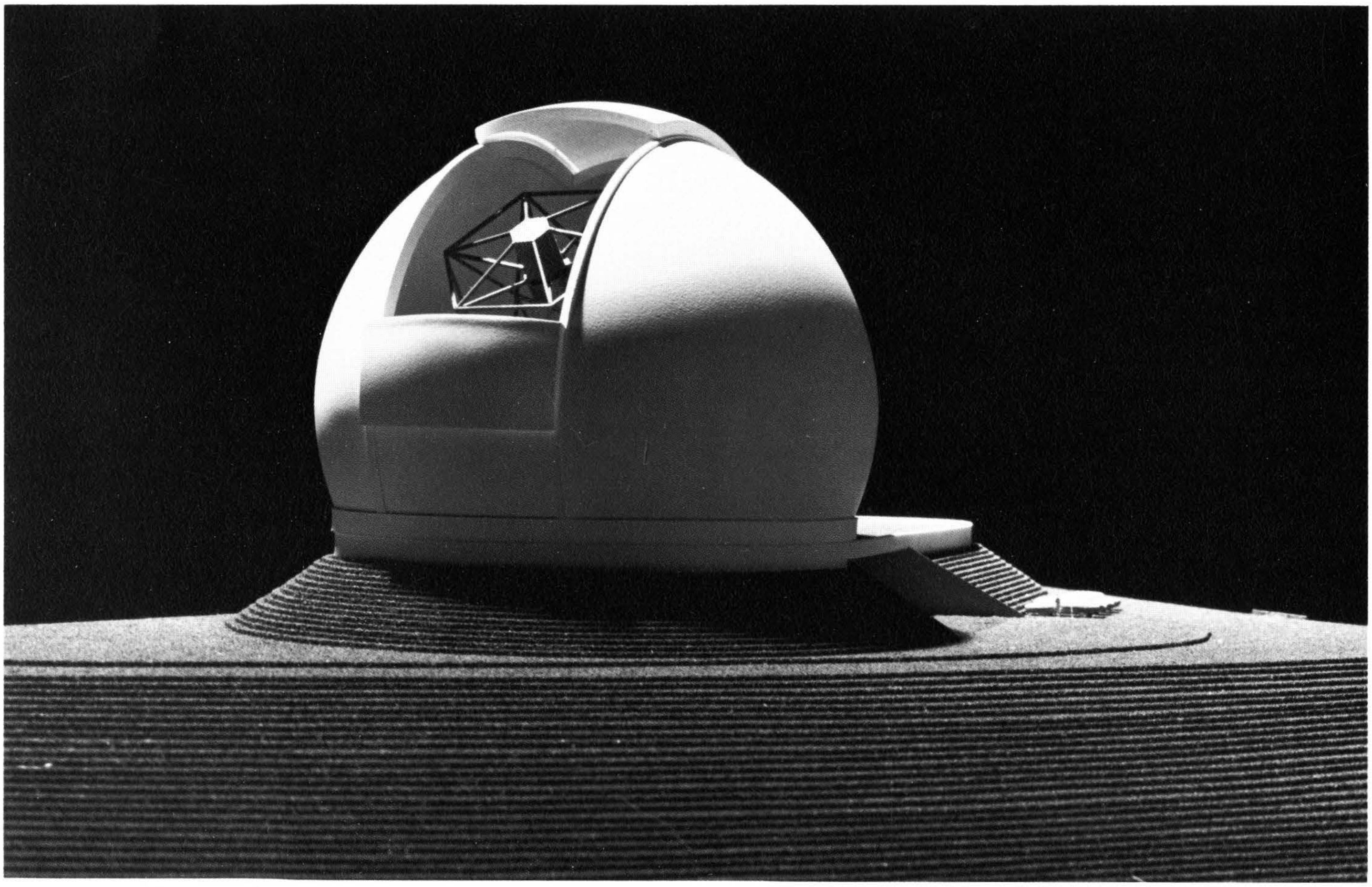
The Keck 10-meter telescope will complement the work of current telescopes—optical, radio, and space-borne—chiefly because of its exceptional light-gathering power. It will be able to "see" a volume of astronomical space both farther out into the universe and further back into time than has previously been possible.

Such a remarkable new scientific instrument requires equally remarkable new technology for its implementation. A segmented-mirror design developed at the University of California's Lawrence Berkeley Laboratory will be used. The design features a primary mirror that is a mosaic of 36 hexagonal mirrors, each 1.8 meters wide and 7.5 centimeters thick. These mirrors will be effectively combined into a single mirror by a computer-controlled aiming system capable of making adjustments on the order of one-thousandth the diameter of a human hair about 300 times each second.

