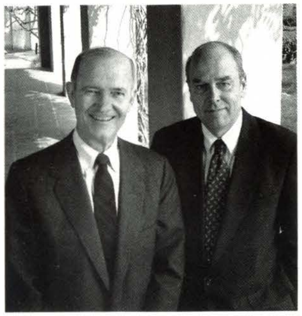
CALIFORNIA INSTITUTE OF TECHNOLOGY

Annual Report

1988 | 89

On the cover:

The Beckman Institute, dedicated on October 26, 1989, is now the largest building on the Caltech campus. An extraordinary gift from Arnold and Mabel Beckman made possible the creation of the Beckman Institute, whose mission is to foster the invention of methods, materials, and instrumentation that will open new avenues of scientific investigation in biology, chemistry, and the related sciences.



It has been a year of looking back and looking forward. With a unique perspective offered by time—Caltech will be 100 years old next year—we've begun a process of reflecting on our past as we prepare for our future.

This last year, members of the Caltech community were asked to participate in an evaluation of the aims and needs of the Institute. Their recommendations, based on a careful review of the Institute's historical practices of conducting education and research, are highlighted in this annual report.

Many ideas for improving Caltech have been suggested. But perhaps as important as these is the one idea—stated repeatedly—that we must find ways to maintain our unique institutional identity, in particular, our...

TRADITION OF EDUCATION... instruction in the fundamental sciences, engineering, and the humanities and social sciences, taught by a faculty of exceptional talent; a student body composed of the most talented and qualified students; and facilities that help provide an ideal learning environment.

FOCUS ON RESEARCH... investigations at the frontier of selected fields in engineering and the fundamental sciences; a faculty whose members distinguish themselves and the Institute through the excellence of their research; and the identification of emerging fields of research and education.

BASE OF SUPPORT... a partnership between the private and public sectors; an organizational base that is flexible enough to respond quickly to the needs of the Institute; and support organizations that maintain critical bonds with the larger community of Caltech friends.

All of us here—Trustees, staff, faculty, students, alumni, and friends—are joining in this important process of reflection and preparation. If early indicators prove true, our second century will not include radical changes for the Institute. Rather, we will find innovative ways to maintain and build on the traditional values of Caltech, even as we face changing times.

Thomas E. Everhart

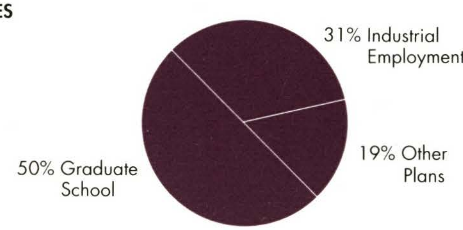
Thomas E. Everhart
President

Ruben F. Mettler

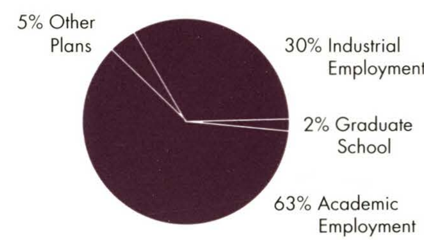
Ruben F. Mettler
Chairman, Board of Trustees

OUR TRADITION OF EDUCATION

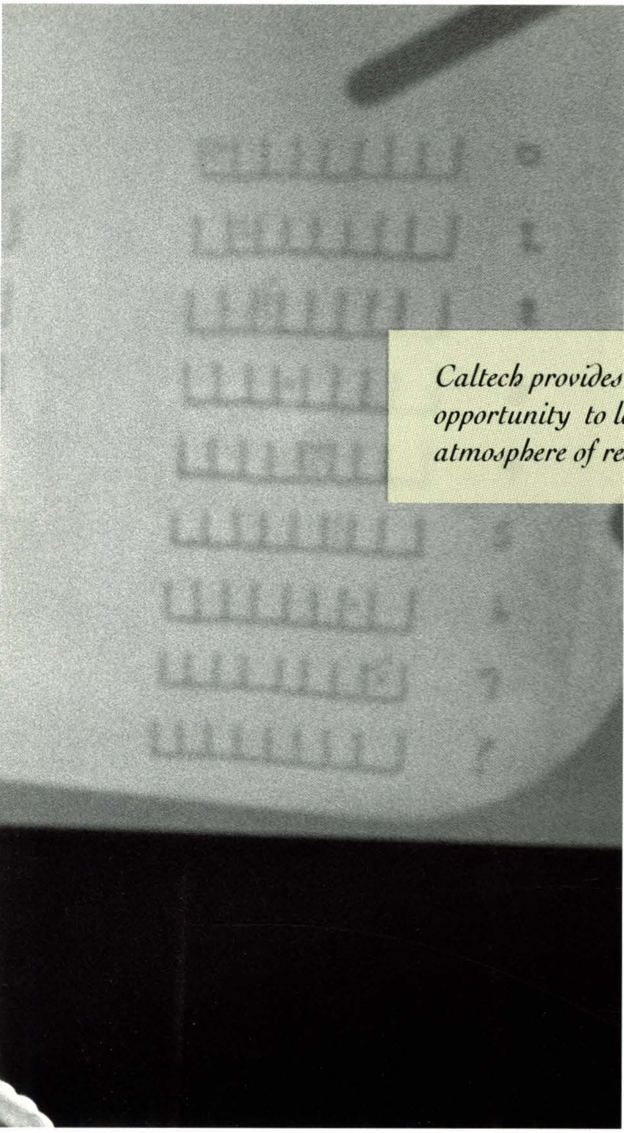
PLANS OF 1989 GRADUATES
by degree



Bachelor of Science



Doctor of Philosophy



Caltech provides an opportunity to learn in an atmosphere of research.

During the 1988–89 academic year, Caltech students worked alongside their faculty colleagues, exploring some of the most complex ideas in science and engineering today, using some of the most highly sophisticated equipment available. They were, quite simply, doing what generations of Caltech students have done: learning in an atmosphere of research.

The benefits of this learning process are many. The percentage of Caltech graduates who later earn their PhDs—nearly 50 percent—is one of the highest for any institution in the nation. That Caltech students can pursue a number of postgraduate options is made clear in the accompanying chart. Individual accomplishments also reflect on the value of a Caltech education. This last year, a number of students and alumni were recognized for their achievements.

Awards: Students and Alumni

Celina Mikolajczak, an undergraduate in engineering, discovered a supernova in the eastern portion of the constellation Leo, some 137 million light-years from Earth. In a project sponsored by the Summer Undergraduate Research Fellowships (SURF) program, she located the supernova on photographic films taken on the 18-inch Schmidt telescope at Palomar Observatory.

Vivian Chow, a senior in engineering and applied science and a graduate student in computer science, was selected one of the top ten college women for 1989 by *Glamour* magazine. Craig Sosin, a senior in physics, was one of 20 winners of *Time*'s annual College Achievement Awards.

Gregory Dubois, a doctoral candidate in high-energy physics, was named a Rhodes Scholar. Richard Boylan and Shawn Kantor, graduate students in economics, were awarded Alfred P. Sloan Foundation Doctoral Dissertation Fellowships.

Four alumni were awarded the National Medal of Science—the nation's highest scientific honor. The recipients were Arnold O. Beckman (PhD '28) founder chairman of Beckman Instruments, Inc.; Harden M. McConnell (PhD '51) of Stanford University; Eugene N. Parker (PhD '51) of the University of Chicago; and Robert P. Sharp (BS '34, MS '35), the Robert P. Sharp Professor of Geology, Emeritus, at Caltech. Dr. Alvin V. Tollestrup (PhD '50) of Fermilab was presented the National Medal of Technology.

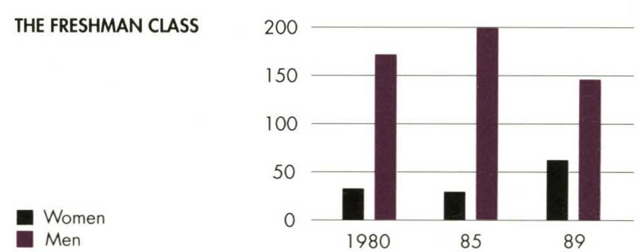
Caltech conferred its highest honor—the Distinguished Alumni Award—on five graduates: James J. Duderstadt (MS '65, PhD '68), president of the University of Michigan and cochairman of the National Science Board's Committee on Education and Human Resources; Max V. Mathews (BS '50), of Stanford University's Center for Computer Research in Music and Acoustics; Robert L. Noland (BS '41), president and CEO of Ketema, Inc.; Cornelius J. Pings (BS '51, MS '52, PhD '55), senior vice president for academic affairs and provost at the University of Southern California; and Donald C. Shreffler (PhD '62), professor of genetics at the Washington University School of Medicine.

The Atmosphere of Learning

While education and research remain at the center of Caltech's tradition, the atmosphere in which these endeavors unfold has changed dramatically over the history of the Institute. These changes are most noticeable in the makeup and needs of the students, in the type of facilities needed to create an ideal environment for student life, and in the kinds of courses best suited to prepare students for the future.

The composition of the student body today is radically different from student populations of the past. Men and women of many ethnic backgrounds and nationalities now attend the Institute, reflecting not only demographic changes in the larger population, but also a concerted effort on the Institute's part to seek out the most talented and qualified students—regardless of race, religion, color, sex, national or ethnic origin, or nondisqualifying handicap—and prepare them to become tomorrow's leaders in science and engineering.

THE FRESHMAN CLASS



An ambitious program to recruit women resulted in a record-high number entering the 1989 freshman class. The 64 women matriculating represent 30 percent of their class, an increase from the usual 17 percent. Caltech first began admitting women to the undergraduate program in 1970.

