CALIFORNIA INSTITUTE OF TECHNOLOGY

Annual Report
1987-88

"In times like these, there need to be a few places that look ahead and still dare to do the most ambitious things that human beings can accomplish."

DR. THOMAS E. EVERHART
INAUGURAL ADDRESS, APRIL 12, 1988

On the cover:
The Beckman Institute, an innovative center for integrated research in the chemical and biological sciences, which is now under construction, will be dedicated in October 1989.

Chairman's Message

On April 12, 1988, the trustees invested Thomas E. Everhart as the new president of the California Institute of Technology. Placing on his shoulders the academic hood first worn by Robert A. Millikan, the first executive officer of the Institute, we wished him a long and successful career as president.

Thousands of people, including delegates from academic institutions and learned societies, special guests, and family, filled Beckman Mall to witness the historic occasion. In his inaugural address, Dr. Everhart offered his perspective on the long tradition of excellence at Caltech, noting that "the heritage of the past is the foundation upon which we build the achievements of the present and our vision of the future."

Just the day before, a groundbreaking ceremony marked the beginning of construction of the Beckman Institute, a facility where such future advancements in science surely will be made. The Beckman Institute, due to open in 1989, is being funded through a major gift from Arnold O. and Mabel Beckman, matched in part by gifts to the Beckman Institute from other donors, and gifts from trustees to general endowment.

Dr. Beckman, long known to the Caltech community for his work as a trustee and, with his wife Mabel, for his generosity, was recognized last summer by President Reagan, who awarded him a National Medal of Technology "for exceptional creativity in designing analytical instruments that are recognized as the best in the world and for developing a successful business whose products have helped to keep the United States in the forefront of chemistry, chemical engineering, and biotechnology." As fellow trustees, we congratulate Dr. Beckman on this most prestigious —and deserved—national award.

Excellent progress is being made on the construction of the W. M. Keck Observatory on Mauna Kea, Hawaii. Last fall, Caltech received the final payment on the pledge from the W. M. Keck Foundation for this important facility. The grant, awarded in 1985, is the largest private gift ever given for a scientific project. Ground was broken in May for the headquarters building, which, when completed in 1989, will house the observatory's administrative and technical staff. The 10-meter telescope is scheduled to see first light in 1991.

This past year was an especially active one for the Board, thanks to the many talents of our members, their sound advice on significant issues, and their active participation on committees that oversee a range of Caltech activities. We welcomed two new members—Walter Weisman, former chairman and chief executive officer of American Medical International, Inc., Beverly Hills; and Arthur Rock, venture capitalist and principal of the San Francisco-based Arthur Rock and Company. Trustee Ralph Landau was named a Senior Trustee; and Benjamin F. Biaggini and Robert S. McNamara were elected Life Trustees.

We were deeply saddened by the sudden and untimely death of James E. Olson, chairman and chief executive officer at AT&T, who died last spring at the age of 62. Although he served only briefly on the Board, his concerns for the quality of American education—especially its availability to minorities—inspired us to set still higher goals for Caltech. We will miss him.

In closing, I want to thank all the trustees for their work, which has contributed greatly to the successful year just ended. We look forward to a new chapter in Caltech's history, in partnership with Dr. Everhart and all members of the Caltech community, as we strive to build a future for Caltech that is as distinguished as its past.

Ruben F. Mettler
Chairman

This Annual Report is my first after serving a complete year as the President of the California Institute of Technology. I now have a much better understanding of the traditions and the remarkable people who make up Caltech. Focused primarily on science and technology, striving to be excellent in those few endeavors we undertake, and trying to choose activities that will have high impact for the future, Caltech dares to be different. More than ever, I am convinced that we live in the most exciting age in the history of mankind. Because science and technology are increasing in importance, we in research, we in academia, we at Caltech, are at the center of the action.

As a private university, we enjoy a special freedom to experiment and innovate. During the last year, faculty members—together with outstanding undergraduate and graduate students—exercised this freedom, making significant contributions in their fields of study. Often these contributions spring from the minds of individuals, although teams may bring them to fruition. Sometimes colleagues stimulating each other produce contributions that individuals working alone would miss, and increasingly, knowledge from several fields is necessary for important discoveries or developments. Our faculty was highly successful in gaining support for their research, both as individuals, and also cooperatively, through the National Science Foundation Science and Technology Centers, for example. As highlighted later in this Report, researchers offered new insights into the AIDS virus, developed a new method for dating prehistoric earthquakes, and presented new theories in such diverse areas as medieval history and modern chemical engineering. And these highlights are only a few of many that might have been chosen for mention here.

Our excellent people need state-of-the-art facilities and equipment for maximum accomplishment. Important new facilities were started and developed during the past year, as well as several smaller renovation projects. For example, ground was broken in April for the Beckman Institute, which will be a world center for research in the chemical and biological sciences. Last fall, the Microdevices Lab at the Jet Propulsion Laboratory was officially opened. The headquarters building for the W. M. Keck Observatory in Hawaii is under construction, and the dome for the telescope on Mauna Kea is virtually complete.

Funding for research, facilities, and operations depends upon the support and cooperation of government, industry, and many generous people and organizations. An increasing number of friends and private organizations helped the Institute to its greatest single year in receipt of gifts, with more than $97 million provided as an investment in our future. This support is timely and important, for research and teaching both require expensive equipment to increase our ability to probe more deeply and learn more rapidly. We are faced with an increasing challenge of finding new ways to support research and education of the quality that has become a Caltech hallmark. One avenue, good for both Caltech and industry, is cooperation based on shared goals and common interests. For example, our Chemistry Consortium, unveiled last year, brings people from four private-sector organizations together with expert researchers at the Institute; it is off to an excellent start.

But Caltech cannot rest on past or present successes. We need to harness our knowledge, understanding, and ingenuity to educate, discover, and innovate even better in the future. To address this issue, I have initiated Institute-wide discussions on our Aims for the future, and our Needs to achieve these aims. These discussions should enable us to make

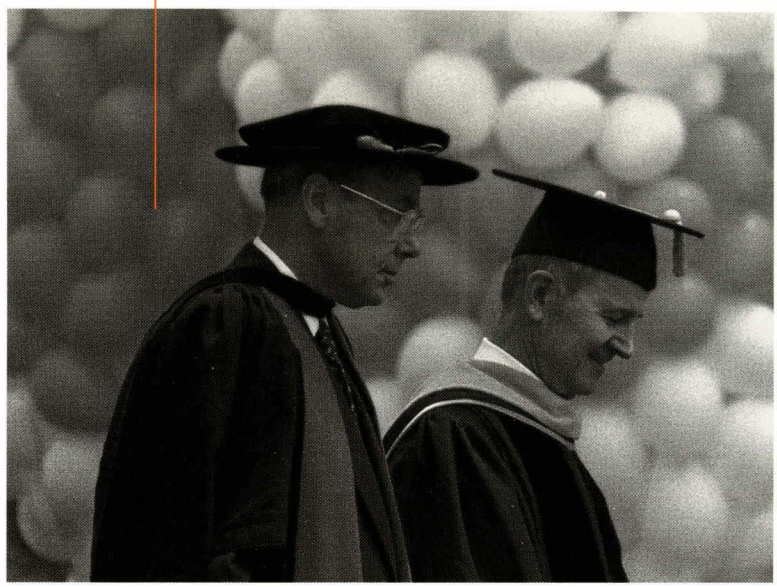
wiser decisions about our future. And that future will likely include more women and minorities as members of our faculty, students, and staff. A committee on Affirmative Action is working actively to ensure that the Institute's cultural, racial, and demographic future is as rich in quality-based diversity as its educational opportunities are focused and preeminent.