The segmented design of the mirrors will allow a much lighter support structure than was possible for previous large telescopes. Thus the 158 tons of the Keck Telescope will be about one-third of the weight of the 5-meter Hale Telescope at Palomar Observatory. Also, the new design reduces the focal length of the instrument to about 57 feet, making it possible to reduce the size of the required dome to the dimensions of the one housing the Hale Telescope—about 137 feet.

In addition to the telescope, the Keck Observatory will include space for computer rooms, electronic and mechanical shops, mechanical equipment, mirror aluminizing facilities, a control room, storage, staff facilities, and a visitors' gallery. Total cost of the observatory will be about $85 million. Caltech and the University of California plan to direct the construction and to operate the observatory jointly. Routine observations are expected to begin in 1992.

A model of the W. M. Keck Observatory with a glimpse of the 10-meter Keck Telescope showing through the open dome. Construction of the world's largest optical telescope is slated to begin in Hawaii within the next year.



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, 1984, 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 $460.6 million to $493.3 million, consisting primarily of an increase of $21.6 million in campus equipment, buildings, and land and an increase in investments of $8.3 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. Significant increases in revenue were realized in gifts and grants from private sources of $4.9 million and in investment income of $2.9 million.

The *Statement of Operating Expenditures* provides the detail of current fund expenditures for educational and related purposes. Total expenditures for fiscal year 1984 for the campus increased $9.3 million or 8.6 percent over fiscal year 1983. Expenditures for direct costs of sponsored research at the Jet Propulsion Laboratory increased $80.0 million or 18.8 percent.

Current Funds are those funds available for operating purposes. They are classified as unrestricted—available for any purpose; or restricted—to be used only 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

	1980	1981	1982	1983	1984
Current funds expenditures (in thousands)					
Instruction and research (including libraries)	$56,920	$62,259	$64,938	$74,535	$80,516
Scholarships and fellowships	3,232	3,540	4,494	5,095	6,198
Institutional and student support	9,608	11,399	12,836	14,314	15,692
Plant operation, maintenance, and utilities	6,571	6,587	8,116	9,586	10,013
Total operating expenses	76,331	83,785	90,384	103,530	112,419
Auxiliary enterprises	3,417	3,870	4,219	4,435	4,796
Total	79,748	87,655	94,603	107,965	117,215
Capital expenditures, campus (in thousands)	14,078	19,967	10,526	12,459	21,679
Jet Propulsion Laboratory, direct expenditures (in millions)	375.4	396.6	384.8	425.2	505.2
Total gifts and nongovernment grants (in thousands)	16,958	22,271	25,652	24,747	29,697
Endowment and similar funds at market value (in millions)	197.4	184.3	208.3	248.3	247.0
Investment income (in millions)	16.3	19.8	20.4	19.6	22.5
Student enrollment (first term)—Undergraduate	817	844	866	874	829
Student enrollment (first term)—Graduate	892	865	888	936	936

Summary of Changes in Fund Balances

Year Ended September 30, 1984

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.	$36,117
Gifts and Nongovernment Grants. Includes gifts and grants from private sources for education and research.	$29,697
Indirect Costs and Management Allowance. Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	$26,486
Investment Income. Endowment income and investment income of other funds, including earnings from short term investments.	$22,533
Plant Acquisitions. Additions to campus plant for land, buildings, and equipment.	$20,961
Tuition and Fees. Includes tuition and fees assessed students.	$14,999
Realized Gains. Net realized gains on investments sold.	$7,226
Auxiliary Enterprises. Revenues from sales by food services, student housing, and bookstore.	$4,952
Other. Income from sales and services, and other miscellaneous revenue.	$2,263

Total Additions

(Excluding Reimbursement of Direct Costs at the Jet Propulsion Laboratory) $165,234

Deductions

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

Instruction. Expenditures for activities that are part of the instructional program, including departmental research.
$41,350

Research. Activities specifically organized to produce research outcomes supported by federal and private sponsors.
$39,166

Institutional and Student Support. Includes Business and Financial Affairs, Student Services, Institute Relations, and general administration.
$15,692

Plant Fund. Includes plant fund expenditures for buildings, equipment, renewals, payments on interfund advances for plant purposes, as well as retirement of plant assets.
$13,301

Plant Operations. Represents utilities and other expenditures for the operation and maintenance of the campus grounds and facilities.
$10,013

Scholarships and Fellowships. Awards made to students enrolled in formal course work with no requirement that they perform services or repay the awards.
$6,198

Auxiliary Enterprises. Expenditures, including maintenance, of auxiliary enterprises.
$4,796

Other. Includes payments to life beneficiaries with life income and annuity agreements and miscellaneous other charges.
$2,041

Total Deductions

(Excluding Direct Costs at the Jet Propulsion Laboratory) $132,557

Increase in Fund Balances $ 32,677

Total $165,234

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.