Addressing the concerns of affirmative action in another way, Caltech's Jet Propulsion Laboratory formalized a set of agreements with seven of the nation's Historically Black Colleges and Universities (HBCUs) to utilize the scientific and technical talent pool in these institutions. The agreements will provide for joint research projects, exchanges at the faculty and staff levels, and student summer employment with Atlanta University Center, Clark Atlanta University, Morehouse College, Morehouse School of Medicine, Morris Brown College, Tuskegee University, and Jackson State University.

Looking Ahead

The aims and needs process identified a need shared by many of our students: financial aid. Both the number of students needing aid, and the amount needed, have risen substantially in recent years. At the same time, the number and amount of state and federal awards have decreased. Caltech has traditionally provided aid to any student needing it, believing that the ability to pay tuition should not be a criterion for attendance. To maintain this important tradition, Caltech seeks to increase endowments for student aid.

The facilities of Caltech also belong to our tradition of education. The Institute's founders carefully considered both the design of the buildings and their arrangement on campus as important elements in an ideal learning environment. Today, these architectural matters are being reconsidered by members of the student body, faculty, and administration.

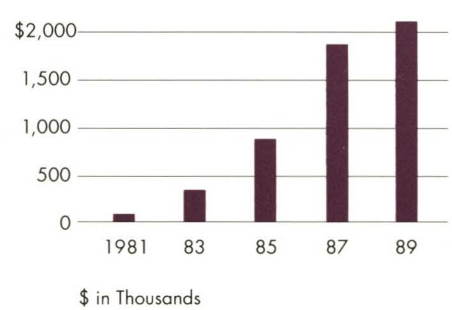
Changing faces and changing needs may characterize the many generations of Caltech students, but the core curriculum they study is remarkably similar, one student to the next, one year to the next. Indeed, since the 1920s, when the Trustees formulated the present educational policy, the core has remained a combination of "thorough courses in engineering and pure science," enriched by a "liberal amount of instruction" in the humanities.

The faculty aims and needs committee looked at the undergraduate curriculum to determine if any changes might be needed to maintain its value to current and future students. Recognizing the merits of the core, the committee did recommend further study of how the requirements might be met: in particular, the types of courses offered and the way they are taught. The committee observed that students today, and in the future, will be required to learn both a body of knowledge and the means to assimilate and decipher information more efficiently, especially in fields different from their own. They will need to think more intuitively. They will require more training in problem definition and the synthesis of complex ideas from simpler concepts derived from many fields. In the area of the humanities and social sciences, students will need courses that help them develop a keener understanding of the larger community and the role science and technology can play in it.

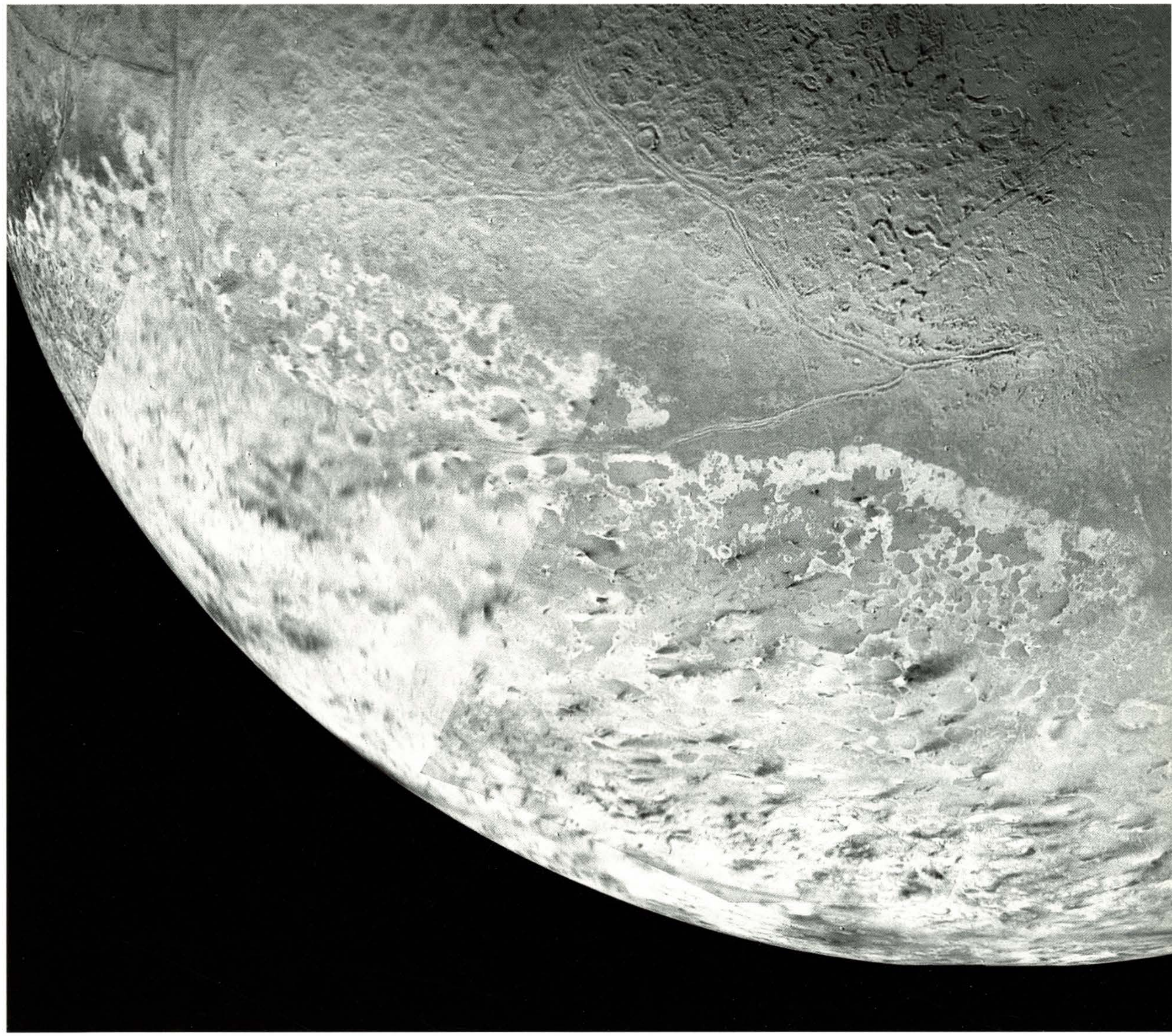
The Future

Caltech, in its second century, will continue to explore its own role in the larger community. We trust that our tradition of education—learning in an atmosphere of research—will prepare our students to do the same.

GENERAL BUDGET FUNDS ALLOCATED FOR STUDENT AID

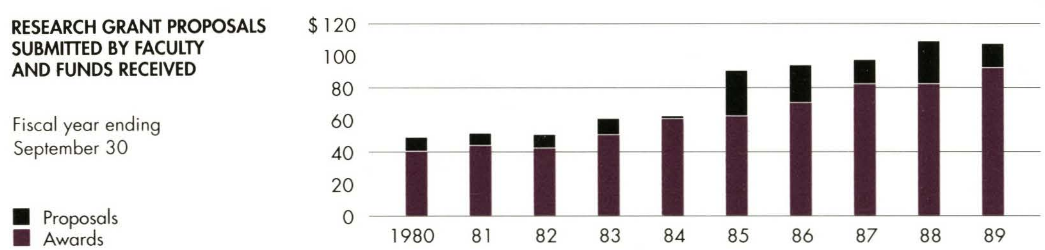


FOCUS ON RESEARCH

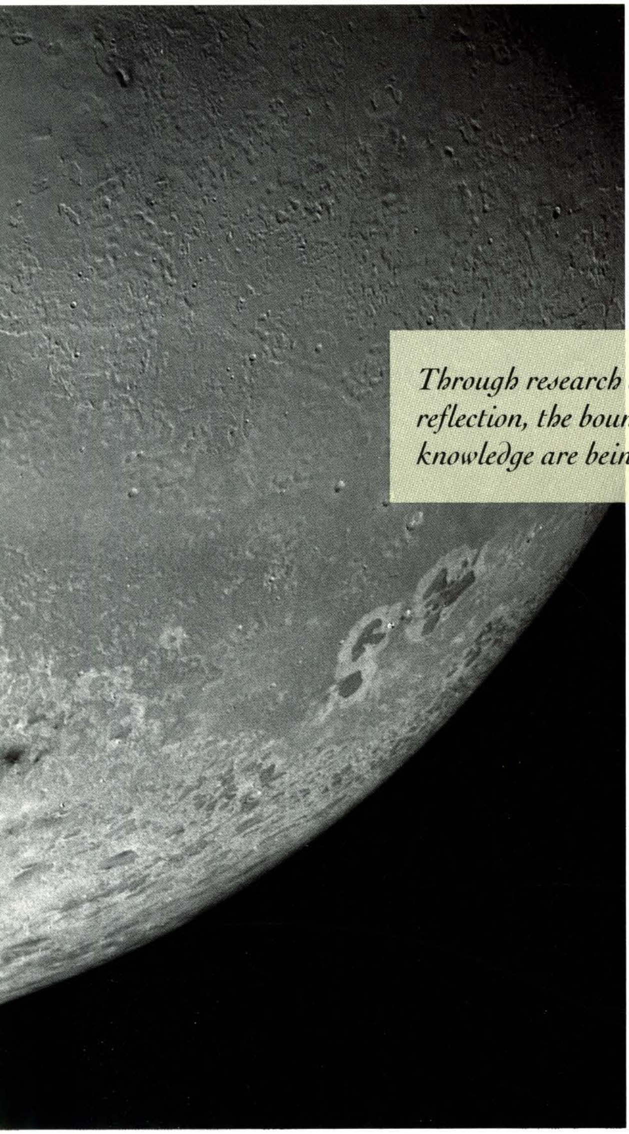


RESEARCH GRANT PROPOSALS SUBMITTED BY FACULTY AND FUNDS RECEIVED

Fiscal year ending September 30



$ in Millions



Through research and reflection, the boundaries of knowledge are being extended.

