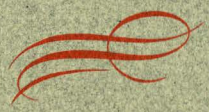
CALIFORNIA INSTITUTE of TECHNOLOGY

Annual Report 1991-92

ON THE COVER:

Nobel prize winner and Noyes Professor Rudy Marcus teaching a graduate-level chemistry class, "Electron Transfer Reactions in Chemistry and Biology."



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. Caltech still has that ambition and that daring.

Thomas E. Everhart

President, California Institute of Technology

We live in a time of profound uncertainty and change. A nation that fails to address this in a systematic, thoughtful way risks losing out economically, militarily, socially, and politically. We believe that Caltech can make a difference as we enter the 21st century. Caltech continues to provide students with the foundations for a career in science and engineering, as well as for life. We also continue to innovate—last year we taught the first freshman course in the country on how to program massively parallel computers. Still, in light of the changing world around us, we must make every effort to be certain we are teaching the right subject matter and providing our students with the right approach to learning. Under the leadership of faculty chairman Jack Richards, we have started a comprehensive review of Caltech's undergraduate curriculum. In science and basic research, Caltech remains at the forefront. The Institute can point with pride to its pivotal role in creating new instruments such as the W. M. Keck Telescope, an ambitious cooperative effort with the University of California, Berkeley. However, while basic research can produce unexpected results—new scientific discoveries, new applications, even new industries—that is not enough. If we believe in a strong competitive United States, we must encourage our graduates to support the competitiveness of U.S. industry, whether they enter the corporate world or remain in academia. Our graduates, after all, are our most effective means of technology transfer. We are expanding our own collaborations with industry. A strong industrial consortium is funding air-quality research here at Caltech. In the area of supercomputing, we have a partnership with Intel and other corporations—we work with prototypes and help in making better computers. We continue to enjoy a strong and productive relationship with the aerospace industry. Our horizons are broadening with regard to

Ruben F. Mettler, Chairman of the Board of Trustees, and Thomas E. Everhart, President.

other kinds of outreach as well. Project SEED (Science for Early Educational Development), created by Institute faculty members concerned by the inadequacies of U.S. precollege science education, is now part of a far larger effort—CAPSI, the Caltech Precollege Science Initiative. Both SEED and CAPSI will likely pay off in future years by turning kids on to science and engineering in grade school and then leading them to institutions such as Caltech. We have already gained many good students who knew Caltech primarily through our *Mechanical Universe* television series. In fact, *The Mechanical Universe* represents a kind of worldwide outreach—it has been copied and translated by other nations, including Japan. Caltech is increasingly involved with other social issues besides education. In response to the L.A. riots, for instance, the Division of the Humanities and Social Sciences has created a new program—Race, Politics, and Region—that will comprise both a think tank and a seminar series. The seminars began last October. Whatever its involvements, Caltech must maintain its sound financial position. It has succeeded in doing so, despite national economic difficulties. The Institute lives within its means and gets the maximum value for every dollar spent. Caltech's endowment has grown in the past five years from $418 million to more than $580 million—a remarkable achievement given Caltech's relatively small size. We are now deriving a slightly larger percentage of our expenditures from our endowment return. Aid from outside sources has shrunk, however, and we are spending more of our endowment income on student aid. The investment committee of our Board of Trustees continues to provide excellent oversight of our investment program. Even as we all miss Jim Glanville, who chaired this committee, his efforts are being carried forward by his successor, Tory Atkins, who is known to many in the Caltech community, and by the new vice chairman, Richard Rosenberg, currently CEO of the Bank of America. Our financial campaign, The Campaign for Caltech: A Second Century of Discovery, is on schedule. By the end of the fiscal year, we had received cash and pledges totaling

nearly $282.7 million. This represents 81 percent of our $350 million goal. Thanks to a generous gift from the Braun family, Caltech has added the Braun Athletic Center to its facilities. This is a very positive contribution to our campus. The center provides world-class weight rooms, squash courts, a dance and aerobics facility, and a huge gym and basketball court. Planning for the Moore Electronic Materials and Structures Laboratory, made possible by a gift from Dr. Gordon Moore, PhD '54, and Betty Moore, is moving ahead. So is planning for a different kind of student-housing facility, for now called Centennial House, which will provide for undergraduates, graduate students, and a few faculty an interactive environment.

Finally, our faculty—the key to Caltech's excellence—continues to receive awards far out of proportion to their numbers. We wish to pay special tribute to Professor Rudy Marcus, who won the 1992 Nobel Prize in chemistry for his work on electron transfer, but many others have won prestigious prizes and awards as well. Faculty and administrators are also continuing to take an active role in Washington on a variety of commissions and advisory boards. The National Science Board Commission on the Future of the National Science Foundation had only two faculty members among its many chancellors and university presidents. One of them was from Caltech. All of this says something about how the quality of our faculty is viewed from the outside.

We at Caltech hope to continue educating the American public, Congress, and industry as to the value of science and engineering, and of universities dedicated to teaching and research. Much work remains to be done, and we are committed to playing our part.

Thomas E. Everhart
President

Ruben F. Mettler
Chairman of the Board of Trustees

The foundation of science generates the power of the imagination.

At the beginning of its second century, Caltech looks back upon a year of pioneering accomplishments in science and engineering, together with contributions to its community and nation.

Laurels and Accolades

Caltech was pleased to celebrate the awarding of the 1992 Nobel Prize in chemistry to Rudolph Marcus, Arthur Amos Noyes Professor of Chemistry. Also of special note, Thomas Ahrens, professor of geophysics, was elected to the National Academy of Sciences, and Charles Seitz, professor of computer science, was elected a member of the National Academy of Engineering. During 1992, Mary Kennedy, professor of biology, and Mary Lidstrom, professor of applied microbiology, were among 100 women nationwide who received Faculty Awards for Women Scientists and Engineers from the National Science Foundation.

Amnon Yariv, Thomas G. Myers Professor of Electrical Engineering and professor of applied physics, was honored with one of the two 1992 Harvey Prizes in Technology—the other was given to former Soviet President Mikhail Gorbachev. The award is given by the Technion–Israel Institute of Technology in recognition of major contributions toward progress in science and technology, human health, literature of the Middle East, or the advancement of peace in the Middle East.

Jack Grunsfeld, senior research fellow in physics at Caltech, may be one of the

astronauts to join the crew of an American spacecraft. Out of more than 2,000 qualified applicants, he was selected by NASA as one of 19 new astronaut candidates for the Space Shuttle program.

Those are among the many from Caltech who received special recognition ranging from the National Science Foundation Young Investigator Awards to the International Neural Network Society's Award for Outstanding Research. A complete listing of honors and awards is given elsewhere in this publication.

Although specific individuals brought many honors to the Institute, the university itself was recognized in several different ways as well. The Institute for Scientific Information ranked Caltech first in the world for the impact of its chemistry

THE NEMATODE REVEALED

Biology

Magnified 25 times, the creatures resemble translucent snakes, sliding across the microscope's stage and stretching out to reveal their inner workings. These animals come in two varieties—hermaphrodites (females that can also produce sperm) and males. Beneath their crystal-clear skin, their reproductive cells are visible—a sight the researchers find exquisite, even though these multicellular animals are merely common roundworms, unearthed in gardens and garbage dumps. It is difficult to imagine that this slithering, serpentlike life form is rapidly altering the face of modern biology.