Irrespective of cyclical fluctuations inherent in security markets, the Institute's investment objectives have been successfully attained, as may be judged from the 5- and 10-year data shown below (top table).

Measured in annual percentages, the gain in the earning power of the endowment during the same 5- and 10-year periods is also shown below (lower table). This table shows the annual average rate of growth of principal and income. It should be noted that income earned in excess of a percentage approved annually by the Board of Trustees is retained to help achieve Caltech's investment objectives.

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.

	($ millions)		
	FY 1984	FY 1979	FY 1974
Endowment Market Value	$247.0	$173.9	$130.9
Endowment Income (earned)	17.4	10.6	7.6

	Principal	Income
Compounded Annual Percentage Increases:		
Last 5 years	7.3%	10.4%
Last 10 years	6.6	8.6

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, 1984, the market value of the life income and annuity funds was $27.8 million. Principal transferred to endowment from matured agreements during the year totaled $1.1 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, and pledges.

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

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

Relandscaping the site of old Throop Hall was made possible by a gift from Mrs. Dan Throop Smith, and local quarry owners also donated 60 interesting rocks from the San Gabriel Mountains. Placement of the rocks was supervised by Leon Silver, the Keck Foundation Professor of Resource Geology.

	September 30, 1983
	Total All Funds
Assets	
Cash (demand deposits)	$ 1,182
Accounts receivable:	
United States government (note B)	51,934
Other	2,055
Student accounts and notes receivable	7,379
Investments (notes A and C)	274,132
Interfund advances	
Prepaid expenses and other assets	2,671
Campus properties (note A):	
Equipment	86,062
Buildings	95,188
Land	10,708
	$531,311
Liabilities and Fund Balances	
Accounts payable and accrued expenses (note B)	$ 57,994
Deferred student revenue	4,000
Funds held in custody for others	7,104
Annuities payable (note A)	1,589
Fund balances	460,624
	$531,311
Fund balances comprise (Exhibit 2):	
United States government grants refundable	$ 3,103
Institute funds—	
Unrestricted	3,999
Discretionary endowment:	
Unrestricted	47,317
Restricted	29,510
Endowment principal	141,738
Other restricted funds	49,077
Invested in plant	185,880
	$460,624

See accompanying notes to financial statements

Balance Sheet
(in thousands)

Exhibit 1

September 30, 1984

Total All Funds	Current Funds	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
$ 941	$ 553	$ 23	$ 5	$ 360	
65,341	65,341				
3,603	3,603				
8,746	3,779	4,967			
282,407	22,142	883	226,801	25,954	$ 6,627
	2,995		3,236		(6,231)
3,078	3,078				
98,282					98,282
102,990					102,990
12,365					12,365
$577,753	$101,491	$5,873	$230,042	$26,314	$214,033
$ 72,850	$ 70,005			$ 345	$ 2,500
4,884	4,884				
5,748	4,509		$ 1,239		
970				970	
493,301	22,093	$5,873	228,803	24,999	211,533
$577,753	$101,491	$5,873	$230,042	$26,314	$214,033
$ 3,238		$3,238			
4,053	$ 701				$ 3,352
48,470			$ 48,470		
27,242			27,242		
153,091			153,091		
52,301	21,392	2,635		$24,999	3,275
204,906					204,906
$493,301	$ 22,093	$5,873	$228,803	$24,999	$211,533

	Year Ended September 30, 1983
	Total All Funds
Fund balance at beginning of year (Exhibit 1)	$ 411,261
Revenues and other additions (notes A, D and G):	
Student tuition and fees	13,189
Investment income	19,634
Net gain on disposal of investments—	
Unrestricted	19,856
Restricted	14,971
Gifts and nongovernment grants	24,747
United States government grants and contracts—	
Reimbursement of direct costs	35,200
Recovery of indirect costs and management allowance	23,293
Auxiliary enterprises revenues	4,589
United States government advances	168
Plant acquisitions, etc. (including $9,307 included in campus operating expenditures and $11,654 included in plant acquisitions, payments on interfund advances and renewals)	14,438
Adjustment of actuarial liability for annuities payable (note A)	(178)
Other	1,120
Total revenues and other additions	171,027
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(107,965)
Plant acquisitions, payments on interfund advances and renewals	(9,696)
Retirement and disposal of campus properties	(2,055)
Interest on advances for plant purposes	(173)
Payment to life beneficiaries	(1,634)
Other	(141)
Total expenditures and other deductions	(121,664)
Transfers among funds:	
Gifts allocated	
Discretionary endowment transfers to (from) current funds	
Allocations for plant purposes	
Terminated trust and annuity agreements	
Other	
Total transfers	
Increase (decrease) for the year	49,363
Fund balance at end of year (Exhibit 1)	$ 460,624