This past year, a variety of investigations and major accomplishments took place at Caltech. Perhaps the most spectacular of these was Voyager 2's successful mission. The spacecraft zoomed past Neptune in late August, sending back dramatic photographs of the planet and its satellites. "What a way to leave the solar system!" said a principal investigator for the JPL project; his was an enthusiasm shared by many. Other important research projects are summarized below.

Division Highlights

Biology

A rose is a rose is a rose. But a wild rose has five petals per flower, while the roses you buy from a florist have 30 to 40 petals. People have bred roses since the time of the ancient Greeks to get these luscious blossoms, in exactly the same way that sheep have been bred for soft wool or horses for speed—by selecting individuals with the desired traits and mating them.

The extra petals come at the expense of the flower's other components, particularly the pollen-bearing stamens. Sometime early in the bud, an aberrant gene tells the young cells that normally become stamens to grow up as petals instead. Nor are roses the only flowers to be enhanced by such means—camellias, stocks, and many other species have been similarly bred.

Now Caltech biologists have isolated and cloned at least one of the responsible genes, using *Arabidopsis thaliana*, a common, harmless weed of the mustard family. The gene, which codes for a protein called a ''transcription factor,'' resembles genes that govern cell differentiation in fungi and animals. A transcription factor controls genetic processes by binding to a specific site on a DNA molecule, activating the adjacent gene. The gene's instructions are then carried out by the cellular machinery.

Arabidopsis is a particularly handy plant for geneticists. It's small (five inches tall), fast-growing (a five-week life cycle), hardy, and produces thousands of seeds per plant. In addition, its genetic information is economically packaged. A petunia uses 16 or more genes to make a certain protein essential to photosynthesis, for example, but *Arabidopsis* does the same job with just three, and its DNA has hardly any of the repetitive DNA sequences found between the genes of all higher organisms. Yet the genes themselves are very similar to those of other flowering plants, so that once a gene has been found in *Arabidopsis*, it's fairly easy to locate its match in a species of commercial interest. Several hundred scientists worldwide now use *Arabidopsis* as a road map for plant genes, a fact largely traceable to these Caltech geneticists' pioneering work. And *Arabidopsis* isn't just a shortcut to finding the genes controlling flower production, drought resistance, and other agricultural attributes; the same work also probes the fundamental mysteries of how plants grow.

Chemistry and Chemical Engineering

The ability of living cells to synthesize useful complex compounds has earned cells a central role in contemporary and future manufacturing. Research conducted in Caltech's Division of Chemistry and Chemical Engineering concerns discovery of new strategies for improving the performance of cells in bioprocessing, and also the systematic invention of new types of cells with properties desirable for engineering purposes.

Contemporary technology for genetic engineering of cells—namely, changing the DNA blueprint for cellular function—is extremely powerful and enables pinpoint alteration of the cell's characteristics at the level of its DNA. This technology opens the door for rational design of cells using chemical engineering principles and methods allied with concepts, methods, and instruments that are more commonly associated with biochemistry and life sciences. By introducing new DNA into a cell, the researchers have the opportunity to create a new cellular system, with capabilities and characteristics which have never before existed, to perform the tasks needed for engineering applications. The discovery of the desired manipulations comes from a combination of genetic methods, ideas taken from nature, and engineering sensitivity analyses applied to validated mathematical descriptions of detailed cellular function. One particular recent advance has enabled bacterial cells to synthesize hemo-

The tiny *Arabidopsis thaliana* provides Caltech geneticists with clues on plant growth.

globin so that the cells use nutrients more efficiently under oxygen-starved conditions. This is important in practice since supply of oxygen often limits production of biological materials or biological degradation of wastes. The research team employs nuclear magnetic resonance spectroscopy extensively in order to study the energetic state and internal composition of cells, and applies high-resolution analytical two-dimensional gel electrophoresis to effect rapid analysis of many different proteins in the cell before and after genetic manipulations.

Another main theme of research in the group is the interrelationship between process conditions and the particular modifications that are made in proteins after their amino acid backbone is constructed. Specifically, the researchers are investigating the degradation, aggregation, membrane transport, and chemical modifications that many proteins undergo and that are of crucial importance in determining the value of a protein as a catalyst, a drug, or a diagnostic reagent. Their work encompasses cloned protein synthesis in bacteria, yeast, mammalian, and insect cell systems.

Engineering and Applied Science

When the wing tears off of a jetliner, or an overloaded steel cable snaps, the crack moves through the metal faster than a mile a second. Scientists studying fracture behavior would love to watch a crack as it travels, but have been stymied by its speed. Attempts to observe the stresses around the crack's tip have usually been limited to a single snapshot of the crack in progress. Furthermore, multiple images of a single crack could only be made if the stressed material was transparent, like Plexiglas—a class of materials of limited use to structural engineers. And many techniques only gave data about one point, instead of the entire region surrounding the crack.

Caltech researchers now have developed a method for photographing the stresses in an opaque plate, such as a metal or ceramic one, at the rate of two million frames per second—fast enough to follow a crack as it crosses the plate. The plate is polished until it's optically flat—any two points a centimeter apart on its surface differ in elevation by less than one wavelength of the high-intensity, twenty-billionths-of-a-second-long laser pulses that take the photos. Each pulse illuminates the area the crack will traverse, which deforms around the crack as it propagates. The no-longer-optically-flat surface reflects the laser light slightly out of phase, creating interference patterns when the reflected light passes through a set of diffraction gratings placed in front of the specimen. The diffracted light enters a drum-shaped camera, where a whirling mirror slings the patterns onto the photographic film lining the drum. The researchers analyze the interference patterns to track how much each point on the specimen's surface moves from its initial position, which in turn reveals the stresses at that point. The succession of patterns thus records the stress at every point on the surface throughout the cracking process.

The research group has developed numerical models based on these experiments. These models, which run on supercomputers at Caltech's JPL and at the supercomputing center in San Diego, help scientists develop theories on how cracks form and how they can be prevented from becoming catastrophic.

Geological and Planetary Sciences

Seismologists in Caltech's Division of Geological and Planetary Sciences have launched a project to install an advanced technology seismic network—a terrestrial telescope known as the TERRAscope—in California. When it is completed, this instrument will supply seismic data of unprecedented quality during major earthquakes throughout the world. Seismologists using it will be able to make assessments of earthquake ground-motions during the critical moments and hours after a major shock, rather than waiting days and sometimes weeks to get detailed information on the quake's characteristics. The TERRAscope will also allow researchers to instantaneously compare new earthquakes with past temblors that have occurred in the same region.

Analyzing a series of interference patterns like this one reveals the stresses inside a metal plate as it cracks. The crack is moving up the middle of the photo.

The completed TERRAscope will be one of the world's largest continually operating scientific instruments, covering an area bounded by San Luis Obispo, the Mexican border, the Channel Islands, and the California-Nevada border. Its seismic network will ultimately consist of an array of at least 10 broad-band, high-dynamic-range, digital seismometers, interlinked by satellite telemetry, and supported by high-speed computers.

Thus far, one element of the projected TERRAscope array has been installed in Pasadena's San Rafael Hills, the original site of Caltech's Seismological Laboratory. Several additional elements, known as the Whittier Advanced Geophysical Observatory, are under construction.

In addition to real-time data transmission, the TERRAscope will have other crucial advantages. While standard seismometers are often knocked off-scale by major earthquakes in their immediate vicinity, the TERRAscope's new technology will enable it to withstand such shake-ups and continue operating effectively. Furthermore, most conventional seismometers only register the ordinary, "short-period" seismic waves generated by earthquakes. The TERRAscope will also record the slower-moving "long-period" waves, which carry additional valuable information about a quake's origin and properties. In recent years, some studies have suggested that these slow-motion waves, also known as "silent quakes," may sometimes occur in the moments before an earthquake's ground-motion is actually felt.

Seismologists also expect the TERRAscope to provide a great deal of data about the structure and the physics of the earth's interior, allowing them to build up an extraordinarily detailed picture of the crust and mantle. When this information is integrated with information from digital seismometers in other parts of the world, the resulting three-dimensional pictures will portray the earth's interior with unprecedented clarity.

The Humanities and Social Sciences

Research conducted in Caltech's Laboratory for Experiments in Economics and Political Science has produced support for a theory of competitive behavior that has broad implications for defense department procurement policies. When used to analyze the defense department procurement system, the theory supported by the research predicts that certain mandated policies, intended to promote competition in the defense procurement system, may instead lead to increased cost and decreased efficiency.

The policy choice is between two ways of awarding contracts: "sole-sourcing" and "second-sourcing." In a sole-sourced contract, a company is awarded a contract for a multiyear production run after competitive bidding. In a second-sourced contract, an "initial procurement phase" is separate from the "reprocurement phase." The winner of a first round of bidding is given a contract to make the initial production run on the defense system. Later, there is a second round of bidding for the next production run, after which the reprocurement contract might well be awarded to another company. Competition is used only once in sole-sourcing while it is used at several stages in second-sourcing. Second-sourcing, on the face of it, would seem to be more competitive.