A growing research field focuses on understanding how this extraordinary creature's cells talk to each other to start the gene-by-gene, molecule-by-molecule development of its reproductive organs. A Caltech worm watcher was part of a team investigating the nematode, believing an in-depth study of the worm's reproductive-organ development, normal or abnormal, might provide insight into this phenomenon in higher animal forms. During 1992 the team made a significant breakthrough: the discovery of a signaling molecule that controls the development of the earthworm's reproductive organs.

This control molecule is a product of the *lin-3* gene, which can be traced back to the same point of origin as the epidermal-growth-factor (EGF) gene in humans, as well as to a related gene in a tumor virus. The *lin-3* gene is crucial to the development of the nematode's reproductive organs. It is also known to activate a series of genes to initiate reproductive-organ development.

Not only is the timing of these signals important, but the quantity of them makes a difference in the extent of reproductive-organ development. When multiple copies of *lin-3* are introduced into the hermaphrodite, the result is the development of extra vulvas. This occurs because the overabundance of this gene simply produces too much of the signaling protein. On the other hand, if *lin-3* is interfered with, the cells that are the precursors to the reproductive organs act as if no signals were sent, and so no vulva is formed.

Researchers have since discovered yet another gene in the nematode that is not only involved in sex-organ development, but resembles an oncogene that causes the uncontrolled growth of cancerous cells when mutated. Although developmental genetics and cancer research were once distinct territories, they have in part merged over the last several years because a Caltech developmental biologist has helped identify genes in the nematode that bear a strong resemblance to known oncogenes in humans. The genes turned out to be key participants in the internal signaling pathways of normal cells. These pathways consist of several proteins, each of which passes a chemical message on to the next protein. The end result may be to turn a gene on or off, or to alter the activity of key proteins, thereby causing a change in the cell. Thus, the cell may begin to divide normally, begin the uncontrolled division of cancerous cells, or become some type of specialized cell.

Nematode biologists believe their study of this experimental animal can provide insight into additional similarities between nematode and human genes. Their research may eventually shed light on genetic diseases and cancer in humans.

"NEW AGE" CRYSTALLOGRAPHY

Chemistry and Chemical Engineering

Next time you visit a home that has a crystal hanging in the window, notice the points of sunlight scattered around the room by the crystal. Now consider trying to figure out the crystal's shape, just by studying the splintered sunshine. Impossible?

That suggests the scale of a major breakthrough announced this year, in which a Caltech researcher and his colleagues used the well-known technique of X-ray crystallography to "crack" the structure of the "active center" of the nitrogenase protein. X-ray crystallography involves first crystallizing a batch of protein molecules, then bombarding them with X rays and recording the X-ray pattern that emerges. By analyzing the pattern, the researchers can decipher the protein's structure.

In revealing this crystallographic breakthrough, the scientists have detailed the arrangement of metal atoms in nitrogenase's "active center." Nitrogenase is an enzyme that enables bacteria to "fix" nitrogen—to convert it from its usual inert, useless state as nitrogen gas into useful ammonia, which living organisms can convert into the amino acids essential for life.

Chemists study nitrogenase because of its ability to fix nitrogen at room temperature. Today's industrial method of fixing nitrogen relies on high temperatures and pressures, and gulps petroleum. If scientists can understand how nitrogenase works, they might replicate it and eventually produce fertilizer and other ammonia-based products for a fraction of their current cost.

Nitrogenase has been known for decades, but no one had been able to determine how it is put together, let alone how it works. The problem is complicated by the fact that it disintegrates rapidly in the presence of oxygen, and by its large size. Nitrogenase is composed of two linked proteins, just one of which contains more than 16,000 atoms.

The Caltech research group simplified the task by studying the two proteins separately. They found that one part, the iron protein, consists of two identical units, bound like pages of a book on a cluster of iron and sulfur atoms. But it was with the other part, the molybdenum-iron or Mo-Fe protein, that they made their significant advance.

A Caltech graduate student proposed that six iron atoms in the active center, located in the Mo-Fe protein, share bonds with only three neighboring atoms, instead of four. This arrangement is almost never seen. Indeed, that may be why the structure eluded researchers for so long—because the arrangement is so unusual.

The nitrogen-fixing reaction is fueled by molecules of adenosine triphosphate, or ATP, a common source of energy in biochemical reactions. The Caltech group proposes that the iron protein in nitrogenase attaches to the ATP, probably by folding its "pages" around the molecule. During this process, the iron protein changes shape, propelling electrons from the iron protein to the Mo-Fe protein, where they flow into the active center.

These electrons are used to convert nitrogen—which is possibly bound to the six unusual iron atoms in the active site—to ammonia. But scientists don't yet understand exactly how this occurs. Attempts to understand the mechanism and to synthesize nitrogenase in the lab will keep chemists occupied for years to come.

research—a ranking based on the number of times that Caltech chemists are cited in scientific papers by researchers at other institutions. In addition, *U.S. News & World Report* rated Caltech number one in its faculty resources and again ranked it fifth overall in the prestigious national university category. It also ranked Caltech's engineering graduate school among the top six in the United States in 1992.

Administrative Appointments

Several notable administrative appointments were made during the year. Roderick Kiewiet, professor of political science, was named dean of students in August 1992. He replaced Christopher Brennen, professor of mechanical

engineering, who had served in that capacity for the past four years, and who is now on sabbatical. John Ledyard, professor of economics and social sciences, was named chairman of the Division of the Humanities and Social Sciences in September 1992, replacing Professor of Economics David Grether, who had served as chairman for ten years.

During 1991–92, we were fortunate to welcome three new members to the Board of Trustees—George Argyros, chairman and chief executive officer of Arnel Development Company, Thomas Cruikshank, chairman of the board and chief executive officer of the Halliburton Company, and Robert Schultz, vice chairman (retired) of General Motors Corporation.

Campaign Highlights

While many universities have recently suffered cutbacks and other financial difficulties, the Institute can be proud that its sound budgetary philosophy has carried it solidly forward. Further, the Institute can report significant progress in its fund-raising campaign, The Campaign for Caltech: A Second Century of Discovery. As of the end of fiscal year 1991–92, Caltech had reached 81 percent of its $350 million goal. The combination of generous support and prudent budgeting has not only helped the Institute add needed facilities—a substantial gift from the Braun family allowed Caltech to construct the Braun Athletic Center, which was dedicated just after the fiscal year closed—but has also allowed Caltech

Ideas tranform and connect
in a rhythm all their own.

FUTURE SHOCK

Engineering and Applied Science

Imagine a futuristic "space plane" making its escape from the earth's gravitational pull. Screaming through the atmosphere at hypersonic speeds of up to Mach 25 (25 times the speed of sound, or about 19,000 miles per hour), the plane brutally pushes the air out of its way in a curved shock wave. The air molecules in this stream dissociate, altering the air's chemistry and playing havoc with aerodynamic principles. The craft, seared by the resultant high temperatures and deformed by high compression, does not yield. In its return from orbit, the vehicle reenters the atmosphere, through the same catastrophic conditions—ready to withstand this abuse again and again.

At the Graduate Aeronautical Laboratories at the California Institute of Technology (GALCIT), scientists are replaying this scenario repeatedly, simulating the aerodynamics and chemical consequences encountered in transportation through planetary atmospheres. The mechanism that enables this study on terra firma is called "T5."