Each year we welcome excellent new faculty, students, and staff to our midst, who bring ideas and vigor. Each year we lose colleagues who have helped make Caltech what it is today. During the past year, we were saddened by the loss of several of our faculty, among them Nobel Laureate Richard P. Feynman.

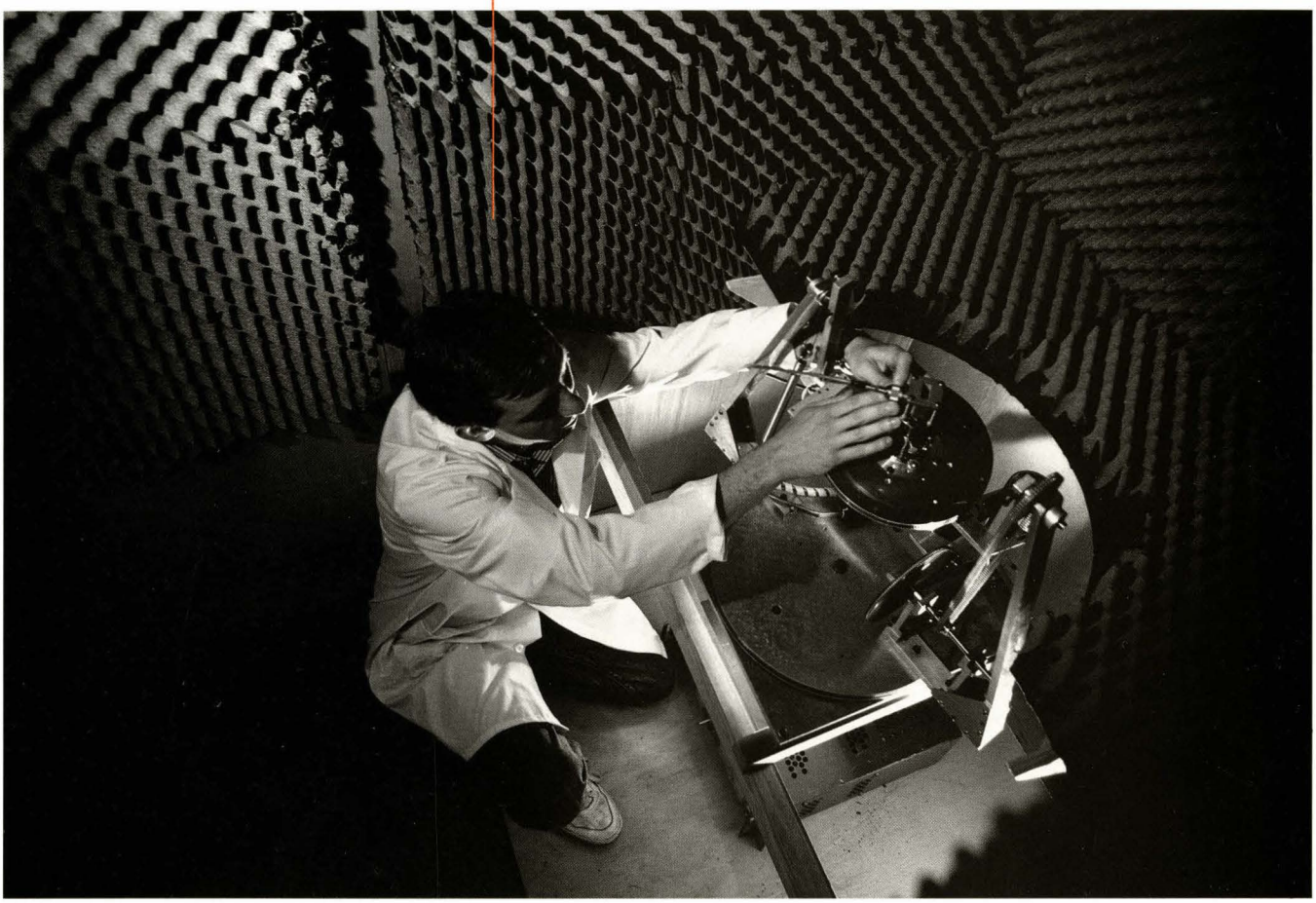
The past is but prologue. Our challenge in the years ahead will be to build upon a foundation set by those who have come before, who have thought well and worked hard to establish our present Institute. As we change to meet new challenges, we shall continue to stand for quality, to focus on a few important areas of study, and to aspire to be second to none.

Thomas E. Everhart

Thomas E. Everhart
President



Dr. Thomas E. Everhart with Dr. Ruben F. Mettler at Everhart's inauguration as president of Caltech, April 12, 1988.



"We have returned good measure to society, both in the results of our research and in the young people who have gone forth with an excellent education to make their mark upon the world."

DR. THOMAS E. EVERHART

A research fellow in electrical engineering tests a microwave antenna.

Biology

Caltech researchers have identified a specific binding site on the cell-surface protein that the AIDS virus must latch onto before infecting a cell. In addition, the researchers created a synthetic version of that binding site and have demonstrated that this synthetic protein fragment acts as a decoy to prevent the virus from infecting cells in test tubes.

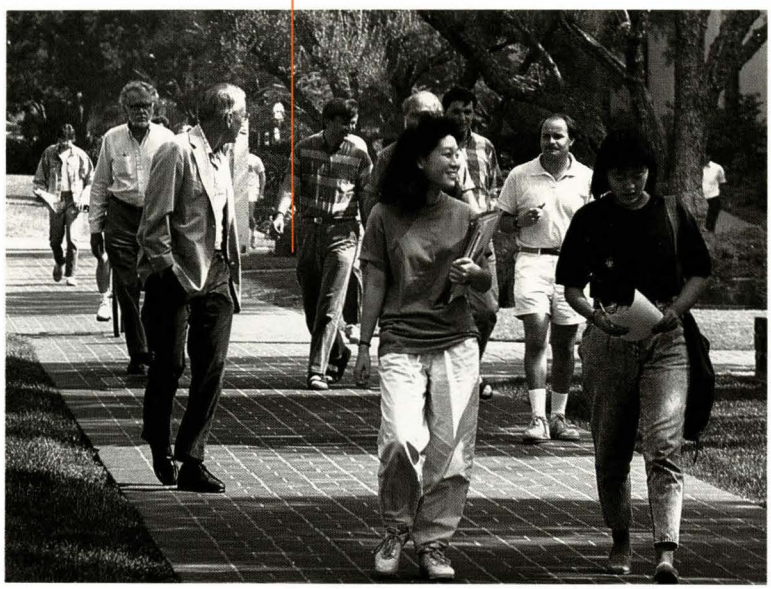
The researchers cautioned that this does not constitute a cure for AIDS. Nevertheless, they regard this as a significant advance not only in AIDS research but in virology in general. This is the first time that the binding site for any virus has been identified with this degree of precision.

The initial step in AIDS infection is the binding of the virus to susceptible cells. If researchers could synthesize large quantities of a protein fragment that include the binding site, these might be made to act as decoys, overwhelming AIDS-virus particles and preventing them from infecting cells.

The researchers relied on the fact that the entire amino acid sequence is known for CD4, the protein to which the AIDS virus binds. The first thing the Caltech researchers did was to synthesize 10 overlapping segments of the CD4 protein, each about 30 amino acids in length. The researchers then used a panel of monoclonal antibodies, each of which binds to a different segment of CD4. Some of these monoclonal antibodies have the ability to prevent the AIDS virus from infecting susceptible cells and some do not.