The theory supported by the Caltech experiments suggests the existence of a number of serious problems with a second-sourcing policy, problems that may drive up the total cost of the final product. The crux of the problem is the data-rights issue. In a second-sourced contract, the winner of the initial-phase contract must give up all exclusive rights to the technology and data developed during the course of its initial production run and make them available to any company that wishes to bid on the reprocurement contract. Relinquishing data rights is not a problem if there are no other markets for the technology that the initial-phase company has developed. But if other markets do exist, that company will be reluctant to relinquish its data rights and lose its position in these markets to competitors. This reluctance manifests itself in several ways according to the theory. Some companies, fearing the loss of proprietary technology, will not submit bids at all. Remaining bidders, facing less intense competition, will bid less aggressively, thereby driving up the dollar value of the winning contract. In addition, the overall intensity of the research effort will be decreased.

The Caltech research is continuing to refine both theories and experimental methodology. The aim is to develop better methods for field measurements and to develop policies that avoid problems like those the research has uncovered.

Physics, Mathematics and Astronomy

Using a sensitive gamma-ray camera hanging from a balloon floating 120,000 feet over Alice Springs, Australia, a Caltech team has observed a very bright gamma-ray object near, but not at, the center of our Milky Way galaxy. The gamma-ray source has been tentatively identified with a previously known X-ray object that appears at least 340 light-years from the galactic nucleus.

The object emits copious amounts of radiation in an energy range including "hard X rays" and "soft gamma rays." This object is only slightly less luminous than the brightest galactic object known at those energies—Cygnus X-1. Cygnus X-1 is believed to be a binary star system in which one of the objects is a black hole.

The researchers are not exactly sure what the object is. One possibility is that it's a black hole similar to Cygnus X-1—one with a mass five to ten times that of our sun. Another possibility is that it's a neutron star onto which material is accreting.

The object was observed with a special gamma-ray camera that was built entirely at Caltech. It is basically a flared cylinder three meters long and one meter in diameter mounted on a pointing platform. The camera's gamma-ray detector is a large circular plate of sodium iodide crystal 40 centimeters in diameter and 5 centimeters thick. Gamma rays striking the crystal produce faint scintillations of light, which are detected by photomultiplier tubes behind the crystal.

The key component of the camera is its unique "lens," which consists of an array of 175 small, hexagonal, lead blocks, arranged in a pattern that creates a series of apertures through which the gamma rays pass. The entire 300-pound mask rotates at one revolution per minute, causing the view of a source to be turned off and on at every point on the detector. This "chopping" or modulation of the source signal allows precise subtraction of the large gamma-ray background.

The camera must be sent aloft on a large high-altitude balloon since Earth's atmosphere absorbs most gamma rays. But because the camera hangs freely beneath the balloon, it requires an elaborate pointing system to keep it trained on a single object. The pointing system uses Earth's magnetic field, detected by an internal magnetometer, as its guide. In addition, two CCD (charge-coupled device) cameras view the sun in the day and the stars and planets at night to measure the telescope's pointing direction accurately.

Jet Propulsion Laboratory

Jubilant flight teams at JPL had a rewarding year. In May, Magellan was launched on its voyage to Venus; this was the first JPL planetary spacecraft to leave Earth since Voyager 1 in 1977. Voyager 2 made its final rendezvous—with Neptune—in August. And, in October, Galileo began its oft-delayed six-year trip to Jupiter, by way of Venus and two Earth flybys.

Magellan will reach Venus this August, after a 15-month journey. The spacecraft's radar will scan the planet from a nearly polar orbit, and will map 70 percent of the surface. The radar will show features as small as 150 meters, making it possible to study the processes that formed the surface, and their similarities to and differences from Earth's surface-formation processes.

Voyager 2's last encounter was spectacular—the spacecraft flew within 4,950 kilometers of Neptune's cloud tops and within 40,000 kilometers of Triton. Among its accomplishments, Voyager fixed Neptune's rotation at 16 hours 7 minutes; found that Neptune's atmosphere is mostly molecular hydrogen, with less than 25 percent helium, plus small amounts of methane and traces of acetylene; and photographed a storm called the Great Dark Spot, which is more than 12,500 kilometers across and circles Neptune in just under 18 hours.

Measurements taken by the spacecraft also revealed that Neptune's magnetic field is like Uranus's, which scientists had thought was unique: Neptune's dipole tilts 47 degrees from the rotational axis (Uranus's is tipped 59 degrees), and Neptune's magnetic north is in the southern hemisphere. Neptune also has complete rings, not just the arcs of material previously observed. Voyager images showed a narrow ring about 62,900 kilometers from Neptune's center, a second 53,200 kilometers from the center, a third lying inside the two narrow ones, and a sheet of material that may extend down to the atmosphere.

The surface of Triton, Neptune's largest satellite, is young. Several geyserlike plumes, each eight kilometers high, were found. The prospect that anything flows on Triton's surface is remarkable—the temperature is only 39 K (about -400° F), and the pressure is about 14 microbars. Pictures revealed at least six small, new satellites as well, ranging in diameter from 50 to 420 kilometers.

The encounter marked both the end of Voyager 2's planetary visits and the beginning of its Interstellar Mission. Voyager 1 explored its last planet (Saturn) in 1980.

JPL's second 1989 launch was Galileo, destined to study the Jupiter system from 1995 to 1997. Lacking enough energy to reach Jupiter directly, the spacecraft must fly by Venus (February 1990) and Earth (December 1990 and December 1992) for gravity-assist boosts. The scientists are using these opportunities for extra planetary observations, and will have a first asteroid encounter (October 1991) as well. Galileo will drop a probe in Jupiter's atmosphere and observe the planet, satellites, and magnetosphere from orbit.

Future Trends in Research

The research programs of the Institute have long been situated at the frontiers of science and engineering, at that intersection between what is known and what might be known through scientific investigation. This last year, President Everhart asked a committee of faculty members to look beyond the frontier and imagine the areas of research that will be important in the next five to ten years. Their study resulted in an outline of six overarching themes of research. These represent areas of study well suited to the kind of research traditionally undertaken in the Institute's six divisions. At the same time, they indicate the growing importance of interdisciplinary research—programs that combine the expertise of faculty members from different parts of the Institute.

National Medal of Science:

RUDOLPH A. MARCUS, Arthur Amos Noyes Professor of Chemistry

ROBERT P. SHARP, Robert P. Sharp Professor of Geology, Emeritus

ROGER W. SPERRY, Nobel laureate; Board of Trustees Professor of Psychobiology, Emeritus

National Academy of Sciences, Member:

ROBERT H. GRUBBS, Victor and Elizabeth Atkins Professor of Chemistry

FRANK E. MARBLE, Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering; and professor of jet propulsion, emeritus

CARVER A. MEAD, Gordon and Betty Moore Professor of Computer Science

AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics

National Academy of Engineering, Member:

CHARLES ELACHI, lecturer in electrical engineering and planetary science; assistant lab director, JPL's Office of Space Science and Instruments

American Association for the Advancement of Science, Fellow:

HARRY B. GRAY, Arnold O. Beckman Professor of Chemistry; director, Beckman Institute

STEVEN E. KOONIN, professor of theoretical physics

Royal Society of London, Foreign Member:

EDWARD B. LEWIS, Thomas Hunt Morgan Professor of Biology, Emeritus

Legion d'Honneur:

WILLIAM A. FOWLER, Nobel laureate; Institute Professor of Physics, Emeritus

USSR Academy of Sciences, Foreign Member:

ROGER W. SPERRY, Nobel laureate; Board of Trustees Professor of Psychobiology, Emeritus

PETER J. WYLLIE, professor of geology

Wolf Prize in Medicine, Corecipient:

EDWARD B. LEWIS, Thomas Hunt Morgan Professor of Biology, Emeritus

Accademia Nazionale dei Lincei, Rome, "Antonio Feltrinelli" International Prize for Medicine:

GIUSEPPE ATTARDI, Grace C. Steele Professor of Molecular Biology

Institute for Theoretical Physics, Trieste, Italy, Dirac Medal:

JOHN H. SCHWARZ, Harold Brown Professor of Theoretical Physics

King Faisal International Prize in Science:

AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics

Presidential Young Investigator Award:

FRANCES H. ARNOLD, assistant professor of chemical engineering

HARRY A. ATWATER, assistant professor of applied physics

GEOFFREY A. BLAKE, assistant professor of cosmochemistry

MELANY L. HUNT, assistant professor of mechanical engineering

ANDREW G. MYERS, assistant professor of chemistry

MITCHIO OKUMURA, assistant professor of chemical physics

STEPHEN R. WIGGINS, assistant professor of applied mechanics

Office of Naval Research Young Investigator Award:

STEPHEN R. WIGGINS, assistant professor of applied mechanics

David and Lucile Packard Fellowship in Science and Engineering:

FRANCES H. ARNOLD, assistant professor of chemical engineering

ANDREW G. MYERS, assistant professor of chemistry

Camille and Henry Dreyfus Foundation, New York, Dreyfus Teacher-Scholar Award:

DANIEL P. WEITEKAMP, assistant professor of chemistry

Pew Scholars Award in the Biomedical Sciences:

PAMELA J. BJORKMAN, assistant professor of biology; assistant investigator, Howard Hughes Medical Institute

Alfred P. Sloan Research Fellowship:

GEOFFREY A. BLAKE, assistant professor of cosmochemistry

American Society for Engineering Education, the Benjamin Garver Lamme Award:

THOMAS E. EVERHART, president; professor of electrical engineering and applied physics

American Chemical Society, Southern California Section, Tolman Medal:

JOHN D. BALDESCHWIELER, professor of chemistry

Named Professorship:

JOHN M. ALLMAN: Hixon Professor of Psychobiology

DON L. ANDERSON: Eleanor and John R. McMillan Professor of Geophysics

JAMES E. BAILEY: Chevron Professor of Chemical Engineering

ROGER D. BLANDFORD: Richard Chace Tolman Professor of Theoretical Astrophysics

ALAN H. DONAGAN: Doris and Henry Dreyfuss Professor of Philosophy

ROBERT H. GRUBBS: Victor and Elizabeth Atkins Professor of Chemistry

WILLIAM L. JOHNSON: Ruben and Donna Mettler Professor of Engineering and Applied Science

BARCLAY KAMB: Barbara and Stanley R. Rawn, Jr., Professor of Geology and Geophysics

HIROO KANAMORI: John E. and Hazel S. Smits Professor of Geophysics

JOHN H. SCHWARZ: Harold Brown Professor of Theoretical Physics

AHMED H. ZEWAIL: Linus Pauling Professor of Chemical Physics

Associated Students of the California Institute of Technology (ASCIT) Award for Teaching Excellence:

YASER S. ABU-MOSTAFA, associate professor of electrical engineering and computer science

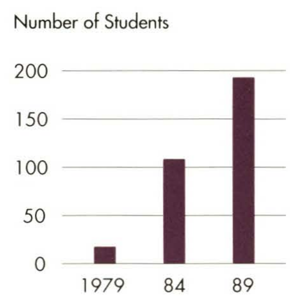
CLINTON D. DODD, swimming coach

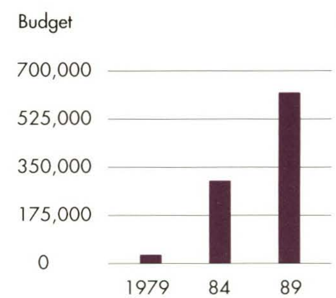
J. MORGAN KOUSSER, professor of history and social science

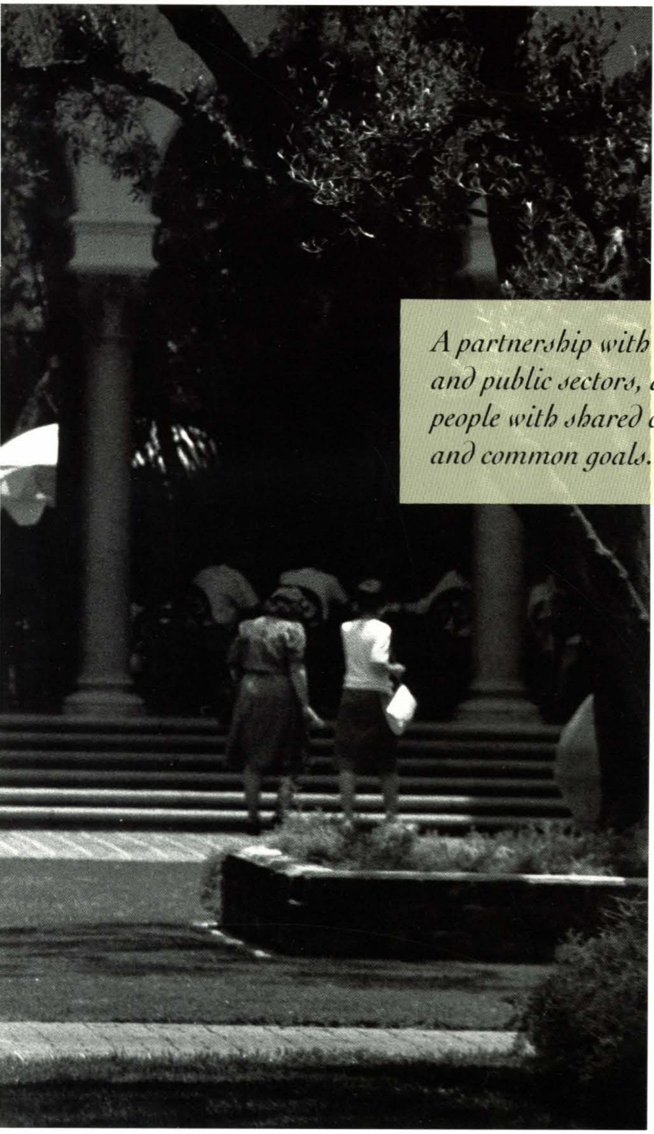
ROBERT J. MCELIECE, professor of electrical engineering

BASE OF SUPPORT

THE SUMMER UNDERGRADUATE RESEARCH FELLOWSHIPS PROGRAM







A partnership with the private and public sectors, among people with shared concerns and common goals.

Caltech's base of support has long comprised members of both the private and public sectors: individuals and groups interested in the advancement of scientific inquiry. This base of support has enabled Caltech to remain flexible in its organizational plan and responsive to variations in intellectual challenges and opportunities.

Private Sector Giving

At the annual Board meeting in October 1989, the Trustees discussed the special needs of Caltech as it faces its second century. They unanimously decided that it was both timely and appropriate to initiate a major campaign to raise funds that will guarantee a secure future for the Institute. The private phase of the campaign has begun; the public phase will be announced early in 1991, Caltech's centennial year.

During this last year, more than 9,000 gifts were made to the Institute by Trustees, alumni, The Associates, other individuals, corporations, and foundations. Together, these gifts totaled over $49 million. This amount includes $8.3 million from the Arnold and Mabel Beckman Foundation for the Beckman Institute. Also included are $2.73 million in life income trusts and annuities and $3.7 million in unrestricted support, which was given primarily by The Caltech Associates, alumni contributing to the Annual Fund, and the Industrial Associates.

The Institute was especially fortunate to receive a number of significant gifts to establish endowed professorships and fellowships. The Weingart Foundation gave $1 million to establish the Lee A. DuBridge Endowed Prize Fellowship Fund, to honor DuBridge, Caltech's president emeritus. The TRW Foundation and Dr. Ruben F. Mettler provided the funds to establish the Ruben and Donna Mettler Professorship. TRW honored Dr. Mettler, Chairman of the Caltech Board of Trustees, on the occasion of his retirement as Chairman and Chief Executive Officer of TRW.

Dr. Harold Brown, Caltech's president from 1969 to 1977, was honored this year when the Institute established the Harold Brown Professorship, with the financial support of friends of Dr. Brown. The Brown Professorship is an Institute-wide chair, meaning it may be awarded to an outstanding faculty member in any discipline.

The Anna L. Rosen Professorship in Biology was established as a gift from Trustee Benjamin M. Rosen, his brother Harold A. Rosen, and his sister Ruth Rosen Weisler, in honor of their mother. The Richard P. Feynman Professorship in Physics was established with a $1.5 million gift from Caltech alumnus Michael Scott, who particularly appreciated the teaching ability of the late Caltech professor and Nobel laureate. A gift from John R. McMillan, a Caltech alumnus and past president of The Associates, set up the Eleanor and John R. McMillan Professorship in the Division of Geological and Planetary Sciences.

Addressing a shared concern for equity in education, The James Irvine Foundation granted Caltech $1 million for graduate and postdoctoral Irvine Fellowships for underrepresented minority students. The Division of Chemistry and Chemical Engineering will benefit from a $1 million gift for prize fellowships from The Ralph M. Parsons Foundation.

This year also marked the successful completion of a challenge grant from the Andrew W. Mellon Foundation to endow postdoctoral fellowships in the humanities. By raising $1.5 million to permanently endow the fellowships, the Institute gained from the Mellon Foundation $750,000 to continue the postdoctoral program that the foundation has supported for many years. Substantially helping Caltech meet the challenge were separate grants from the Ahmanson Foundation, creating an Ahmanson Endowed Postdoctoral Fellowship in the Humanities, and from the Fletcher Jones Foundation. Among individuals who directed their gifts to meeting the Mellon Challenge were Trustees Richard P. Cooley, William F. Kieschnick, Sidney R. Petersen, Mary L. Scranton, Lew R. Wasserman, and Walter L. Weisman.

A gift from Milton E. Mohr created a fellowship for the Division of Engineering and Applied Sciences. Leighton and Associates, Inc., honored the firm's founder with the F. Beach Leighton Fellowship in the Division of Geological and Planetary Sciences.

Several important gifts were made to fund new equipment and laboratory improvements. The L. K. Whittier Foundation generously provided funds for two major projects. A grant of $980,000 will fund the Whittier Advanced Geophysical Observatory for seismology studies at Caltech, thus providing the first stage of the planned 10-element TERRAscope project. The Whittier Foundation also committed $800,000 in support of DNA diagnostics research at Caltech.

The Charles Lee Powell Foundation, recognizing the intertwined needs for equipment, research support, and fellowships, awarded to the Division of Engineering and Applied Science $1.7 million over three years. The interdisciplinary program in computation and neural systems received new support of $600,000 from The Pew Charitable Trusts. Significant pledges to provide major equipment were made by Intel Corporation and the Hewlett-Packard Company.

Public Sector Funding

The largest source of funding for research is the federal government. Even though competition for these funds has increased sharply in recent years, Caltech faculty members continue to compete favorably to win important awards.

Last year, Caltech was selected by the National Science Foundation (NSF) as the site for one of only 11 major Science and

Technology Centers funded throughout the country. The Caltech-based Center for the Development of an Integrated Protein and Nucleic Acid Biotechnology is headed by Leroy E. Hood, the Ethel Wilson Bowles and Robert Bowles Professor of Biology. The center is a cooperative effort by Caltech and JPL scientists. They intend to improve upon and integrate the most advanced techniques in genetic engineering, protein chemistry, and data analysis, to develop new technologies to speed research in protein and gene regulation.

The NSF also funded The Center for Research on Parallel Computation—based at Rice University in Houston—in which Caltech scientists will play a prominent role. Research there will focus on the development of operating systems for the next generation of supercomputers, which will depend on parallel processing—breaking up computations into smaller problems that can be solved more quickly by computer subsystems working simultaneously rather than in sequence.