T5 is the shorthand name for the fifth in a series of devices called free-piston-driven shock tunnels. Housed on the top floor of Caltech's Guggenheim Laboratory, it extends 170 feet in length and weighs about 40 tons. On June 25, 1992, T5 was dedicated as a cooperative project between Caltech and the Rocketdyne Division of Rockwell International. Many of the studies being conducted at the T5 shock tunnel relate to the proposed National Aerospace Plane and its air-breathing ramjet engines (designed to scoop up oxygen from the atmosphere rather than from heavy tanks of liquid oxygen).

A shock tunnel operates by creating a high temperature and pressure environment. And it does so in just a fraction of a second, as a 250-pound aluminum piston drives gases down the length of the shock tunnel at the speed of sound. It can compress gas up to 15,000 pounds per square inch and heat it to temperatures in excess of 18,000 degrees Fahrenheit. The tunnel produces flows of gas comparable to those encountered by space vehicles.

During a test run, researchers attend to a long safety checklist. A bank of gauges indicates desired gas mixture and pressure buildup. At the end of a tense countdown, they fire the T5 piston, which pushes a parcel of highly compressed helium toward a quarter-inch steel diaphragm. In a loud burst, the diaphragm ruptures, and the gas instantaneously accelerates 15-fold in a tremendous shock wave. Left in its wake, the center of the steel plate has blown open in a flower-petal-like pattern. The shock heats the test gas, and the hot, pressurized, high-velocity parcel of gas enters a test chamber where model wings or other aircraft components can be subjected to realistic atmospheric conditions.

The knowledge gained through this ground-based experimentation will enable the space plane to become a reality, but this is not the only focus of research. Other applications that can be simulated include entry into the atmospheres of other planets or moons, and space maneuvering that involves aerodynamic braking. The research being done at the T5 facility is not only necessary for further advancement in aeronautics, but is also a key to maintaining a leading role in space exploration.

to remain in the forefront of research universities.

The continued generosity of Caltech's supporters also makes possible other important aspects of the university, such as endowed professorships. This past year, the generosity of Katharine and alumnus Warren Schlinger enabled Caltech to establish the Schlinger Professorship in Chemistry and Chemical Engineering. In addition, Mrs. Nico Van Wingen made a significant donation in trust to be added to the Nico and Marilyn Van Wingen Professorship, established by Mrs. Van Wingen and her late husband, a Caltech alumnus.

As always, the Institute continues to attract top-caliber students. However, Caltech has had to redirect more of its

endowment to student aid; this is a further reason why contributions in the area of endowment continue to be so important.

A gift from the Lambach Family Trust has helped meet this need by establishing the Fritz and Kate Lambach Scholarship Fund, an endowment that will fund two full undergraduate scholarships. Also in support of undergraduate education, the Howard Hughes Medical Institute has awarded the Institute a substantial grant for undergraduate education in the biological sciences.

Recognizing the Institute's continuing need for undergraduate student aid and for unrestricted funds, several alumni of Caltech made significant gifts in trust. A charitable trust gift from Charles and Catherine Blair established a fund for undergraduate student aid and/or undergraduate instruction. The proceeds of a trust established by Mason Logan will be used to create the Mason A. Logan and Mildred B. Logan Fund, both to support the Caltech Radio Club and to provide funds for unrestricted endowment. Mr. and Mrs. Return F. Moore established a substantial charitable trust for unrestricted purposes.

For graduate students, endowed fellowships supported the research of two dozen graduates this past year. A substantial pledge was made by the Charles Powell Foundation for graduate fellows in Engineering and Applied Science. The grant will also include funds to support new faculty and to purchase equipment. Mr. and Mrs. Milton E. Mohr made substantial additions to the Mohr Graduate Fellowship Fund.

In addition, a generous gift from long-time Caltech friend O. K. "Bill" Earl established the O. K. Earl Postdoctoral Fellowship, to be awarded to an outstanding candidate in any field within the Division of Geological and Planetary Sciences.

Professors John and Olga Taussky Todd, both faculty emeriti, endowed the Taussky-Todd Visiting Scholar Fund to bring distinguished mathematicians to campus as visiting scholars. The Taussky-Todd Fund will have a lasting positive impact on mathematics at Caltech.

Not all contributions are in cash. This past summer, Cadence Design Systems donated a substantial amount of electronic design automation software to Caltech, which will be deployed across multiple disciplines on campus. The software will provide students with access to a full array of advanced design tools and solutions—including the technology of integrated circuit design—affording them the opportunity to gain valuable experience using commercial tools to design advanced components.

Caltech has also received significant donations and pledges in direct support of research. Norman Davidson, Norman Chandler Professor of Chemical Biology, Emeritus, and his wife, Annemarie, contributed toward the establishment of the Norman and Annemarie Davidson Fund for Research in Biology. Jesse Greenstein, Lee A. DuBridge Professor of Astrophysics, Emeritus, and his wife, Naomi, established an endowed fund to support research in physics. The Ralph M. Parsons Foundation

renewed from last year its substantial grant to developmental biology, to support research into the mechanisms by which a single-celled egg develops into a highly complex organism.

Caltech has especially appreciated the continued generosity of its support groups during these difficult economic times. This support reflects the dedication of trustees, alumni, Associates, Industrial Associates, and other individuals, corporations, and foundations.

Caltech's Industrial Associates program, encouraging technical exchange between corporations and the Institute, has been a major source of unrestricted support for the past 45 years.

Under the leadership of its president, Doris Pankow, the Caltech Associates has

STATE-OF-THE-ART SEISMOLOGY

Geological and Planetary Sciences

Seismology today is vastly different at Caltech than it was only a decade ago. This is primarily the result of the Institute's improved, 230-station Southern California Seismic Network (SCSN), complemented by TERRAscope, a group of eight state-of-the-art computerized seismic stations. TERRAscope, which is mainly supported by the L. K. Whittier and Arco Foundations, provides data of unprecedented quality that allows seismologists to study earthquakes more rapidly and thoroughly than ever before.

The new technology was put to the test during the 7.4 temblor last summer in Landers, California. Fortunately, the quake occurred in a sparsely populated portion of the eastern Mojave Desert that was surrounded by six of the eight broadband stations constituting TERRAscope. Using the data from TERRAscope and SCSN, seismologists found that the fault ruptured from south to north, with slip ranging from six to 18 feet, on two distinct zones about 18 miles apart. This suggested that at least two distinct faults broke sequentially. In addition, the effects of the northward fault propagation on the distribution of intensity of ground shaking were quickly estimated. In the past such analysis took at least a few days; now the technology enables complete analysis within a few hours, and the time can be as brief as 10 minutes.

Geologists made a very extensive field survey and obtained a detailed picture of surface break; this picture is in remarkable accord with the seismologists' findings. Their combined findings have provided important insight into the mechanics of earthquake faulting and California's ongoing and complex seismic activity.

Landers is the largest quake to have occurred in the contiguous United States in four decades, but it was not generated by the prominent San Andreas fault. It began with the failure of the minor Johnson Valley fault. As the earthquake grew in size, ruptures propagated onto several nearby large faults. Indeed, scientists expressed concern that such a phenomenon might trigger the San Andreas fault. Most individual faults in the Landers area are relatively short, and most scientists had expected that the maximum earthquakes in this area would be no larger than 6.5. The Landers earthquake demonstrated that many small faults can break sequentially to activate a very large earthquake.