The researchers reasoned that the antibodies that prevent the virus's infectivity are likely to be attaching themselves at or near the binding site. They tested each synthesized CD4 fragment against each antibody in the panel, and by doing this they were able to determine which antibodies attached themselves to which CD4 fragments. It turned out that the antibodies that prevented infectivity happened to attach themselves preferentially to a particular CD4 fragment. It is this fragment that contains the binding site.

The next step was to synthesize just that part of the CD4 molecule that contains the binding site and to see if the binding site alone inhibits infectivity. The synthesis of that fragment was performed at Caltech and the infectivity assay was performed at the University of Alabama. (There are no laboratories at Caltech working with live AIDS virus.) This assay showed that the fragment did, in fact, inhibit AIDS infectivity. Three other fragments of the CD4 molecule, taken from areas adjacent to the presumed binding site, were used as controls. They had no such inhibitory effect.



Noontime along the Olive Walk.

Chemistry and Chemical Engineering

Plastics are so much a part of our lives, from Astroturf to zippers, that one might think that almost anything that can be made of plastic has been. Not so: Over the last two years, researchers at Caltech have developed ways to create materials with properties not usually found in plastics, such as the ability to conduct electricity.

Plastics are polymers—enormous molecules made by linking together hundreds, or even thousands, of small molecules called monomers. The specific properties of a given polymer sample depend largely on the precise number of monomers per polymer molecule, a difficult quantity to control precisely until now.

Caltech chemists have discovered a family of catalysts that assemble monomers the way a riveting machine assembles steel plates—one by one at a constant rate, and that can be turned on and off at will. These catalysts give chemists the control they need to create precision-designed polymers with exotic properties—polymers that had previously been difficult or impossible to make.

For example, an electrically conductive form of polyacetylene has been known since the 1970s. But research progressed slowly. The material had to be made from highly explosive acetylene gas, and could only be made in films thinner than an eyelash. The new techniques use easy-to-handle liquids, and can make chunks of plastic in any size and shape.

The researchers are now trying to create polymers whose conductivity can be altered at will. Such variable conductors might be used as switches or sensors. Optically conductive plastics are also feasible. A variable optical conductor could be useful in fiber optics.

Other polymers are designed for their structural properties: strength, flexibility, elasticity, crystallinity, and so forth. Some have unique chemical properties. One family of molecules may be useful as a binder (the material that holds the other ingredients together) for solid rocket fuel. Another shows promise to mimic certain proteins' abilities to select and transport specific ions across membranes. And still on the drawing board is a polymer family the researchers hope will have magnetic properties.

Engineering and Applied Science

Today's computers are reaching an information bottleneck. The chips on a circuit board can process information faster than the wires connecting the boards can carry it. A system using lasers to send information as

pulses of light through fiber optic cables wouldn't be bound by the limits that hobble copper wires, but the lasers would have to be incredibly tiny, require virtually no power to operate, and be capable of turning on and off almost instantaneously.

This past year Caltech researchers made such a laser. It's made of semiconductors: infinitesimal gallium arsenide layers on a much larger silicon chip. (Creating these layers to the requisite quality standards is a first in its own right.) The laser measures 300 microns, or 300 millionths of a meter, long by 1 micron wide by 0.005 microns—a mere 20 atoms—thick, and has the lowest ever threshold current, or amount of power needed to turn on the laser. It requires a mere 0.5 milliamps—a 20-fold reduction from conventional lasers and close to the theoretical minimum for this kind of device. Called a quantum-well laser, it is so small that the electrons within it can only move in two dimensions (length and width). This small size means it takes very few electrons to operate the device, enabling it to switch on and off in response to pulses of electrical current in less than 2×10^{-11} seconds, a record-breaking response time. Such lasers are expected to become a critical component of computer design in 4 to 5 years.

But that's only one step to making ultimately small devices. Next comes a 100-atom-wide quantum wire, so small that electrons can only move lengthwise, and ultimately a quantum dot, where the electrons essentially can't move at all. Quantum wire lasers should have a threshold current another 10 to 20 times lower than quantum wells. Caltech scientists are beginning to build and test these devices, which may be in use by the year 2000.

Building these devices is formidable, but testing them is even more daunting. The researchers have had to develop sophisticated techniques just to be able to see what they're doing. They've built a three-legged probe that walks a tiny optical fiber across the crystal. When an electron beam irradiates the crystal, its atoms emit light at characteristic frequencies. The fiber collects this light from an area 0.05 microns square to locate the quantum zone on the crystal. The probe also uses an 0.2-micron-diameter needle from a scanning tunneling electron microscope as the world's tiniest jumper cable. Once the device has been located, the needle sends an electric current through it, and the same fiber collects any light it emits.

Geological and Planetary Sciences

Recent advances in radiocarbon dating have led to the discovery of an intriguing pattern in the occurrence of prehistoric earthquakes along the San Andreas fault. The new analysis indicates that the past 10 large earthquakes on this segment of the fault have occurred in bursts of two or three closely timed earthquakes separated by 200- to 330-year-long periods of dormancy.

The radiocarbon analysis depends largely on data from sedimentary layers at Pallett Creek, California. This site is traversed by a section of the San Andreas fault that last experienced a large earthquake 132 years ago, in 1857. The sedimentary layers show clear evidence of 12 earthquakes within the last 1,800 years, the 10 most recent of which Caltech scientists have been able to date with higher precision than ever before.

To date the prehistoric earthquakes, the researchers collected samples of peat layers broken by the fault during large temblors. By using recent innovations in the radiocarbon dating method, they were able to achieve much more precise dates for the 10 earthquakes than had previously been possible. Previously, the radiocarbon date determinations for each prehistoric earthquake had

been uncertain by about a century. The new analysis reduces most of the uncertainties to less than 25 years.

The researchers estimated that the average time between large earthquakes on the segment of the San Andreas nearest Los Angeles is about 131 years. The previous earthquake dates, based on less precise analyses, indicated an average recurrence interval of about 145 years.

Although a cursory glance at this 131-year average recurrence interval suggests that we are due for a large quake, since the great Fort Tejon quake of 1857 occurred just 132 years ago, a closer examination of the dates indicates considerable variability in the intervals between quakes. Five of the nine intervals are less than 100 years long, and three of the remaining four are about two to three centuries long.

Despite these variations, these 10 earthquakes seem to occur in a regular pattern. Groups of two or three quakes occurring within a relatively short period have been followed by much longer periods of quiescence. The researchers say that if this pattern continues into the future, it will be important for them to determine whether we are now in one of the very long or one of the very short periods. If we are now in the middle of a long quiescent period, for exam-

A number of awards, prizes, and honors were conferred upon faculty members last year.

National Medal of Science:

George W. Housner, the Carl F Braun Professor of Engineering, Emeritus, for his profound and decisive influence on the development of earthquake engineering worldwide. This is the 23rd National Medal of Science awarded to a Caltech faculty member or alumnus.