National Science Foundation funding was received for *Project MATHEMATICS!*, a series of videotaped modules that use computer animation to help instructors teach basic concepts in mathematics at the high school and community college levels. The project had earlier received funding from the Association of Computing Machinery Special Interest Group on Computer Graphics (ACM/SIGGRAPH) and the Educational Foundation of America; an equipment grant was made by the Hewlett-Packard Company. The videotapes are now used in 32 states, and the project has been endorsed by two professional mathematics organizations. Last year, it was honored with four major awards: the Gold Medal at the 1988 International Film and TV Festival of New York; the Gold Apple at the 1989 National Educational Film and Video Festival; the Blue Ribbon, Best of Category, at the 1989 American Film and Video Festival; and the Electra Certificate, Best of Category, at the 1989 Birmingham International Educational Film Festival.

Collaborative Efforts

The costs of conducting research are rising dramatically as the complexities of science increase. Caltech is exploring various avenues of funding to keep pace with these needs. In certain instances, the Institute has decided to pool resources with other institutions.

As of January 1990, Cornell University astronomers are allotted 25 percent of the observing time on Palomar Observatory's 200-inch Hale Telescope. In return, Cornell will cover one-fourth of the operating costs of the telescope and provide new, ultra-sensitive detectors for it. A similar agreement was signed in February 1989 with the Observatories of the Carnegie Institution of Washington.

Caltech and the Howard Hughes Medical Institute have established a long-term collaborative agreement to conduct biomedical research at the university.

Another fruitful collaboration, this one between Caltech and the University of California, is the W. M. Keck Observatory atop Mauna Kea, Hawaii. Progress on the 10-meter telescope—which will be the world's largest optical telescope—continues on schedule. The steel framework, fabricated in Taragona, Spain, was shipped to the site over the summer.

Among other projects on the drawing board is the Laser Interferometer Gravitational-Wave Observatory (LIGO), a joint effort with Caltech and the Massachusetts Institute of Technology. LIGO will be a facility dedicated to the detection of cosmic gravitational waves and the harnessing of these waves for scientific research. During 1989, the LIGO project team completed a conceptual design of the observatory. A proposal to begin construction has been submitted to the NSF.

On October 21, 1988, the U.S. Post Office issued a 21-cent stamp commemorating alumnus Chester Carlson (BS '30), who, 50 years earlier to the day, had invented Xeroxing. Carlson is the first alumnus ever to grace a postage stamp.

Organizational Base

Caltech's organizational structure is as distinctive as the programs it facilitates. It is small and flexible by design, administered largely by the faculty itself. This last year, several appointments were made, including a new vice president and provost, vice president of student affairs, master of student houses, and three division chairmen.

Paul C. Jennings, professor of civil engineering and applied mechanics and formerly chairman of the Division of Engineering and Applied Science, was appointed vice president and provost, succeeding Barclay Kamb, the Barbara and Stanley R. Rawn, Jr., Professor of Geology and Geophysics, who served in that position from 1987 to 1989.

Gary A. Lorden, professor of mathematics, follows James J. Morgan, the Marvin L. Goldberger Professor of Environmental Engineering Science, as vice president for student affairs; Morgan had held the post since 1980. Louis L. Wilde, professor of economics, became the new master of student houses, following Robert W. Oliver, professor of economics, emeritus, who had served as the MOSH during 1987–88. In the Division of Biology, John N. Abelson, professor of biology, was named chairman; Leroy E. Hood, the Ethel Wilson Bowles and Robert Bowles Professor of Biology and director of the Center for the Development of an Integrated Protein and Nucleic Acid Biotechnology, was the division chairman from 1980 to 1989. David J. Stevenson, professor of planetary science, became the new chairman of the Division of Geological and Planetary Sciences, succeeding Gerald J. Wasserburg, Crafoord laureate and John D. MacArthur Professor of Geology and Geophysics, who had been chairman since 1987. John H. Seinfeld, the Louis E. Nohl Professor and professor of chemical engineering, was named chairman of the Division of Engineering and Applied Science, following Paul C. Jennings, who had served as chairman since 1985.

Support Organizations

The Caltech Associates have a long history of making significant unrestricted gifts. Generous support and a keen interest in Caltech characterize this group of friends, guided in calendar year 1989 by Associates President Joanna Muir. In fiscal year 1988–89, The Associates gave $1.5 million in unrestricted funds and $4.5 million in restricted contributions. At year's end, Associates membership was 1145, with 30 percent being alumni. There are 202 President's Circle members, those Associates who make annual donations of $6,000 or more.

The October 1988 Black Tie Dinner was the first of some 27 Associates events, including luncheons and dinners with faculty speakers and a day trip to Big Bear Solar Observatory led by its director, Harold Zirin. After autumn trips to the Owens and Imperial Valleys, an April trip brought a group of President's Circle members to Hawaii, for a visit to the W. M. Keck Observatory, Caltech Submillimeter Observatory, and Volcanoes National Park; leading the group was physicist Edward C. Stone, Caltech's vice president for astronomical facilities. In September, Caltech historian Eleanor M. Searle led another group to Normandy and southern England, in a program called "In the Steps of William the Conqueror." On campus, Associates toured the Thomas J. Watson, Sr., Laboratories of Applied Physics, and GALCIT (Graduate Aeronautical Laboratories) and the Caltech Wind Tunnels; many attended an Associates Colloquium, at which physicist and Vice Provost David L. Goodstein led eight sessions on "The Mechanical Universe and Beyond."

The Caltech Alumni Association, numbering 6,819, or 41 percent of the alumni, was led this past year by President Charles H. Holland, Jr. Major programs for the year included Seminar Day in May, when 1,203 alumni and guests visited the campus for faculty lectures and exhibits, and heard keynote speaker Dr. Simon Ramo (PhD '36), cofounder and director emeritus of TRW Inc. and a Life Trustee at Caltech, discuss the contrasts between real-world engineering and university engineering education; the annual Rose Parade program; a trip to the Temecula wine country; a dinner/theater event featuring the Caltech spring musical, *Bye Bye Birdie*; six class reunions; and many chapter activities around the country. Travel/study programs offered not only the second and third geology trips to New England and Alaska respectively, but an inaugural trip abroad attracted over 70 alumni and their guests to Antarctica. The urban settings of Washington, D.C., and San Francisco provided travel/study programs highlighting both historical and engineering aspects of the areas. The alumni directory was published in the fall and sent to members of the Association. Caltech students participated in both "day-on-the-job" and summer work opportunities through joint efforts with the Association and the Career Development Center, and approximately 150 alumni volunteers served as Alumni Admissions Representatives throughout the country.

Heading the seven alumni chapters this year were: Walter A. Specht, Boston; Spicer V. Conant, Phoenix; Peter V. Serrell, Portland; Frank Davis, San Diego; William L. Martin III, San Francisco; Gilbert Peppin, Seattle; and John P. Andelin, Washington, D.C.

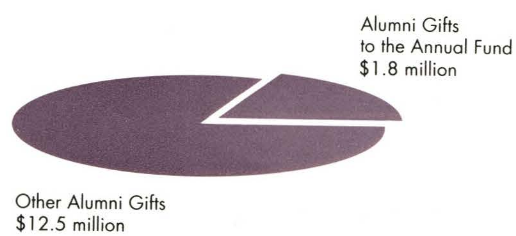
Caltech alumni contributed $1.8 million to the Annual Fund. The 6,637 donors represent a 43 percent participation rate. The Young Alumni Program was inaugurated during the year and had an auspicious beginning, achieving a participation rate of better than 30 percent of the alumni who graduated within the last ten years. Generous alumni giving reflects the fine efforts of more than 1,000 volunteers under the able leadership of Stan Holditch (BS '48), the Annual Fund Chair.

The Industrial Associates program offers corporations a vital link with the technical expertise at the Institute and in return brings unrestricted funds to Caltech. The 50 members in 1988–89 contributed over $1 million in unrestricted support and were responsible for almost 75 percent of the $12 million donated by corporations to the Institute. The Office for Industrial Associates sponsored three conferences attended by more than 500 corporate personnel and their guests, and arranged 145 campus visits and seminar days for member companies. Corporate members benefited from the library, publication, and technical information services available through the program, while Caltech faculty made 38 off-campus visits to companies worldwide.

The Future of Funding

Today, and certainly in our second century, Caltech must find ways to maintain both a research environment that encourages creativity and a base of support that can sustain it. Through partnership with individuals and organizations sharing our institutional mission, we intend to meet those needs.

TOTAL ALUMNI GIFTS 1988-89
$14.3 million



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, 1989, 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 pages 34 and 35 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 $866.4 million to $931.1 million, reflecting principally an increase of $62.0 million in campus equipment, buildings, and land.

The STATEMENT OF CHANGES IN FUND BALANCES reflects the impact of revenues, expenditures, and transfers in the fund balances, thus portraying the sources and uses of funds by major category. Gifts and grants from private sources totaled $49.9 million for fiscal year 1989, a decrease of $54.5 million from fiscal year 1988. $14.2 million was realized as the net gain from disposal of investments in fiscal year 1989, compared with $8.3 million for fiscal year 1988.

The STATEMENT OF OPERATING EXPENDITURES provides the detail of current fund expenditures for educational and related purposes. Total expenditures for fiscal year 1989 for the campus, $188.4 million, increased $17.5 million or 10.3 percent over fiscal year 1988. Expenditures for direct costs of sponsored research at the Jet Propulsion Laboratory, $1,057.1 million, increased $37.8 million or 3.7 percent.