Rapid determination of an earthquake's characteristics, such as location, depth, and size, is very important. All of those factors directly control the distribution of damage. Considering those parameters, Caltech and the U.S. Geological Survey initiated a pilot project in early 1991 called CUBE (Caltech/USGS Broadcast of Earthquakes). This is a cooperative research project between Caltech, USGS, and several utility and transportation firms. CUBE quickly broadcasts earthquake information obtained from SCSN and TERRAscope via a radio pager-computer display system. This information is used by the utility and transportation firms to identify areas of potential damage, and that role was essential during the Landers earthquake. Also, Caltech's newly created Earthquake Media and Exhibit Center, funded by the Times-Mirror Foundation and jointly operated by Caltech and the USGS, played a key role in providing up-to-the-minute earthquake information to journalists.

Solutions are the result of single thoughts gathered together in a partnership of ideas.

continued to provide a significant source of unrestricted gifts to the Institute. Last year, members of The Associates also made substantial restricted outright gifts.

More than 5,500 donors, primarily alumni, participated in Caltech's Annual Fund, providing ongoing support for current Institute programs. The Institute received 23 bequests and 17 planned gifts during the fiscal year. Most of these will support endowment needs.

Caltech's Graduates

Despite a tight job market, the plans of the 191 members of the class of '92 receiving their BS degrees were similar to those of '91. Graduates in computing or electronics had the most job offers. Fifty-eight percent of the class went on to graduate work—the largest percentage in more than 20 years. Of the 132 MS recipients, most plan to continue working toward their PhDs at Caltech. Just over 15 percent of those with master's degrees went into industry, as did the four graduate students who earned engineer's degrees—mostly electrical engineering, aeronautics, or chemical engineering. Of the 134 PhD recipients, 41 percent accepted positions in industry. Another 52 percent accepted postdoctoral research or tenure-track positions; the small remaining percentage went on to further study or other endeavors.

More than 17,500 alumni serve as living examples of Caltech's excellence in education. Six Caltech graduates received Distinguished Alumni Awards at the

Caltech Alumni Association's 55th Annual Seminar Day this past May. Those receiving Caltech's highest honor included Robert Hall, BS '42, PhD '48, a prominent former physicist with the General Electric Research and Development Center; Chia-Chiao Lin, PhD '44, Institute Professor Emeritus at the Massachusetts Institute of Technology; Robert Parks, BS '44, retired deputy director of Caltech's Jet Propulsion Laboratory; Irving Reed, BS '44, PhD '49, the Charles Lee Powell Professor of Electrical Engineering and Computer Science at the University of Southern California; Ozires Silva, MS '66, Brazil's minister of infrastructure; and Mark Wrighton, PhD '72, provost and holder of the CIBA-GEIGY Chair in Chemistry at the Massachusetts Institute of Technology.

WILL RUSSIAN DEMOCRACY SURVIVE?

The Humanities and Social Sciences

Decades ago, when the Soviet Union wrote its national anthem, it was impossible for the anthem-makers to agree on lyrics; thus the song never had any words. As the Russian Federation faces the challenge of designing political institutions for a democratic system of government, the hope is that this time the country's *political* tunesmiths will find a voice.

But such an outcome is by no means certain, say Caltech political scientists who visited Russia earlier this year to observe the nation's efforts to put democratic principles into practice. A Caltech analysis of one of those efforts—the drafting of Russia's constitution—was published in the newspaper *Izvestia*. The critique points out that although the document "represents a valiant attempt at establishing a viable democracy, its philosophy is deficient in ways that preclude it from fulfilling its original promise."

The draft constitution runs to 45 pages, and its length and content, according to the critique, reflect a fundamental confusion about the role of political institutions in a democracy. The document's authors appear to view the constitution as a complex business contract between the Russian people and their government, rather than as a document whose aim is to define the state and safeguard individual freedoms. Instead of representing a general, guiding statement of governing philosophy and institutions, the draft attempts to provide for virtually any social or political situation that may arise. This excessive attention to detail, according to the critique, derives from the fact that the Russian people have traditionally placed little trust in promises and even less faith in constitutional guarantees.

What is the outlook for participatory democracy at the grass-roots level? A second analysis focused on the emergence of voting patterns in Russia and concluded that, with their unbroken history of authoritarian rule, the Russian people do not yet understand the role of political parties in pluralistic societies. A party system does seem to be emerging, however, in which the supporters of President Boris Yeltsin represent the forces of reform. A coalition of state-enterprise managers makes up a second faction, with the old-line Communists and their supporters constituting a third faction.

There may also be cause for optimism, say Caltech analysts, in Russia's growing openness to the West. Some foreign investment is entering the country. Russia's communications media are increasingly Westernized, and scholars and educators are working with their Western counterparts in unprecedented numbers. (Caltech hosted four Russian visiting instructors on its campus in late 1992.)

Despite these encouraging signs, the future of democracy in Russia remains very much in question. President Yeltsin wants a strong presidency that will safeguard his own authority, while the Russian parliament—which is still heavily populated by the conservative old guard—wants a much weaker central authority.

At the same time, President Yeltsin appears to have become increasingly vigilant in opposing what he perceives to be the nation's antidemocratic forces. His continued success, analysts say, probably represents Russia's best prospect for the future.

EXPLORING THE BIRTHPLACE OF STARS

Physics, Mathematics and Astronomy

Delving into the secrets of star and planetary formation . . . these are the "voyages" of the latest Caltech astronomical enterprise. Astronomers at the Institute's Owens Valley Radio Observatory are now orchestrating the construction of what will be the world's most powerful millimeter-wave telescope array, thanks to combined funding from the Kenneth T. and Eileen L. Norris Foundation, Caltech, and the National Science Foundation. Caltech astronomers will use the instrument to launch the first large-scale study of "stellar nurseries," where stars are born. Not only will their work provide new insights into the conditions that gave rise to our sun and planets, but their quest could ultimately lead to the discovery of new planets—and possibly life—beyond our solar system.

Their mission requires adding three new radio telescopes to the three 10-meter dishes already in operation at Owens Valley. Slated for completion by the end of 1993, the array will make observations complementary to the optical and infrared studies of star-forming regions, to be carried out at the W. M. Keck Observatory in Mauna Kea, Hawaii, a facility jointly owned by Caltech and the University of California.

The expanded array at Owens Valley will make use of a technique known as aperture synthesis, in which a half-dozen radio telescopes will be positioned along a T-shaped railroad track where they will be electronically linked to simulate a single radio dish of more than 200 meters in diameter. By effectively functioning as a dish of this size and power, the expanded array will have the ability to produce radio maps of unprecedented detail and clarity, at a speed ten times faster than has been achieved previously.

Using these detailed maps, the Caltech scientists will attempt to reveal the secrets of how young stars and planetary systems are born. Planetary systems are thought to begin with the collapse of an interstellar cloud of gas and dust. This is the culmination of a lengthy process that includes the birth of stars. After about 100,000 years of slow contraction, increasing pressure and temperature ignite nuclear reactions, and result in the birth of a star. Much of the enveloping gas and dust falls into this new star, but some of it swirls around in a disk of debris called a protoplanetary cloud. Dust in this thin disk gradually collects into larger clumps, which eventually coalesce into planets.