American Association for the Advancement of Science, Fellow:

Don L. Anderson, Professor of Geophysics; Director, Seismological Laboratory
Thomas E. Everhart, Professor of Electrical Engineering and Applied Physics; President
Murray Gell-Mann, Nobel Laureate, Robert Andrews Millikan Professor of Theoretical Physics

National Academy of Sciences, Member:

Fred C. Anson, Professor of Chemistry; Chairman of the Division of Chemistry and Chemical Engineering

National Academy of Sciences, James Craig Watson Medal:

Robert B. Leighton, William L. Valentine Professor of Physics, Emeritus, for his achievements in astronomy

American Academy of Arts and Sciences, Fellow:

Peter Dervan, Bren Professor of Chemistry

Gairdner Foundation International Award:

Edward B. Lewis, Thomas Hunt Morgan Professor of Biology, Emeritus, for his pioneering research on how genes direct an embryo's growth

Royal Society of London, Fellow:

Philip G. Saffman, Professor of Applied Mathematics

Royal Astronomical Society of Great Britain, Gold Medal:

Don L. Anderson, Professor of Geophysics; Director Seismological Laboratory, for his investigations into the structure of the Earth's deep interior

Guggenheim Fellowship:

Roger D. Blandford, Richard Chace Tolman Professor of Theoretical Astrophysics
Barry M. Simon, IBM Professor of Mathematics and Theoretical Physics

Presidential Young Investigator Award:

Brent T. Fultz, Assistant Professor of Materials Science
Christof Koch, Assistant Professor of Computation and Neural Systems
Shrinivas R. Kulkarni, Assistant Professor of Astronomy
Paul W. Sternberg, Assistant Professor of Biology
Kerry J. Vahala, Assistant Professor of Applied Physics

Office of Naval Research Young Investigator Award:

Frances H. Arnold, Assistant Professor of Chemical Engineering

Searle Scholar Award:

Howard Lipshitz, Assistant Professor of Biology
Paul W. Sternberg, Assistant Professor of Biology

Sloan Research Foundation Fellowship:

David J. Anderson, Assistant Professor of Biology
S. George Djorgovski, Assistant Professor of Astronomy
Shrinivas R. Kulkarni, Assistant Professor of Astronomy

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

Bruce E. Cain, Professor of Political Science
Paul H. Patterson, Professor of Biology
Charles W. Peck, Professor of Physics
Thayer Scudder, Professor of Anthropology
Charles L. Seitz, Professor of Computer Science
Kerry J. Vahala, Assistant Professor of Applied Physics

ple, the probability of a large earthquake along the section of the San Andreas nearest Los Angeles would be exceedingly small.

The Humanities and Social Sciences

During the so-called Dark Ages in medieval Europe, the Normans transformed themselves from scattered and unruly barbarian communities into one of the best organized states in western Europe. Best known for their conquest of England in 1066, and for installing their leader, William the Conquerer, as its king, the Normans can also be credited with laying the foundations of the English legal code and, eventually, the British Constitution.

What made the Normans so successful? Research by a Caltech history professor, published as the book, *Predatory Kinship and the Creation of Norman Power, 840-1066*, has resulted in an explanation that differs from that of most historians. The unification of Normandy, she suggests, grew out of a complicated network of kinship alliances. The notion that an effective state could be built on cooperation expressed in terms of kinship may be remote from our modern experience, but it was, according to the historian, a way of tying together local war bands and therefore of spreading and increasing the bands' security.

The turning point in the development of Normandy, she says, came around 960 A.D., when the quarrelsome descendants of the Vikings had to choose between fighting each other and making a unified stand against the French, who had mobilized to push them out of Normandy. This was the beginning of a recognized leadership, which could channel resources to the seriously endangered and could coordinate policy. Kin loyalty was added to the more fragile bonds of chosen leadership. From then on, not only could this group of cousins-by-marriage defend itself against French threats, but it could (and did) see to it that no other, unallied group flourished in Normandy.

Her research also provides a fresh look at how women were viewed in Norman society. There has been a tendency among historians to see women only as chattel, with no substantive role in the political life of the community. Among the propertied, records show that female heirs were often given preference over their brothers, if the group wished to recruit a talented fighter or wished a particular alliance.

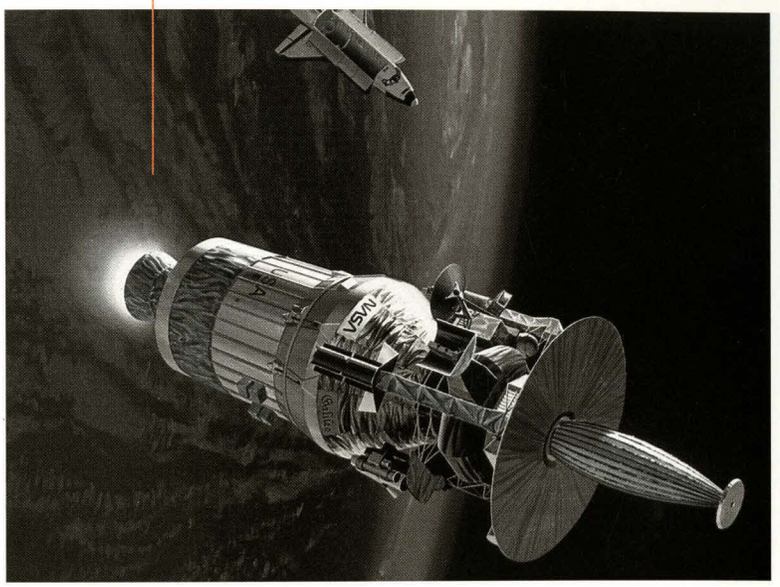
An important aspect of her study is the new light it sheds on the Normans' concept of the exercise and distribution of political power. Unlike most historians, who assume the Normans built a centralized state, with subjects subservient to a few ultrapowerful lords, she now suggests that there was no such state to "obey." The warrior quality of men, and indeed of women, and their ability to act together voluntarily, has been overlooked, resulting in an incomplete understanding of the medieval Norman state.

Physics, Mathematics and Astronomy

In November 1987, a team of Caltech physicists was among the first in the world to witness the creation of chemical elements during a stellar explosion, or supernova. Their findings provided the first direct confirmation of the theory that all of the heavy elements in the universe, from iron to plutonium, are created as massive stars exhaust their nuclear fuel, collapse under their own weight, and explode into space.

The Caltech scientists obtained their data when they observed and measured the gamma-ray spectrum of Supernova 1987A, which detonated in a nearby galaxy in February 1987. At a distance of 170,000 light years, SN1987A is closer to Earth than any supernova observed in the last four centuries and the first to be closely scrutinized with modern astronomical instruments.

The researchers carried out their observations with a highly sensitive



The Galileo spacecraft is carried away from the Space Shuttle by a burn of its Inertial Upper Stage rocket.

gamma-ray telescope designed and built at Caltech. Because Earth's atmosphere interferes with gamma-ray detection, the two-ton instrument was lofted by balloon to an altitude of 120,000 feet from a NASA launch site in Alice Springs, Australia. To counteract the balloon's rotation, the telescope was equipped with a specially designed, computer-controlled pointing platform, which kept it accurately pointed at the gamma-ray source.

According to the theory of nucleosynthesis, the intense heat and pressure within a supernova fuse the star's lighter chemical elements into progressively heavier ones. Among these elements are nickel, which then decays to radioactive cobalt. As the cobalt in turn decays to iron, it emits gamma rays. It was these rays that were detected and measured by the Caltech researchers.

Two other teams at the Alice Springs site also observed gamma-ray emission in the general direction of SN1987A. However, only the Caltech instrument had enough resolution to verify that the radiation could be emanating from no other source, a crucial point in confirming the nucleosynthesis theory. In the months ahead, Caltech's gamma-ray physicists will be looking to verify reports that SN1987A has evolved into a superdense, compact neutron star, an event that would confirm yet another tenet of supernova theory.