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

LOAN FUNDS for students are provided by gifts from private donors and participation in the government's Perkins Loan Program, and are subject to repayment with interest after graduation. As repayments are made, the principal and accumulated interest become available for loans to other students.

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.

(continued on page 23)

	1979	1984	1989
Current funds expenditures *(in thousands)*			
Instruction and research (including libraries)	$47,696	$ 80,516	$132,753
Scholarships and fellowships	2,827	6,198	9,834
Institutional and student support	8,657	15,692	25,813
Plant operation, maintenance, and utilities	5,148	10,013	12,387
Total operating expenses	64,328	112,419	180,787
Auxiliary enterprises	2,829	4,796	7,668
Total	$67,157	$117,215	$188,455
Inflation adjusted (1979 dollars)	$67,157	$ 85,515	$117,009
Capital expenditures, campus *(in thousands)*	$ 6,973	$ 21,679	$ 62,043
Jet Propulsion Laboratory, direct expenditures *(in millions)*	319.0	505.2	1,057.1
Total gifts and nongovernment grants *(in thousands)*	16,770	29,697	49,891
Endowment and similar funds at market value *(in millions)*	173.9	247.0	499.8
Investment income *(in millions)*	13.8	22.5	35.9
Tuition rate *(in thousands)*	4.3	8.7	11.6
Student enrollment (first term)			
Undergraduate	801	829	854
Graduate	851	936	987
Total	1,652	1,765	1,841
Degrees granted			
B.S.	195	213	233
M.S.	125	147	151
Eng.	1	2	2
Ph.D.	125	123	134
Total	446	485	520

Summary of Changes in Fund Balances

(in thousands)

Year Ended September 30, 1989

Additions

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

Plant Acquisitions Additions to campus plant for land, buildings, and equipment.	$ 66,624
United States Government Grants and Contracts Reimbursement from various government agencies for direct costs of research, instruction, and student support.	65,806
Gifts and Nongovernment Grants Includes gifts and grants from private sources for education and research, and physical facilities.	49,891
Indirect Costs and Management Allowance Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	43,046
Investment Income Endowment income and investment income of other funds, including earnings from short-term investments.	35,904
Tuition and Fees Tuition and fees assessed students.	20,832
Realized Gains Net realized gains on investments sold.	14,164
Auxiliary Enterprises Revenues from sales by food services, student housing, and bookstore.	9,041
Other Income from sales and services, and other miscellaneous revenue.	5,657
Total Additions	**$310,965**

Deductions

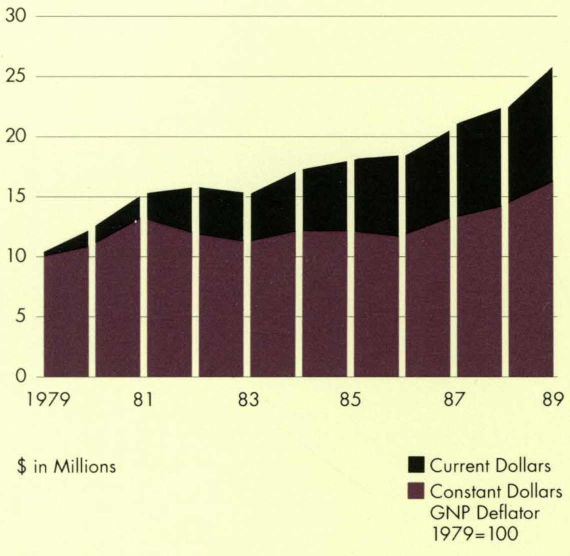
(Excluding Direct Costs at the Jet Propulsion Laboratory)

Research Expenditures for activities specifically organized to produce research outcomes supported by federal and private sponsors.	$ 70,476
Instruction Expenditures for activities that are part of the instructional program, including departmental research.	62,277
Plant Fund Consists of expenditures for buildings, equipment, renewals, payments on interfund advances for plant purposes, as well as retirement of plant assets.	55,328
Institutional and Student Support Expenditures for business and financial affairs, student services, Institute relations, and general administration.	25,813
Plant Operations Expenditures, including utilities, for the operation and maintenance of the campus grounds and facilities.	12,387
Scholarships and Fellowships Awards made to students enrolled in formal course work, with no requirement that they perform services or repay the awards.	9,834
Auxiliary Enterprises Expenditures, including maintenance, of auxiliary enterprises.	7,668
Other Includes payments to life beneficiaries with life income and annuity agreements, and miscellaneous other charges.	2,526
Total Deductions	**$246,309**
Increase in Fund Balances	**64,656**
Total	**$310,965**

ENDOWMENT AND SIMILAR FUNDS (continued) 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 which, after inflation, will strike a fair balance between current and future support of its instruction and research programs.

The market value of the Institute's endowment at September 30, 1989 was $499.8 million, compared to $424.0 million at September 30, 1988. In addition to U.S. equities and fixed income securities, the fund has diversified investments in real estate, oil and gas properties, international securities, and venture capital partnerships. As highlighted on the following graph, endowment income has steadily increased to $26.4 million from $10.6 million ten years ago, a compound annual increase of 9.6 percent. During this period, inflation, as measured by the GNP Deflator, averaged 4.9 percent annually.

ENDOWMENT INCOME



LIFE INCOME AND ANNUITY FUNDS consist of gifts received to establish living trusts for which the Institute is trustee, or annuity agreements. Payments are made to beneficiaries and annuitants during their lifetimes in accordance with the terms of these agreements.

Life income and annuity 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 gifts during their lifetimes while obtaining a charitable income tax deduction for their gifts. Upon termination of beneficiary agreements, the principal is transferred to the endowment or other fund groups as designated by the donor.

The Institute's life income and annuity agreements consist of pooled income funds, annuities, and taxable and nontaxable unitrusts. Investment assets include cash equivalents, equities, and fixed-income securities (including tax-exempt municipal bonds, where appropriate), real estate, and various royalty interests. The Institute functions as trustee, with the majority of the marketable securities managed by a major institutional investment advisory firm. The Institute does not charge a trustee fee at present. At September 30, 1989, the market value of the life income and annuity funds was $45.0 million.

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

The NOTES TO FINANCIAL STATEMENTS are an integral part of the financial statements and provide significant information on accounting policies, investments, funds held in trust, retirement and deferred compensation plans, pledges, and revenue bonds.

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

David W. Morrisroe

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

BALANCE SHEET

California Institute of Technology

(in thousands)	September 30, 1988
	Total All Funds
ASSETS	
Cash	$ 1,059
Accounts receivable:	
United States government (note B)	173,017
Other	3,564
Student accounts and notes receivable	10,986
Investments (notes A and C)	503,338
Interfund advances	
Prepaid expenses and other assets	3,359
Campus properties (note A):	
Equipment	161,715
Buildings	199,992
Land	17,496
	$1,074,526
LIABILITIES AND FUND BALANCES	
Accounts payable and accrued expenses (note B)	$ 179,554
Deferred student revenue	4,712
Funds held in custody for others	2,700
Annuities payable (note A)	1,135
Revenue bonds payable (note H)	20,000
Fund balances	866,425
	$1,074,526
Fund balances (Exhibit 2):	
United States government grants refundable	$ 4,465
Institute funds–	
Unrestricted	9,516
Discretionary endowment:	
Unrestricted	65,763
Restricted	62,398
Endowment principal	266,369
Other restricted funds	111,201
Invested in plant	346,713
	$ 866,425

See accompanying notes to financial statements

September 30, 1989

Total All Funds	Current Funds	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
$ 612	$ 252	$ 68		$ 292	
173,718	173,718				
2,299	2,054			245	
11,276	4,030	7,246			
508,502	36,958	2,214	$409,246	37,796	$ 22,288
	2,457		8,131		(10,588)
4,439	4,439				
185,237					185,237
238,158					238,158
17,851					17,851
$1,142,092	$223,908	$9,528	$417,377	$38,333	$452,946
$ 182,559	$177,815		$ 297	$ 523	$ 3,924
4,525	4,525				
3,221	1,321		1,900		
1,111				1,111	
19,595					19,595
931,081	40,247	$9,528	415,180	36,699	429,427
$1,142,092	$223,908	$9,528	$417,377	$38,333	$452,946
$ 4,432		$4,432			
9,060	$ 3,431				$ 5,629
65,125			$ 65,125		
68,240			68,240		
281,815			281,815		
92,435	36,816	5,096		$36,699	13,824
409,974					409,974
$ 931,081	$ 40,247	$9,528	$415,180	$36,699	$429,427

EXHIBIT 1

STATEMENT OF CHANGES IN FUND BALANCES

California Institute of Technology

(in thousands)	Year Ended September 30, 1988 Total All Funds
Fund balances at beginning of year (Exhibit 1)	$762,264
Revenues and other additions (notes A, D and G):	
Student tuition and fees	19,424
Investment income	31,261
Net gain on disposal of investments	8,292
Gifts and nongovernment grants	104,429
United States government grants and contracts–	
Reimbursement of direct costs	59,632
Recovery of indirect costs and management allowance	41,073
Auxiliary enterprises revenues	7,832
United States government advances	203
Campus property acquisitions ($18,403 included in campus current funds expenditures and $48,221 included in campus property acquisitions and renewals, and payments on interfund advances and revenue bonds)	45,632
Other	3,330
Total revenues and other additions	321,108
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(170,933)
Campus property acquisitions and renewals, payments on interfund advances and revenue bonds	(38,478)
Retirement and disposal of campus properties	(2,830)
Interest on advances for plant purposes	(592)
Interest on revenue bonds payable	(1,650)
Payment to life beneficiaries	(2,183)
Other	(281)
Total expenditures and other deductions	(216,947)
Transfers among funds:	
Gifts allocated	
Discretionary endowment transfers to current funds	
Allocations for plant purposes	
Terminated trust and annuity agreements	
Other	
Total transfers among funds	
Increase for the year	104,161
Fund balances at end of year (Exhibit 1)	$866,425