Caltech astronomers will examine the molecular gas and dust that remain in orbit around the youngest stars, and will search for solid debris surrounding the more mature, sunlike stars. This study should clarify the physical conditions prior to and during the birth of planets, and provide definitive estimates of when and how often planets form. The new project will also investigate how the chemistry of youthful solar systems evolves toward a stage where the chemical environment on individual planets becomes, in the words of one researcher, "benevolently inclined toward sustaining life."

Expanding Educational Boundaries

The Institute is providing significant assistance to American schools at the primary and secondary levels. One way has been through Caltech's prize-winning video course funded by the National Science Foundation, *Project MATHEMATICS!*, which now has six shows geared to high schools across the nation. Its predecessors, *The Mechanical Universe* and *The Mechanical Universe. . . and Beyond*, video courses supported by the Annenberg/CPB Project, have now been translated into several languages.

Undergraduates from Caltech and other universities made up the largest group of participants to date in the Summer

Undergraduate Research Fellowships—a program that gives students the opportunity to conduct original research in close association with a member of the Caltech faculty. Nearly half of the 198 students were fully supported by donations from individuals, corporations, and foundations. The participants included nine recipients of the Institute's Minority Undergraduate Research Fellowships.

Elsewhere in this report, a special section details some of Caltech's other educational outreach programs.

Research

This past year a variety of investigations and major research accomplishments took place at the Institute. The sidebars on various pages highlight specific projects in Caltech's six academic divisions and JPL. However, they are by no means exhaustive of the Institute's research achievements during the past year, which range from the discovery of magnetite crystals in human brain tissue—raising the question of whether humans, like many migratory animals known to carry magnetite, possess some type of directional sixth sense—to the finding of ice on scorching-hot Mercury through an analysis of radar images of the planet.

Of particular interest are Caltech's interdisciplinary programs. For example:

- Crucial work in developing air pollution-control models is being done at the Caltech Center for Air Quality Analysis, a collaborative effort that brings together researchers from chemistry, environmental

Action unlocks
a new way of thinking.

engineering science, and chemical engineering. An aim of the Center is to assist both regulatory agencies governing environmental policy and industry in devising and implementing controls for improving air quality.

- Caltech researchers in Computation and Neural Systems have taken the technology used to design and make computer chips and have applied it to the creation of "neural networks," silicon arrays that function less like conventional computers and more like the sensory apparatus or the brains of living organisms. This past year, significant progress was made on designing an artificial retina, a silicon chip that emulates a piece of the visual system.

- The Biological Imaging Center for Teaching and Research in the Beckman Institute provides facilities for the creation of new technologies for imaging biological structures and processes, trains students in their use, and uses these tools to investigate biological phenomena ranging from the invasiveness of cancer cells to the development of the nervous system.

Thanks to the faculty, students, and staff who perform such research, Caltech maintains one of the strongest records of scientific and engineering advancement in the world today.

Caltech's Next Century

In an era when society relies heavily on new research findings and high-technology developments to make progress on problems ranging from health crises to environ-

mental pollution, Caltech will continue to investigate unexplored realms, seek creative answers, and propose innovative alternatives. The foundation of our previous success has been to concentrate on vital topics, admit the best students, and attract top-notch faculty—those values are a century old, and Caltech is committed to upholding them as it moves ahead into its second century.

RETURN TO MARS AND OTHER MILESTONES

Jet Propulsion Laboratory

The past year was an extremely active one for the Jet Propulsion Laboratory, with new spacecraft being launched and milestones being reached for several missions in progress.

The first U.S. return to Mars in a decade and a half was marked by the launch of the JPL-managed Mars Observer mission. Carried aloft on a Titan III rocket in September 1992, the spacecraft is due to reach the planet's orbit within one year. It will then begin a 687-day mission making highly detailed maps of the Martian surface and studying the geology and climate.

Just prior to the launch of the Observer, JPL was involved in shifting the focus of its in-progress Magellan mission. After the spacecraft had completed its third eight-month mapping cycle at Venus, Magellan's orbit was lowered so that flight controllers could use its radio signal to study variations in the planet's gravity field. Using its radar imager to pierce the perpetual cloud cover over Venus, Magellan mapped 99 percent of the planet's surface.

In August 1992, the joint U.S.-French TOPEX/Poseidon satellite was launched on a mission to study the topography of the world's oceans. This Earth-orbiting satellite was launched on an Ariane 42P rocket from the French launch center at Korou, French Guiana. The spacecraft carries two altimeters, one provided by NASA and one French-built, in addition to several instruments that provide precise orbit determination. Data from the three- to five-year mission are expected to improve our understanding of ocean circulation and such phenomena as El Niño. JPL manages the U.S. portion of the project for NASA.

Another milestone was reached by JPL's Galileo spacecraft, which executed the first-ever flyby of an asteroid when it encountered Gaspra in October 1991 and then flew by Earth in December 1992. In August 1993, the spacecraft will fly by a second asteroid, Ida. The Galileo spacecraft is scheduled to arrive at Jupiter in December 1995.

Finally, the joint NASA–European Space Agency spacecraft, Ulysses, also passed an important mark when it executed a gravity-assisted flyby at Jupiter in 1992. This maneuver pulled the spacecraft out of the ecliptic plane and sent it into a highly inclined orbit that will take it over the sun's north and south poles. The spacecraft will continue to transmit information for studies of the sun and its energy environment through late 1995.

Improving Precollege Science Education

For the past several years, scientists and engineers have become increasingly concerned over the plight of precollege science education. As funding and support for the U.S. educational system have been reduced, science education has been particularly hard hit. It is generally believed that continued deterioration in precollege science education will have profound social, economic, and political consequences.

Reflecting national trends, interest in improving precollege science education has also been growing at Caltech. Through the initiatives of individual faculty members, as well as Caltech staff and students, this interest has recently culminated in the formation of the Caltech Precollege Science Initiative (CAPSI). This new organization grew out of a seven-year collaboration between the Pasadena Unified School District (PUSD) and Caltech personnel, to improve elementary science education in the local schools. This effort, called Project SEED (Science for Early Educational Development), by the fall of 1993 will have trained all 540 kindergarten through sixth grade (K–6) teachers in the school district to teach experimental science. Furthermore, the hands-on science curriculum used in Project SEED was recently adopted by the PUSD school board as the official K–6 curriculum for the district.

Building upon the success of Project SEED, CAPSI has branched into numerous other areas related to precollege science education. For example, support has recently been obtained from the National Science Foundation (NSF) to extend Project SEED into middle school. A separate grant from the NSF is being used to support the creation of a hands-on science course for teachers in training, in collaboration with the Claremont Graduate School of Education. Through another grant from the NSF, CAPSI participates with the education school at the University of California at Santa Barbara to develop new assessment techniques for early science learning.

In addition, the Howard Hughes Medical Institute funded the development of a related hands-on science curriculum at the high school level. In collaboration with the UCLA Graduate School of Library and Information Science and with support from the Alfred P. Sloan Foundation, CAPSI is involved in the development of software to improve children's access to science information in school and public libraries.