Jet Propulsion Laboratory

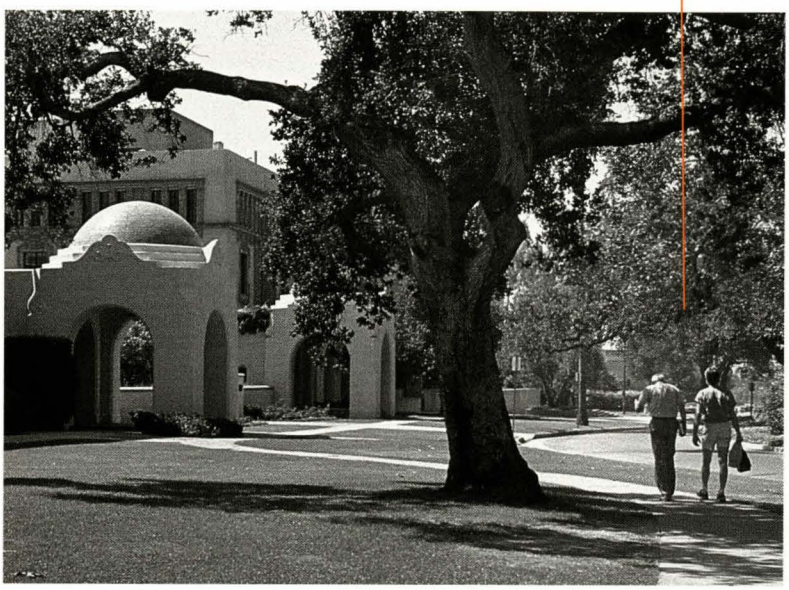
Caltech operates the Jet Propulsion Laboratory under contract to the National Aeronautics and Space Administration. The Laboratory is the principal architect of NASA's efforts to explore the solar system.

NASA returned to space in September with the successful flight of the space shuttle Discovery, and JPL stepped up its preparations to launch its spacecraft that had been delayed by the loss of the shuttle Challenger in January 1986.

The Challenger's loss did not, of course, adversely impact the mission of the two Voyager spacecraft. Voyager 2 is approaching its final planetary encounter—with Neptune in August 1989—and Voyager 1 continues to explore the outer solar system, searching for the transition between interplanetary and interstellar space.

Magellan, a mission to explore Venus with an imaging radar, is scheduled to be launched in April 1989. Magellan will spend almost a year orbiting Venus and will provide the first high-resolution maps of that planet's surface. It will be the first JPL planetary spacecraft to be launched by NASA's space shuttle, and the first launch of a JPL spacecraft since the Voyagers in 1977.

Galileo, the long-awaited mission to orbit Jupiter and probe its atmosphere, is due to be launched in October 1989. Galileo will spend at least 20 months observing Jupiter, its four largest satellites, and its



The west side of campus.

magnetic environment. The spacecraft will arrive at Jupiter in December 1995.

The Mars Observer and Ulysses missions, to Mars and the Sun's polar regions, respectively, await launch in later years.

Meanwhile, this year the Laboratory moved forward with plans for a project to probe a comet and the planet Saturn. NASA planned to present the Comet Rendezvous Asteroid Flyby and Cassini missions to the Administration, for approval by the Congress.

Late in the year, JPL was chosen by NASA for a major role in its new Earth-Observing System, to put instrument-laden platforms in Earth orbit to study our home planet as a total entity or system. Such an approach to Earth science has never been taken before. JPL will manage one of the two space platforms and will assist NASA's Goddard Space Flight Center in development and operation of the other. The Laboratory will also provide many key instruments for the Earth-Observing System, including an Atmospheric Infrared Sounder. That instrument will provide an important data base on global warming, depletion of Earth's ozone layer, the air-sea interface, and other parameters.

Other non-flight projects made important progress during the year. For example, the Hypercube parallel-processing computer moved forward with fabrication of the Mark III version. The Hypercube promises to outperform even the fastest current serial-processing supercomputers. The project enjoys extremely close cooperation between JPL and the Caltech campus.

Administrative Appointments

The Institute honored several faculty members with administrative appointments this last year. Edward C. Stone, Jr., Professor of Physics, became the Institute's first Vice President for Astronomical Facilities, in which capacity he will be responsible for Caltech's involvement in the design, construction, and start-up phases of the W. M. Keck Observatory and Telescope in Hawaii. In addition, he will represent Caltech in policy-making and negotiating aspects of the joint project with the University of California. Another first-time appointment was made to Charles R. Plott, the Edward S. Harkness Professor of Economics and Political Science, who was named the Director of the Laboratory of Experimental Economics and Political Science. Serving as the new Chairman of the Division of Physics, Mathematics and Astronomy is Gerry Neugebauer, Howard Hughes Professor and Professor of Physics, and Director of Palomar Observatory. Norman R. Davidson, Norman Chandler Professor of Chemical Biology, Emeritus, was named the Acting Chairman of the Division of Biology. Christopher E. Brennen, professor of mechanical engineering, became the new Dean of Students.

The Institute has long been recognized for the excellence of its educational programs. National attention was focused on this last fall, when *U.S. News and World Report* ranked us as one of the top three institutions of higher learning in the United States. "If the quality of a college faculty can be measured by its professorial 'stars,' then the constellation at the California Institute of Technology ranks among the most luminescent on any American campus," the magazine stated. It went on to credit our faculty for "the sort of intellectual critical mass that any national university might envy," and cited Caltech's "overall student-faculty ratio of 3 to 1 and an astronomical instructional budget of $24,206 per student."

The Institute is also winning recognition for its outreach education projects—ranging from Vice Provost David Goodstein's *The Mechanical Universe* physics telecourse, which has captured more than a dozen national and international awards—to the elementary school hands-on science education project, which was fostered by professors Jerome Pine and James Bower.

The beginning of the tenth year of SURF (Summer Undergraduate Fellowships Program) was celebrated last summer. A group of 173 students "surfed," as compared with only 18 participants in the first year. SURF has now become the model for similar programs across the country.

And, in a project squarely focused on the future, a team of three Caltech undergraduates won the grand prize in the "Race for Space Software Chase," co-sponsored by the Smithsonian's National Air and Space Museum and Apple Computer, Inc. The goal of the contest was to develop an interactive software program, using the Macintosh II computer, "that demonstrates how computers can give wings to aeronautical ideas that otherwise might not get off the ground." The winning program will go on display in the National Air and Space Museum's new Aerospace and Computing Gallery, scheduled to open in 1989, where it will be viewed by the 9 million people who visit the museum each year. The Caltech team members were Pierce T. Wetter III, Glenn C. Smith, and Michael Meckler.

Thomas J. Watson Fellowship:
- Kenneth D. Haynes, independent studies program major, for travel in Europe to investigate the classical role of the city in man's perception of himself

National Science Foundation Incentive for Excellence Scholarship Award to Minority Students:
- Miguel Errea, Senior in Mechanical Engineering
- Philip Fernandez, Junior in Electrical Engineering
- Gregory James, Sophomore in Aeronautical Engineering

National Science Foundation Creativity in Science Fellowship:
- John W. Miller, Ph.D. Candidate in Electrical Engineering

Alfred P. Sloan Doctoral Dissertation Fellowships:
- Renato Feres, Ph.D. Candidate in Mathematics
- Patrick Legros, Ph.D. Candidate in Social Science
- Guofu Tan, Ph.D. Candidate in Social Science

"Caltech is grateful for the support of all our benefactors, who have shared our dream of a better tomorrow through vitality and excellence in science and technology."

DR. THOMAS E. EVERHART

The W.M. Keck Observatory is under construction on Mauna Kea, Hawaii. The 10-meter telescope is scheduled to see first light in 1991.

Fiscal 1987-88's total of $97.4 million in gifts exceeded 1986-87's record total by over $17 million, establishing a new all-time high. This remarkable achievement was obtained through more than 8300 gifts from trustees, alumni, Associates, other individuals, corporations, and foundations. Included in this total were payments of $30 million from Mabel and Arnold Beckman for the Beckman Institute, $10 million from the W. M. Keck Foundation for the W. M. Keck Observatory, and $21 million from the estate of Liliore G. Rains. The gift total included $3 million in life income trusts and annuities and $4 million in unrestricted support, which was provided primarily by The Caltech Associates, the Annual Fund, and the Industrial Associates.