See accompanying notes to financial statements

Year Ended September 30, 1989

EXHIBIT 2

Total All Funds	Current Funds Unrestricted	Current Funds Restricted	Loan Funds	Endowment and Similar Funds	Life Income and Annuity Funds	Plant Funds
$866,425	$ 2,815	$35,503	$8,729	$394,530	$34,572	$390,276
20,832	20,832					
35,904	12,333	18,027	315		2,401	2,828
14,164				13,611	553	
49,891	6,682	18,853	2	9,987	2,758	11,609
65,806		65,601				205
43,046	43,046					
9,041	9,041					
438			438			
66,624						66,624
5,219	518	3,418	131		146	1,006
310,965	92,452	105,899	886	23,598	5,858	82,272
(188,455)	(85,012)	(103,443)				
(49,393)						(49,393)
(3,364)						(3,364)
(934)						(934)
(1,637)						(1,637)
(2,402)					(2,402)	
(124)			(124)			
(246,309)	(85,012)	(103,443)	(124)		(2,402)	(55,328)
	(342)	(696)		1,038		
	3,700			(3,700)		
	(8,271)	(1,150)		(2,786)		12,207
				1,329	(1,329)	
	(1,911)	703	37	1,171		
	(6,824)	(1,143)	37	(2,948)	(1,329)	12,207
64,656	616	1,313	799	20,650	2,127	39,151
$931,081	$ 3,431	$36,816	$9,528	$415,180	$36,699	$429,427

STATEMENT OF OPERATING EXPENDITURES

EXHIBIT 3

California Institute of Technology

(in thousands)	Year Ended September 30, 1988	1989
Educational and general:		
Instruction, including departmental research	$ 53,802	$ 62,277
Organized research	64,377	70,476
Scholarships and fellowships	8,383	9,834
Institutional and student support	24,702	25,813
Plant operation, maintenance and utilities	12,573	12,387
Total educational and general	163,837	180,787
Auxiliary enterprises	7,096	7,668
Total campus expenditures	$ 170,933	$ 188,455
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government) (note A)	$1,019,312	$1,057,092

See accompanying notes
to financial statements

NOTES TO FINANCIAL STATEMENTS

California Institute of Technology

NOTE A

SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

Basis of accounting and reporting

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

Jet Propulsion Laboratory

The Institute manages and operates the Jet Propulsion Laboratory (JPL) under a cost reimbursable contract with the National Aeronautics and Space Administration. JPL land, buildings, and equipment are owned by the United States government and are excluded from the Institute's financial statements. However, liabilities arising from JPL activities are those of the Institute and are reflected in its financial statements as are receivables arising from such activities (note B). The volume of activity at JPL is reflected in Exhibit 3.

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 at JPL and the Campus for sponsored research. These contracts gave rise to a substantial portion of the accounts payable and accrued expenses in the current funds at September 30, 1989 and 1988, and in turn to accounts receivable from the United States government. Accounts payable and accrued expenses (and related receivables) for JPL amounted to approximately $166,000,000 and $164,000,000 for 1989 and 1988, respectively.

NOTE C

INVESTMENTS

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

	September 30, *1988*	*1989*
Marketable securities—		
Debt securities (approximate market value of $191,760,000 in 1988 and $190,330,000 in 1989)	$195,978,000	$190,141,000
Equity securities (approximate market value of $230,760,000 in 1988 and $302,478,000 in 1989)	196,301,000	210,593,000
	392,279,000	400,734,000
Short-term commercial obligations	58,217,000	48,347,000
Settlements in process—		
Receivables for securities sold	635,000	1,571,000
Payables for securities purchased	(1,378,000)	(1,571,000)
Real estate, less amortization and accumulated depreciation of $2,325,000 in 1988 and $2,326,000 in 1989	24,898,000	28,042,000
Mortgages, notes, and other securities	28,687,000	31,379,000
	$503,338,000	$508,502,000

Investments shown above include the investment pool as follows:

	September 30, *1988*	*1989*
Investment pool assets at year end—		
At carrying value	$351,699,000	$365,502,000
At approximate market value	$375,990,000	$444,834,000
Pool share value at market	$ 17.28	$ 20.31
Annualized income earned per pool share	$ .87	$ 1.04

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 $16,700,000 and $14,100,000 at September 30, 1989 and 1988, respectively. The income derived from these funds amounted to $879,000 and $717,000 for the years ended September 30, 1989 and 1988, 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 $3,390,000 and $3,750,000 at September 30, 1989 and 1988, 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 of its employees that are funded by periodic transfers to the respective insurance companies. Academic and senior administrative staff are covered by a defined contribution pension plan, while non-academic staff are covered by two defined benefit pension plans. Retirement benefits under these defined benefit pension plans are based on years of service and career average compensations and accrue partially on a fixed dollar basis, and partially on a variable dollar basis. The Institute's defined benefit plan funding policy is to contribute amounts sufficient to maintain retirement plan assets at levels adequate to cover all accrued benefit liabilities.

Effective October 1, 1987, the Institute adopted the Statement of Financial Accounting Standard No. 87, "Employers' Accounting for Pensions." The net pension cost for the year ended September 30, 1989, and the funded status at September 30, 1989, for the defined benefit plans are as follows:

Net Pension Cost

	Campus	*JPL*
Service cost—benefits earned during the year	$ 2,045,000	$ 9,275,000
Interest cost on projected benefit obligation	2,378,000	10,908,000
Actual return on plan assets	(2,662,000)	(12,573,000)
Net amortization and deferral	378,000	1,802,000
Net pension cost	$ 2,139,000	$ 9,412,000

Funded Status

	Campus	*JPL*
Actuarial present value of benefit obligations—		
Accumulated benefit obligation, including vested benefits of $42,626,000 and $203,431,000	$ 44,390,000	$212,145,000
Projected benefit obligation	$ 47,821,000	$228,414,000
Plan assets at fair value	45,844,000	223,691,000
Projected benefit obligation in excess of plan assets	1,977,000	4,723,000
Unrecognized net gains or (losses)	(1,999,000)	(4,464,000)
Unrecognized net asset at October 1, 1987, being amortized over 16 and 18 years, respectively	77,000	723,000
Accrued pension cost	$ 55,000	$ 982,000

The weighted-average discount rate and assumed rate of increase in future compensation levels used in determining the actuarial present value of the projected benefit obligation are 8% (1988—8½%) and 6%, respectively. The expected long-term rate of return on assets is 8%.

Pension costs for the defined contribution plan for academic and senior administrative staff for the year ended September 30, 1989, were $3,993,000 for the Campus, and $14,716,000 for JPL.

All pension costs for JPL are included in direct costs of sponsored research.

NOTE F

Deferred Compensation Plan

The Institute has 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 $26,890,000 and $23,020,000 at September 30, 1989 and 1988, 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, 1989, the Institute had pledges on hand (principally for restricted purposes) totaling approximately $39,000,000, of which $23,000,000 is expected to be collected in 1990. It is not practicable to estimate the net realizable value of such pledges.

NOTE H

Revenue Bonds

On December 26, 1985, the Institute borrowed $20,000,000 through the California Educational Facilities Authority for the purpose of constructing, acquiring, and refinancing the cost of certain educational facilities. Funds were obtained through the sale of revenue bonds, repayable together with interest from the general revenues of the Institute over a 30-year period. Interest rate varies from 6.4% to 8.625%. Required principal and interest payments are approximately $2,040,000 a year for the fiscal years 1990 through 2005, and approximately $940,000 a year thereafter until 2016, when the bonds will be fully redeemed. Institute investments include $1,470,000 held by a trustee as a required Bond Reserve Fund.

NOTE I

Contingencies

The Institute is a defendant in various legal actions incident to the conduct of its operations. The Institute's management does not expect that liabilities, if any, for these legal actions will have a material effect on the Institute's financial position.

REPORT OF INDEPENDENT ACCOUNTANTS

Price Waterhouse

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, in all material respects, the financial position of California Institute of Technology at September 30, 1989, and the changes in fund balances and the operating expenditures for the year then ended, in conformity with generally accepted accounting principles. These financial statements are the responsibility of the Institute's management; our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit of these statements in accordance with generally accepted auditing standards which require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management, and evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for the opinion expressed above.

Price Waterhouse

Los Angeles, California
December 18, 1989

BOARD OF TRUSTEES

Board of Trustees

New Trustees are Donald R. Beall, chairman and chief executive officer of Rockwell International Corporation; Richard M. Ferry, president and chief operating officer of Korn/Ferry International; Admiral Bobby R. Inman, private investor; Ronald K. Linde, chairman of the board, The Ronald and Maxine Linde Foundation; Richard M. Rosenberg, president of BankAmerica Corporation and Bank of America NT & SA; and Frank G. Wells, president and chief operating officer of The Walt Disney Company. James W. Glanville was named a vice chairman. Trustee Chauncey J. Medberry III became a Senior Trustee; Robert O. Anderson and William E. Zisch were elected as Life Trustees. George W. Beadle and Dean A. McGee, valued members of the Board, passed away during this last year.

Officers of the Board

Trustees

**Members of the Board of Trustees Audit Committee. Sidney R. Petersen is chairman; Dennis Stanfill is vice chairman; and Paul C. Jennings and David W. Morrisroe are advisory members.*

INSTITUTE ADMINISTRATIVE COUNCIL

California Institute of Technology
Pasadena, California 91125