Finally, Caltech faculty and staff have recently started the process of transporting CAPSI programs to other school districts. Through participation in a program organized by the National Academy of Sciences, Caltech faculty and PUSD staff have made a series of presentations on precollege science education at workshops organized for national scientific societies. CAPSI has also initiated a Project SEED–like program to start up similar educational outreach efforts in other school districts. The first such effort was organized through contacts made with the Caltech Alumni Association, and has resulted in an outreach program on the island of Maui. Another plan is being designed in which CAPSI will support specific collaborations between industry and school districts to improve public science education in selected sites throughout California. In its position as a premier institution of science and engineering, Caltech is poised to have a profound impact on the future of science education throughout the nation.

"YESS" to Science

Forty science aficionados from high schools across the United States got the chance to spend six weeks with top-caliber science educators last summer in Caltech's classrooms and laboratories. These teenagers were selected from a group of 300 applicants from diverse ethnic backgrounds to participate in the second year of Caltech's YESS Program—otherwise known as the Young Engineering & Science Scholars Program.

In furthering its efforts to improve the quality of precollege science education, Caltech developed this program in 1991 to motivate future scientists and to provide hands-on instruction in engineering and science to minority high school students from economically disadvantaged backgrounds who show aptitude in these subjects.

During 1992, YESS received a boost in funding through a large grant from the Bireley Foundation. Now in its second year of operation, the YESS program

Caltech grad student Nikos Georgiades instructs Kimberly Quack and Michael Lopez about transmitters in the Young Engineering and Science Scholars program.

recruited students from high schools in California, with emphasis on those areas affected by the Los Angeles civil disturbances, and students from other regions of the continental United States. The participants were taught by 16 high school teachers, assisted by Caltech undergraduate and graduate students. Supplementing the core teaching staff were 20 Caltech faculty and postgraduate students, who ran seminars, gave demonstrations, and participated in field trips.

The core curriculum consists of three science courses (physics, biology, earth and planetary science), and an art and art history class was added to provide further enrichment and balance. All these courses share the philosophy that students should learn through active laboratory experiences and through consideration of real world events. Say the program's originators, "What YESS hopes to achieve is that students will become intellectually honest with themselves and remain open to new and more rigorous ways of thinking." They emphasize that YESS, by utilizing renowned educators and new techniques in learning, is designed to provide students with a strong motivation to learn science. It also addresses a disadvantaged, underrepresented student population.

In the future, YESS plans to test specific lesson plans and teaching strategies for their effectiveness in promoting conceptual understanding, and to prepare instructional materials for widespread circulation. YESS will then develop integrated hands-on curricula suitable for grades 9–12 and pilot the materials in high schools.

Students who have already taken part in YESS conveyed a deep sense of satisfaction in the hands-on research, and the program's alumni have established a newsletter to keep former participants in touch with one another as they go on to college. Preliminary reports show that of the students in 1991, 12 were admitted to Caltech, with the others enrolling in other top-ranked universities and colleges.

Assistance to Underrepresented Students in Science and Technology

Through the NSF Center for Molecular Biotechnology, Caltech hosted a project in 1992 to assist underrepresented students in the science and technology fields. Biology teachers from public high schools in greater Los Angeles (who teach classes composed primarily of minority students) were brought to campus this past summer for a workshop. Four new laboratory experiments were presented, ranging from DNA fingerprinting to a study using the polymerase chain reaction. The kits used in the experiments were funded through a W. M. Keck Foundation Grant, and they will be incorporated into a curriculum for 2,200 students in its first year. The ongoing teacher-training program is expected to assist more than 12,000 students in the Los Angeles area and Pasadena within five years.

Members of the Caltech faculty and student body continue to win honors far out of proportion to their numbers. This is a list of awards that were announced during the academic year, 1991-92.

Faculty Awards and Honors

National awards and honors

American Academy of Arts and Sciences, Fellow:
Michael Aschbacher, *Professor of Mathematics*
Marshall H. Cohen, *Professor of Astronomy*
Richard D. McKelvey, *Professor of Political Science*
Peter C. Ordeshook, *Professor of Political Science*

American Association for the Advancement of Science, Fellow:
Clarence R. Allen, *Professor of Geology and Geophysics, Emeritus*
Sunney I. Chan, *George Grant Hoag Professor of Biophysical Chemistry*
Donald S. Cohen, *Professor of Applied Mathematics*
David L. Goodstein, *Professor of Physics and Applied Physics; Vice Provost*
Rudolph A. Marcus, *Arthur Amos Noyes Professor of Chemistry*
Richard E. Marsh, *Senior Research Associate in Chemistry, Emeritus*
Paul H. Patterson, *Professor of Biology*

National Academy of Sciences, Member:
Thomas J. Ahrens, *Professor of Geophysics*

National Endowment for the Humanities, Fellowship for University Teachers:
Ronald L. Bush, *Professor of Literature*

National Endowment for the Humanities, NEH Summer Fellowship:
Diana L. Barkan, *Assistant Professor of History*

National Institutes of Health, Javits Neuroscience Investigator Award:
Mary B. Kennedy, *Professor of Biology*

National Science Foundation, Faculty Awards for Women Scientists and Engineers:
Mary B. Kennedy, *Professor of Biology*
Mary E. Lidstrom, *Professor of Applied Microbiology*

National Science Foundation, Young Investigator Award:
John E. Carlstrom, *Assistant Professor of Astronomy*

National Science Foundation, Alan T. Waterman Award:
Shrinivas R. Kulkarni, *Professor of Astronomy*

International awards and honors

International Neural Network Society, Award for Outstanding Research:
Carver A. Mead, *Gordon and Betty Moore Professor of Engineering and Applied Science*

Kaj Linderstrøm-Lang Endowment Fund, Kaj Linderstrøm-Lang Prize:
Harry B. Gray, *Arnold O. Beckman Professor of Chemistry and Director of the Beckman Institute*

Royal Swedish Academy of Sciences, Nobel Prize for Chemistry, Recipient:
Rudolph A. Marcus, *Arthur Amos Noyes Professor of Chemistry*

Societe de Physique et d'Histoire Naturelle de Geneve, Marc-Auguste Pictet Prize:
Diana L. Barkan, *Assistant Professor of History*

Technion-Israel Institute of Technology,
Harvey Prize in Technology, Corecipient:
Amnon Yariv, *Thomas G. Myers Professor of Electrical Engineering and Professor of Applied Physics*

Carl Zeiss, Inc. (West Germany), Carl Zeiss Research Award:
Ahmed H. Zewail, *Linus Pauling Professor of Chemical Physics*

Awards and honors from professional societies

American Anthropological Association,
Edward J. Lehman Award:
Thayer Scudder, *Professor of Anthropology*

American Astronomical Society,
Gerard P. Kuiper Prize of the American Astronomical Society's Division for Planetary Sciences:
Peter M. Goldreich, *Lee A. DuBridge Professor of Astrophysics and Planetary Physics*

American Chemical Society,
Arthur C. Cope Scholar Award:
Dennis A. Dougherty, *Professor of Chemistry*

American Chemical Society,
Willard Gibbs Medal:
Harry B. Gray, *Arnold O. Beckman Professor of Chemistry and Director of the Beckman Institute*

American Chemical Society,
Pauling Award:
Rudolph A. Marcus, *Arthur Amos Noyes Professor of Chemistry*

On December 10, 1992, Noyes Professor Rudolph Marcus accepted the 1992 Nobel Prize in chemistry from King Carl XVI Gustaf of Sweden in a ceremony in Stockholm.