Fund-raising activity continued to be focused on the Beckman Challenge, Phase II of which requires the Institute to raise $10 million in endowment from its Trustees to qualify for an additional $10 million from the Beckmans. Caltech successfully completed Phase I of the Challenge last year, qualifying for $40 million of the $50 million pledge. Caltech's Trustees have contributed $5.4 million thus far toward the $10 million Phase II goal.

Trustee Donald L. Bren provided a substantial gift to the Institute to establish the Bren Professorship of Chemistry, and Dr. Peter B. Dervan was named the first Bren Professor. A bequest from the John E. and Hazel Smits Trust will also be used to establish a professorship. The Institute received $875,000 from The Sherman Fairchild Foundation for continued support of the Fairchild Distinguished Scholars Program. In addition, several other private foundations provided major funding for special projects at Caltech: The Carl F Braun Trust, The James Irvine Foundation, the Lucille P. Markey Charitable Trust, and the Weingart Foundation.

Under the direction of Chairman Stan Holditch, more than 1,000 volunteers led the Annual Fund to another successful year. A total of $1.8 million was contributed by 7,135 donors, representing a better than 45% participation rate. Considering more than half of Caltech's living alumni attended the Institute as graduate students only, this is a remarkable achievement. Caltech has been fortunate through the years to have a loyal group of donors and volunteers, providing a stable base of unrestricted support.

Caltech's Industrial Associates program, encouraging technical exchange between corporations and the Institute, also provides unrestricted support. In 1987-88, the 47 member companies donated over $1 million in unrestricted support,

Students celebrate graduation in their own fashion.

and were responsible for 70% of the $10.5 million total donated by corporations to the Institute. Matching gifts from corporations totaled $427,217.

The Office of Industrial Associates sponsored three conferences attended by over 220 corporate personnel and arranged over 150 campus visits and seminar days for member companies. In addition, Caltech faculty made 37 off-campus visits to companies worldwide and member companies actively utilized the library, publication, and technical information services available through the program.

Though these extraordinary results will be difficult to duplicate in the coming year, the committed involvement of volunteers, friends, faculty, and administration bodes well for the long-term success of Caltech's fund-raising efforts. Caltech Trustees continue to play an important role in funding major initiatives undertaken by the Institute and their leadership will be indispensable as Caltech prepares for its second century of service beginning in 1991.

Associates

Caltech Associates continued to provide a major source of unrestricted gifts to the Institute under the capable leadership of President Hugh Colvin. This group provided $1.5 million in unrestricted contributions and an additional $3.2 million in restricted gifts, totaling $4.7 million. Current total membership is 1142, with 29% being alumni. The President's Circle, those Associates making annual donations of $6,000 or more, number 198, a slight increase over last year's record high.

Associates participated in more than 32 events, including luncheons and dinners with faculty speakers, tours, and a ten-day trip to CERN (the Central European Research Nationale) in Switzerland, led by physicists Barry Barish and Harvey Newman. Geologist Kerry Sieh led a three-day trip to Palm Springs and the Imperial Valley to study earthquakes. Radio astronomers Nick Scoville and Anneila Sargent conducted a tour of the Owens Valley Radio Observatory near Bishop, California.

President Everhart and Dr. Murray Gell-Mann addressed the Annual Black Tie Event for the Associates in October, and Mrs. Everhart hosted a holiday tea for women at the Athenaeum in December.

Alumni Association

The Caltech Alumni Association, numbering 7,059, or 44 percent of the alumni, was led this year by President David J. D. Harper, Vice President Charles H. Holland, Jr., Treasurer Rhonda L. MacDonald, Secretary Edward M. Boughton, and Past President Paul H. Winter. The Association serves the Institute as a whole and all of its approximately 16,000 living graduates.

Major programs for the year included Seminar Day in May, when 1,149 alumni and guests visited the campus for exhibits and faculty lectures, and heard keynote speaker Dr. James C. Fletcher, Administrator for NASA, discuss the challenges and opportunities for space exploration; the annual Rose Parade program; a wine tasting; a Palomar trip; two dinner/theater events—one at the Pasadena Playhouse and the other featuring the Caltech spring musical, *Oliver;* five class reunions; and many chapter activities around the country. Travel/study programs were again offered to Alaska and New England, and work continued on the production of the new alumni directory published in the fall of 1988. Thirty students spent a "day-on-the-job" with Caltech alumni at nine Los Angeles area companies this past summer, while approximately 120 volunteers served as Alumni Admissions Representatives in San Francisco, Denver, New York, Boston, Houston, Chicago, and Washington, D.C.

Heading the eight alumni chapters this year were: Walter A. Specht, Boston; Craig Marks, Cleveland; 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.

The Distinguished Alumni Award—Caltech's highest honor—was conferred on four graduates.

Benoit B. Mandelbrot, IBM Fellow at the Thomas J. Watson Research Center, was recognized for his theory of fractal geometry of nature, a theory that gives insight into the complex shape and structure of the natural world.

William R. Sears, distinguished aeronautical engineer, was cited for his leadership role at Northrop Aircraft Corporation, where he participated in the development of a sequence of notable military aircraft, the best known being the P-61 Black Widow fighter and the Northrop Flying Wing. Sears later went on to found the Graduate School of Aeronautical Engineering at Cornell University.

Hung-Chang Yin, director emeritus of the Institute of Plant Physiology, Academia Sinica, People's Republic of China, received his award for the establishment of a world center of plant biology that has made major contributions to China's achievement of food self-sufficiency.

Robert W. Zwanzig, Distinguished Professor of Physical Science at the University of Maryland, was recognized for his contributions to nonequilibrium statistical mechanics at the deepest fundamental level, work that has brought him worldwide renown.

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, 1988, and the results of its operations for the year then ended. These statements have been reviewed by the Board of Trustees Audit Committee, whose members are designated by an asterisk in the list of board members on page 32 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 $762.3 million to $866.4 million, reflecting an increase of $50.4 million in campus equipment, buildings, and land, and an increase of $54.4 million in investments.

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. Gifts and grants from private sources totaled $106.2 million for fiscal year 1988, an increase of $26.8 million over fiscal year 1987. $8.3 million was realized as the net gain from disposal of investments in fiscal year 1988, compared with $31.7 million for fiscal year 1987.

The *Statement of Operating Expenditures* provides the detail of current fund expenditures for educational and related purposes. Total expenditures for fiscal year 1988 for the campus increased $12.8 million or 8.1 percent over fiscal year 1987. Expenditures for direct costs of sponsored research at the Jet Propulsion Laboratory increased $139.1 million or 15.8 percent.

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

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, 1988 was $424.0 million, compared to $418.2 million at September 30, 1987. 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. Although U.S. equities experienced unprecedented volatility during the weeks surrounding the October 19, 1987 market break, the Institute's investment earnings were generally unaffected. As highlighted on the graph on page 21, endowment income has steadily increased to $22.4 million from $9.9 million ten years ago, a compound annual increase of 8.5 percent. During this period, inflation, as measured by the GNP Deflator, averaged 5.3 percent annually.