See accompanying notes to financial statements

Statement of Changes in Fund Balances
(in thousands)

Exhibit 2

Year Ended September 30, 1984

Total All Funds	Current Funds Unrestricted	Current Funds Restricted	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
$ 460,624	$ 881	$ 20,175	$5,519	$218,565	$23,791	$191,693
14,999	14,999					
22,533	6,899	13,180	126		1,844	484
2,437				2,437		
4,789				4,087	702	
29,697	4,231	16,812	74	5,207	831	2,542
36,117		35,594				523
26,486	23,756					2,730
4,952	4,952					
184			184			
20,961						20,961
640					640	
1,439	447	23	79		109	781
165,234	55,284	65,609	463	11,731	4,126	28,021
(117,215)	(55,495)	(61,720)				
(10,918)						(10,918)
(2,150)						(2,150)
(233)						(233)
(1,844)					(1,844)	
(197)		(82)	(115)			
(132,557)	(55,495)	(61,802)	(115)		(1,844)	(13,301)
	(463)	(1,062)		1,525		
	1,252	(769)		(483)		
	(491)	(832)		(3,797)		5,120
				1,074	(1,074)	
	(267)	73	6	188		
	31	(2,590)	6	(1,493)	(1,074)	5,120
32,677	(180)	1,217	354	10,238	1,208	19,840
$ 493,301	$ 701	$ 21,392	$5,873	$228,803	$24,999	$211,533

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

Exhibit 3

	Year Ended September 30, 1983	1984
Educational and general:		
Instruction, including departmental research	$ 37,751	$ 41,350
Organized research	36,784	39,166
Scholarships and fellowships	5,095	6,198
Institutional and student support	14,314	15,692
Plant operation, maintenance, and utilities	9,586	10,013
Total educational and general	103,530	112,419
Auxiliary enterprises	4,435	4,796
Total campus expenditures	$107,965	$117,215
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government)	$425,222	$505,245

See accompanying notes to financial statements

California Institute of Technology Notes to Financial Statements

September 30, 1984

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 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, 1984 and 1983, 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, 1983	September 30, 1984
Marketable securities—		
Debt securities (approximate market value of \$82,483,000 in 1983 and \$78,114,000 in 1984)	\$ 84,799,000	\$ 81,665,000
Equity securities (approximate market value of \$154,820,000 in 1983 and \$152,418,000 in 1984)	124,274,000	132,906,000
	209,073,000	214,571,000
Short-term commercial obligations	35,812,000	36,488,000
Settlements in process—		
Receivables for securities sold	10,000	2,529,000
Payables for securities purchased	(2,306,000)	(2,251,000)
Real estate, less amortization and accumulated depreciation of \$2,753,000 in 1983 and \$2,786,000 in 1984	22,030,000	21,312,000
Mortgages, notes and other securities	9,513,000	9,758,000
	\$274,132,000	\$282,407,000

Investments shown above include the investment pool as follows:

	September 30, 1983	September 30, 1984
Investment pool assets at year end-		
At carrying value	\$185,942,000	\$198,108,000
At approximate market value	\$208,822,000	\$209,070,000
Pool share value at market	\$ 13.04	\$ 12.42
Annualized income earned per pool share	\$ .73	\$ .86

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 $11,000,000 and $12,000,000 at September 30, 1984 and 1983, respectively. The income derived from these funds amounted to $711,000 and $692,000 for the years ended September 30, 1984 and 1983, 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 $3,340,000 and $3,770,000 at September 30, 1984 and 1983, 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, 1984 and 1983, totaled $3,388,000 and $3,479,000, respectively for the campus; $11,228,000 and $11,876,000, 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, 1983) is presented below (in thousands of dollars).

	September 30, 1983	
	Campus	JPL
Actuarial present value of accumulated plan benefits:		
Vested	$18,310	$82,220
Non-Vested	1,574	6,611
	$19,884	$88,831
Plan assets	$20,943	$97,475

In determining the actuarial present value of accumulated plan benefits as of September 30, 1983, 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 $6,276,000 and $3,363,000 at September 30, 1984 and 1983, 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, 1984, the Institute had pledges on hand (principally for restricted purposes) totaling approximately $26,900,000, of which $10,300,000 is expected to be collected in 1985. It is not practicable to estimate the net realizable value of such pledges.

Price Waterhouse

West Los Angeles, California
December 21, 1984

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, 1984, 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, 1983, financial statements which are included in summary form for comparative purposes.

Price Waterhouse

Institute Administrative Council

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President

Rochus E. Vogt
Vice President and Provost

Lew Allen Jr.
Vice President and
Director, Jet Propulsion Laboratory

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