Over the years, 22 Nobel Prizes have been awarded to Caltech faculty members and alumni. Thirty-six Caltech faculty members and alumni have received the National Medal of Science, and four alumni and one trustee have won the National Medal of Technology. On the Caltech faculty are 67 fellows of the American Academy of Arts and Sciences, and on the faculty and board of trustees there are 69 members of the National Academy of Sciences and 37 members of the National Academy of Engineering.

American Chemical Society,
Service Through Chemistry Award:
John D. Roberts, *Institute Professor of Chemistry, Emeritus*

American Institute of Aeronautics and Astronautics, Fellow:
Edward C. Stone, *Vice President; Director of Jet Propulsion Laboratory; Professor of Physics*

American Institute of Chemical Engineers; Food, Pharmaceutical, and Bioengineering Division Award:
James E. Bailey, *Chevron Professor of Chemical Engineering*

American Institute of Medical and Biological Engineering,
College of Fellows, Fellow:
James E. Bailey, *Chevron Professor of Chemical Engineering*

American Physical Society, Fellow:
Lew Allen, *Senior Faculty Associate and Former Director of Jet Propulsion Laboratory*

American Political Science Association,
Gladys M. Kammerer Award, Corecipient:
D. Roderick Kiewiet, *Professor of Political Science*

American Society of Civil Engineers,
Nathan M. Newmark Medal:
Paul C. Jennings, *Vice President; Provost; Professor of Civil Engineering and Applied Mechanics*

American Society of Mechanical Engineers, Fluids Engineering Award:
Christopher E. Brennen, *Professor of Mechanical Engineering*

Astronomical Society of the Pacific,
Catherine Wolfe Bruce Gold Medal:
Maarten Schmidt, *Francis L. Moseley Professor of Astronomy*

Earthquake Engineering Research Institute, Housner Medal:
Donald E. Hudson, *Professor of Mechanical Engineering and Applied Mechanics, Emeritus*

Institute of Electrical and Electronics Engineers, R. G. Baker Prize, Corecipient:
John C. Doyle, *Professor of Electrical Engineering*

Seismological Society of America, Medal:
Hiroo Kanamori, *John E. and Hazel S. Smits Professor of Geophysics and Director of the Seismological Laboratory*

Society for Technical Publications,
Award of Distinction, Corecipient:
George W. Housner, *Carl F Braun Professor of Engineering, Emeritus*

Foundation awards

Bristol-Myers Squibb, Award for Distinguished Achievement in Neuroscience Research, Corecipient:
Seymour Benzer, *James G. Boswell Professor of Neuroscience, Emeritus*

Charles A. Dana Foundation,
Charles A. Dana Award for Pioneering Achievement in Health, Corecipient:
Mark Konishi, *Bing Professor of Behavioral Biology*

Haynes Foundation, Faculty Fellowship:
D. Roderick Kiewiet, *Professor of Political Science*

Institute for Advanced Study in Princeton, Member:
Diana L. Barkan, *Assistant Professor of History*

John and Mary R. Markle Foundation,
Fellow:
Bruce C. Murray, *Professor of Planetary Science and Geology*

David and Lucile Packard Foundation,
Fellowship for Science and Engineering:
Nai-Chang Yeh, *Assistant Professor of Physics*

The Research Institute of Scripps Clinic,
Waterford Award:
Harry B. Gray, *Arnold O. Beckman Professor of Chemistry and Director of the Beckman Institute*

Alfred P. Sloan Foundation, Research Fellow:
John Michael Graf, *Assistant Professor of Mathematics*
Peter B. Weichman, *Assistant Professor of Theoretical Physics*

University honors

University of California, Berkeley;
Clark Kerr Medal, Corecipient:
Thomas E. Everhart, *President; Professor of Electrical Engineering and Applied Physics*

Columbia University, University Medal for Excellence:
Jacqueline K. Barton, *Professor of Chemistry*

Molecular Science Research Center at Pacific Northwest Laboratories in cooperation with Oregon State University and Washington State University, Northwest Regional Lectureship in Physical Chemistry:
Rudolph A. Marcus, *Arthur Amos Noyes Professor of Chemistry*

North Carolina State University College of Physical and Mathematical Sciences,
Distinguished Alumnus Award:
John E. Bercaw, *Professor of Chemistry*

Pembroke College, Cambridge; Honorary Fellowship:
William A. Fowler, *Institute Professor of Physics, Emeritus*

Pomona College, Arnold L. and Lois S. Graves Award:
Diana L. Barkan, *Assistant Professor of History*

St. Catherine's College, Oxford, Christensen Visiting Fellow:
Christopher E. Brennen, *Professor of Mechanical Engineering*

Institute honors

Associated Students of the California Institute of Technology (ASCIT),
Award for Teaching Excellence:
William Bing, *Director of Instrumental Music*
Delores Bing, *Director of Chamber Music*
Barbara Imperiali, *Assistant Professor of Chemistry*
John Sutherland, *Professor of Literature*
Wen-Ching Wang, *graduate student in biology and chemistry*
Greg Willette, *graduate student in applied physics*
Richard M. Wilson, *Professor of Mathematics*

Student Awards and Honors

ARCS (Achievement Rewards for College Scientists) Foundation, Inc.,
Undergraduate Scholarships:
George L. Fox
Anna M. Jaeckel
Robert B. Lee
Julianne M. Rogers
Helen Y. Tsai

Graduate Fellowships:
David H. Bridges
Annmarie Eldering
William K. Funkhouser, Jr.
Marvin W. Halling
Monica D. Kohler
Mark T. Lusk
Scott A. Strobel
John H. Thompson

Winston Churchill Foundation of the United States, Winston Churchill Scholarship:
Christopher Ho

College Board, National Advanced Placement Scholars Award:
Michael C. Deierling

Barry M. Goldwater Scholarship and Excellence in Education Foundation,
Undergraduate Scholarships:
Jonathan E. Baker
Dan Moraru
Michael Pejic
Douglas G. Shiels

James Irvine Graduate Fellowship, for underrepresented minorities:
John Blandino
Todd Fernandez

Clare Boothe Luce Graduate Fellowship, for women in engineering and physical sciences:
Jody White
Bena Currin

Li Ming Scholarship, for students of Chinese birth:
Jiafu Luo
Duo-Min Lin
Mei-Jiau Huang
Langche Zeng

National Endowment for the Humanities, National Younger Scholars:
Zackary D. Berger

National Science Foundation, Graduate Fellowship:
David Cutrer
Tracy Fu
John Henry Gass, Jr.
Delwyn Gilmore
Michael Greenblatt
Mark Lakata
Garland Lee
Robert B. Lee
Alfredo Morales
Christopher Raymond
Christopher Rosin
Andrew Stevens

USA Today, "Best and Brightest" All USA College Academic Team:
Christopher Ho

This financial report of the California Institute of Technology has been prepared from the Institute's accounting records. It reflects the Institute's financial position as of September 30, 1992, and the results of its operations for the year then ended. These statements have been reviewed by the Audit Committee of the Board of Trustees, whose members are designated by an asterisk in the list of board members on page 48 of this report. 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.