Decade in Review

	1978	*1983*	*1988*
Current funds expenditures *(in thousands)*			
Instruction and research (including libraries)	$43,083	$ 74,535	$118,179
Scholarships and fellowships	2,755	5,095	8,383
Institutional and student support	8,247	14,314	24,702
Plant operation, maintenance, and utilities	4,836	9,586	12,573
Total operating expenses	58,921	103,530	163,837
Auxiliary enterprises	2,232	4,435	7,096
Total	$61,153	$107,965	$170,933
Inflation adjusted (1978 dollars)	$61,153	$ 75,002	$101,637
Capital expenditures, campus *(in thousands)*	$ 3,268	$ 12,459	$ 50,381
Jet Propulsion Laboratory, direct expenditures *(in millions)*	269.6	425.2	1,019.3
Total gifts and nongovernment grants *(in thousands)*	13,914	24,747	106,211
Endowment and similar funds at market value *(in millions)*	162.6	248.3	424.0
Investment income *(in millions)*	12.6	19.6	31.3
Tuition rate *(in thousands)*	3.9	7.5	11.0
Student enrollment (first term)			
Undergraduate	826	874	859
Graduate	841	936	963
Total	1,667	1,810	1,822
Degrees granted			
B.S.	168	205	184
M.S.	138	154	123
Eng.	4	1	
Ph.D.	116	136	146
Total	426	496	453

Summary Of Changes In Fund Balances

Year Ended September 30, 1988
(in thousands)

ADDITIONS

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

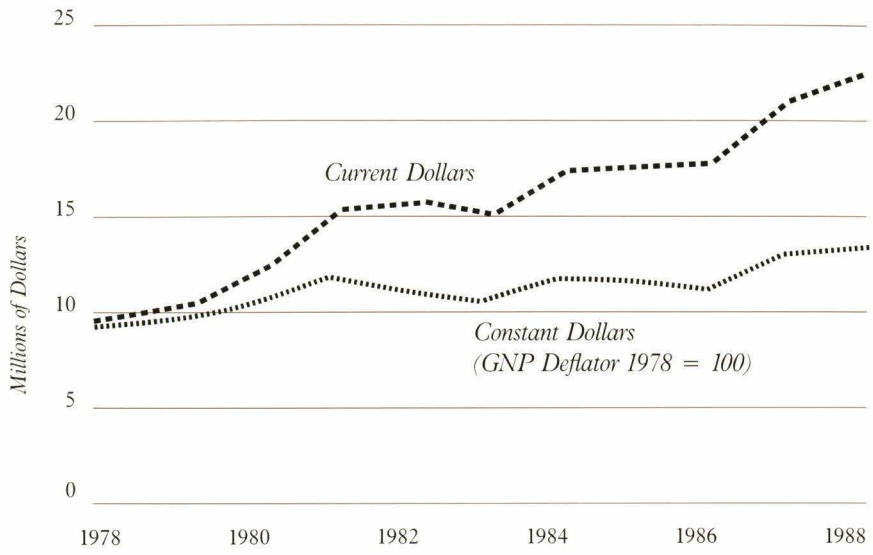
Gifts and Nongovernment Grants Includes gifts and grants from private sources for education and research, and physical facilities.	$106,211
United States Government Grants and Contracts Reimbursement from various government agencies for direct costs of research, instruction, and student support.	59,632
Plant Acquisitions Additions to campus plant for land, buildings and equipment.	45,632
Indirect Costs and Management Allowance Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	41,073
Investment Income Endowment income and investment income of other funds, including earnings from short term investments.	31,261
Tuition and Fees Tuition and fees assessed students.	19,424
Realized Gains Net realized gains on investments sold.	8,292
Auxiliary Enterprises Revenues from sales by food services, student housing, and bookstore.	7,832
Other Income from sales and services, and other miscellaneous revenue.	1,751
Total Additions	$321,108

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.	$65,711
Instruction Expenditures for activities that are part of the instructional program, including departmental research.	52,468
Plant Fund Consists of expenditures for buildings, equipment, renewals, payments on interfund advances for plant purposes, as well as retirement of plant assets.	43,550
Institutional and Student Support Expenditures for business and financial affairs, student services, Institute relations, and general administration.	24,702
Plant Operations Expenditures, including utilities, for the operation and maintenance of the campus grounds and facilities.	12,573
Scholarships and Fellowships Awards made to students enrolled in formal course work, with no requirement that they perform services or repay the awards.	8,383
Auxiliary Enterprises Expenditures, including maintenance, of auxiliary enterprises.	7,096
Other Includes payments to life beneficiaries with life income and annuity agreements and miscellaneous other charges.	2,464
Total Deductions	216,947
Increase in Fund Balances	104,161
Total	$321,108

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

The Institute's life income and annuity agreements consist of pooled income funds, annuities, and taxable and nontaxable unitrusts. Investment assets include cash equivalents, equities, and fixed-income securities (including tax-exempt municipal bonds, where appropriate), real estate, and various royalty interests. The Institute functions as trustee, with the majority of the marketable securities managed by a major institutional investment advisory firm. The Institute does not charge a trustee fee at present. At September 30, 1988, the market value of the life income and annuity funds was $39.7 million.

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

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

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

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

Exhibit 1

BALANCE SHEET

California Institute of Technology

(in thousands)

September 30, 1987

	Total All Funds
ASSETS	
Cash	$ 1,074
Accounts receivable:	
United States government (note B)	148,168
Other	3,318
Student accounts and notes receivable	9,960
Investments (notes A, C and D)	448,919
Interfund advances	
Prepaid expenses and other assets	2,777
Campus properties (notes A and D):	
Equipment	146,034
Buildings	166,419
Land	16,369
	$943,038
LIABILITIES AND FUND BALANCES	
Accounts payable and accrued expenses (note B)	$153,759
Deferred student revenue	3,992
Funds held in custody for others	1,811
Annuities payable (note A)	1,212
Revenue bonds payable (note I)	20,000
Fund balances	762,264
	$943,038
Fund balances (Exhibit 2):	
United States government grants refundable	$ 3,993
Institute funds–	
Unrestricted	5,386
Discretionary endowment:	
Unrestricted	62,956
Restricted	45,338
Endowment principal	242,448
Other restricted funds	98,339
Invested in plant	303,804
	$762,264

See accompanying notes to financial statements

September 30, 1988

Total All Funds	*Current Funds*	*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*
$ 1,059	$ 262	$ 468		$ 329	
173,017	173,017				
3,564	3,465			99	
10,986	4,311	6,675			
503,338	32,241	1,586	$390,237	35,699	$ 43,575
	2,650		6,363		(9,013)
3,359	3,359				
161,715					161,715
199,992					199,992
17,496					17,496
$1,074,526	$219,305	$8,729	$396,600	$36,127	$413,765
$ 179,554	$175,406		$ 239	$ 420	$ 3,489
4,712	4,712				
2,700	869		1,831		
1,135				1,135	
20,000					20,000
866,425	38,318	$8,729	394,530	34,572	390,276
$1,074,526	$219,305	$8,729	$396,600	$36,127	$413,765
$ 4,465		$4,465			
6,533	$ 2,815				$ 3,718
65,763			$ 65,763		
62,398			62,398		
266,369			266,369		
114,184	35,503	4,264		$34,572	39,845
346,713					346,713
$ 866,425	$ 38,318	$8,729	$394,530	$34,572	$390,276

(in thousands)

STATEMENT OF CHANGES IN FUND BALANCES

California Institute of Technology

Exhibit 2

	Year Ended September 30, 1987
	Total All Funds
Fund balances at beginning of year (Exhibit 1)	$658,479
Revenues and other additions (notes A, E and H):	
Student tuition and fees	18,301
Investment income	28,314
Net gain on disposal of investments	31,746
Gifts and nongovernment grants	79,410
United States government grants and contracts–	
Reimbursement of direct costs	53,817
Recovery of indirect costs and management allowance	37,533
Auxiliary enterprises revenues	7,178
United States government advances	374
Campus property acquisitions ($13,246 included in campus operating expenditures and $32,386 included in campus property acquisitions, payments on interfund advances and renewals)	47,934
Other	1,669
Total revenues and other additions	306,276
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(158,182)
Campus property acquisitions, payments on interfund advances and renewals	(36,433)
Retirement and disposal of campus properties	(3,479)
Interest on advances for plant purposes	(508)
Interest on revenue bonds payable	(1,650)
Payment to life beneficiaries	(1,902)
Other	(337)
Total expenditures and other deductions	(202,491)
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	103,785
Fund balances at end of year (Exhibit 1)	$762,264

See accompanying notes to financial statements

Year Ended
September 30, 1988

Total All Funds	*Current Funds*		*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*
	Unrestricted	*Restricted*				
$762,264	$ 2,209	$28,982	$7,516	$350,742	$31,015	$341,800
19,424	19,424					
31,261	11,015	14,557	192		2,183	3,314
8,292				7,809	483	
106,211	6,860	23,393	488	41,188	3,741	30,541
59,632		59,527				105
41,073	41,073					
7,832	7,832					
203			203			
45,632						45,632
1,548	478	546	124		92	308
321,108	86,682	98,023	1,007	48,997	6,499	79,900
(170,933)	(79,610)	(91,323)				
(38,478)						(38,478)
(2,830)						(2,830)
(592)						(592)
(1,650)						(1,650)
(2,183)					(2,183)	
(281)			(281)			
(216,947)	(79,610)	(91,323)	(281)		(2,183)	(43,550)
	(656)	(2,362)		3,018		
	2,800			(2,800)		
	(6,927)			(5,204)		12,131
		44	458	257	(759)	
	(1,683)	2,139	29	(480)		(5)
	(6,466)	(179)	487	(5,209)	(759)	12,126
104,161	606	6,521	1,213	43,788	3,557	48,476
$866,425	$ 2,815	$35,503	$8,729	$394,530	$34,572	$390,276

STATEMENT OF OPERATING EXPENDITURES

California Institute of Technology

Exhibit 3

(in thousands)

	Year Ended September 30,	
	1987	*1988*
Educational and general:		
Instruction, including departmental research	$ 49,775	$ 52,468
Organized research	59,836	65,711
Scholarships and fellowships	8,372	8,383
Institutional and student support	22,739	24,702
Plant operation, maintenance and utilities	11,263	12,573
Total educational and general	151,985	163,837
Auxiliary enterprises	6,197	7,096
Total campus expenditures	$158,182	$170,933
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government) (note A)	$880,199	$1,019,312

See accompanying notes to financial statements

NOTE A—SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

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

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, 1988 and 1987, and in turn to accounts receivable from the United States government. Accounts payable and accrued expenses (and related receivables) for JPL amounted to approximately $164,000,000 and $143,000,000 for 1988 and 1987, respectively.

NOTE C—INVESTMENTS

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

	September 30, 1987	1988
Marketable securities—		
Debt securities (approximate market value of $142,940,000 in 1987 and $191,760,000 in 1988)	$151,537,000	$195,978,000
Equity securities (approximate market value of $258,000,000 in 1987 and $230,760,000 in 1988)	182,603,000	196,301,000
	334,140,000	392,279,000
Short-term commercial obligations	60,204,000	58,217,000
Settlements in process—		
Receivables for securities sold	2,132,000	635,000
Payables for securities purchased	(2,516,000)	(1,378,000)
Real estate, less amortization and accumulated depreciation of $2,323,00 in 1987 and $2,325,000 in 1988	25,356,000	24,898,000
Mortgages, notes, and other securities	29,603,000	28,687,000
	$448,919,000	$503,338,000

Investments shown above include the investment pool as follows:

	September 30, 1987	1988
Investment pool assets at year end—		
At carrying value	$315,561,000	$351,699,000
At approximate market value	$376,240,000	$375,990,000
Pool share value at market	$ 19.23	$ 17.28
Annualized income earned per pool share	$ .95	$ .87

NOTE D—CAMPUS PROPERTIES

In January 1985, the W. M. Keck Foundation awarded the Institute $70 million to construct a 10-meter telescope in Hawaii. As of September 30, 1988, the total $70 million had been received: $56 million had been expended and is included in Buildings and $14 million was unexpended and is included in investments of the Plant Funds. Gifts to Plant Funds for the year ended September 30, 1988 include the final $10 million of this award.

NOTE E—FUNDS HELD IN TRUST

The Institute is the income beneficiary of certain funds, recorded at a nominal value, which are held in trust by others and which had current market values, estimated by the Institute, of approximately $14,100,000 and $15,600,000 at September 30, 1988 and 1987, respectively. The income derived from these funds amounted to $717,000 and $744,000 for the years ended September 30, 1988 and 1987, 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 $3,750,000 and $5,740,000 at September 30, 1988 and 1987, respectively, have been excluded from the financial statements due to their revocable nature.

NOTE F—RETIREMENT PLANS

The Institute has three retirement plans covering substantially all 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, 1988, and the funded status at September 30, 1988 for the defined benefit plans are as follows:

Net Pension Cost

	Campus	*JPL*
Service cost—benefits earned during the year	$ 1,719,000	$ 8,027,000
Interest cost on projected benefit obligation	2,333,000	10,911,000
Actual return on plan assets	(1,986,000)	(10,849,000)
Net amortization and deferral	(311,000)	65,000
Net pension cost	$ 1,755,000	$ 8,154,000

Funded Status

	Campus	*JPL*
Actuarial present value of benefit obligations—		
Accumulated benefit obligation, including vested benefits of $35,176,000 and $168,805,000	$37,245,000	$177,658,000
Projected benefit obligation	$39,714,000	$190,523,000
Plan assets at fair value	39,371,000	190,225,000
Projected benefit obligation in excess of plan assets	343,000	298,000
Unrecognized net gains or (losses)	(70,000)	703,000
Unrecognized net asset at October 1, 1987 being amortized over 15.65 and 17.53 years, respectively	83,000	769,000
Accrued pension cost	$ 356,000	$ 1,770,000

NOTE F—RETIREMENT PLANS (CONTINUED)

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 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, 1988 were $3,472,000 for the Campus, and $12,983,000 for JPL.

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

NOTE G—DEFERRED COMPENSATION PLAN

The Institute has established a deferred compensation plan whereunder eligible employees may elect to defer a portion of their normal salary, generally until retirement. The Institute's liability for future benefits payable to active employees under this plan, which approximated $23,020,000 and $19,260,000 at September 30, 1988 and 1987, respectively, is matched by Institute investments in an annuity contract with a major insurance company. It is expected that any payments by the Institute to employees would be matched by payments from the insurance company to the Institute. The amounts representing future benefits payable and the matching investments are not reflected in the financial statements.

NOTE H—PLEDGES

The Institute does not record pledges in its financial statements. At September 30, 1988, the Institute had pledges on hand (principally for restricted purposes) totaling approximately $47,000,000, of which $21,000,000 is expected to be collected in 1989. It is not practicable to estimate the net realizable value of such pledges.

NOTE I—REVENUE BONDS

On December 26, 1985, the Institute borrowed $20,000,000 through the California Educational Facilities Authority for the purpose of constructing, acquiring, and refinancing the cost of certain educational facilities. Funds were obtained through the sale of revenue bonds, repayable together with interest from the general revenues of the Institute over a 30-year period. Interest rate varies from 6.4% to 8.625%. Required principal and interest payments are approximately $2,040,000 a year for the fiscal years 1989 through 2005, and approximately $940,000 a year thereafter until 2016, when the bonds will be fully redeemed. Institute investments include $1,500,000 held by a trustee as a Bond Reserve Fund.

NOTE J—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.

Price Waterhouse

REPORT OF INDEPENDENT ACCOUNTANTS

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, 1988, 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 28, 1988

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