The Institute maintained its strong financial position during fiscal year 1992 despite the current national economic environment. Caltech owes this strength to a substantial endowment fund and sound investment policies. The exceptional quality of its teaching and research programs continues to generate strong support from private donors and government funding agencies. The following are highlights of fiscal year 1992:

- Individuals, foundations, and corporations have continued to generously support the Institute. Private contributions received through the current Campaign for Caltech totaled $56.5 million in fiscal year 1992. The total amount raised, including pledges, during this three-year development effort, amounts to $282.7 million. The Campaign goal is to raise $350 million by the end of 1993.

- Income from United States government contracts and grants at the campus totaled $106.1 million, as compared with $106.9 million in fiscal year 1991. Of that amount, $77.8 million was for costs that directly relate to specific research projects. The balance, $28.3 million, was for the recovery of indirect costs, such as facilities operation and maintenance, utilities, libraries, and support staff, which cannot be attributed to a single research project. Approximately 90 percent of Caltech's

(in millions)

	1982	*1987*	*1992*
Operating expenditures			
Instruction and departmental research	$ 32.4	$ 49.8	$ 81.7
Organized research	32.6	59.8	79.9
Scholarships and fellowships	4.5	8.4	14.3
Institutional and student support	12.8	22.7	36.1
Plant operation, maintenance, and utilities	8.1	11.3	15.0
Total educational and general	90.4	152.0	227.0
Auxiliary enterprises	4.2	6.2	9.6
Total campus	$ 94.6	$158.2	$ 236.6
Inflation adjusted (1982 dollars)	$ 94.6	$132.6	$ 165.1
Jet Propulsion Laboratory direct expenditures	$384.8	$880.2	$1,124.3
Endowment and Similar Funds			
Market value	$208.3	$418.2	$ 580.5
Total return (5 year average)	9.7%	18.7%	8.8%
Campus Properties			
New construction	$ 4.8	$ 28.3	$ 26.0
Renovations and alterations	2.9	11.6	11.7
Maintenance and repairs	2.4	3.6	8.9
Gifts, Grants and Bequests			
For current operations	$ 18.1	$ 28.4	$ 27.4
For endowment	3.3	8.7	12.1
For facilities	3.2	37.3	11.2
For life income and annuity	1.0	5.0	5.6
Student Information			
Tuition rate *(in thousands)*	$ 6.2	$ 10.4	$ 14.1
Enrollment (first term)			
Undergraduate	866	833	862
Graduate	888	981	1,081
Total	1,754	1,814	1,943
Grant aid as a percentage of total costs for undergraduate students	40.3%	47.1%	53.3%
Student loans granted	$ 0.6	$ 1.1	$ 1.9
Student loans outstanding	4.4	6.4	9.8
Degrees granted			
B.S.	167	176	191
M.S.	130	128	132
Eng.	3	0	4
Ph.D.	121	147	134
Total	421	451	461

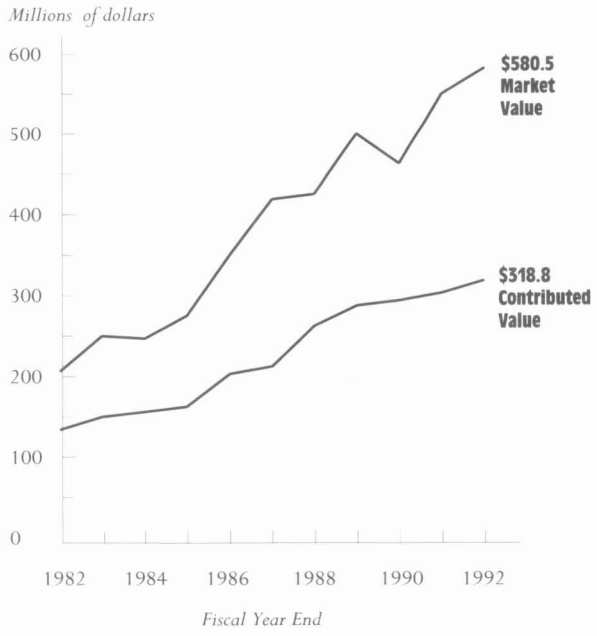
proposals were accepted and funded despite increasing competition for limited federal research funds.

■ The market value of Caltech's endowment at September 30, 1992, was $580.5 million compared to $546.0 million at September 30, 1991. The fund is sizable for a small institution like Caltech with a current undergraduate and graduate student body of just under 2,000. Income from endowment totaled $24.6 million of which $16.9 million was derived from restricted and $7.7 million from unrestricted funds.

The endowment investment policy of the Institute is to: 1) provide income to support Institute operations, 2) achieve long-term appreciation of assets, and 3) preserve endowment principal. With this policy, 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 following graph shows the growth in endowment over the last ten years.

Endowment



■ The market value of the life income and annuity funds was $93.4 million at September 30, 1992, compared with $83.6 million at September 30, 1991, a 12 percent increase. 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

SUMMARY OF CHANGES IN FUND BALANCES

(in thousands)

Year Ended September 30, 1992

Additions

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

United States Government Grants and Contracts Reimbursement from various government agencies for direct costs of research, instruction, and student support.	$ 77,762
Plant Acquisitions Additions to campus plant for land, buildings, and equipment, and retirement of indebtedness.	63,461
Gifts and Nongovernment Grants Includes gifts and grants from private sources for education and research, and physical facilities.	61,385
Indirect Costs and Management Allowance Recovery of indirect costs and management allowance under federally sponsored programs at the campus and the Jet Propulsion Laboratory.	50,618
Investment Income Endowment income and investment income of other funds, including earnings from short term investments.	35,515
Tuition and Fees Tuition and fees assessed students.	26,868
Auxiliary Enterprises Revenues from sales by food services, student housing, and bookstore.	11,180
Realized Gains Net realized gains on investments sold.	10,933
Other Income from sales and services, and other miscellaneous revenue.	10,393
Total Additions	$348,115

Deductions

(Excluding Direct Costs at the Jet Propulsion Laboratory)

Instruction Expenditures for activities that are part of the instructional program including departmental research.	$ 81,666
Research Expenditures for activities specifically organized to produce research outcomes supported by federal and private sponsors.	79,929
Plant Fund Expenditures for buildings, equipment, and renewals, plus retirement of plant assets.	50,922
Payments on revenue bonds and advances for plant purposes, including interest.	5,231
Depreciation of campus properties.	20,631
Institutional and Student Support Expenditures for business and financial affairs, student services, institute relations, and general administration.	36,125
Plant Operations Expenditures, including utilities, for the operation and maintenance of the campus grounds and facilities.	15,034
Scholarships and Fellowships Awards made to students enrolled in formal course work with no requirement that they perform services or repay the awards.	14,296
Auxiliary Enterprises Expenditures, including maintenance, of auxiliary enterprises.	9,584
Other Includes payments to life beneficiaries with life income and annuity agreements, and miscellaneous other charges.	5,155
Total Deductions	$318,573
Increase in Fund Balances	29,542
Total	$348,115

Institute. Donors receive income on their gifts during their lifetime while also obtaining a charitable tax deduction for their gifts.

■ Total net assets increased from $958.9 million to $988.4 million. The increase is due primarily to an increase in campus properties. In September 1992, Caltech dedicated the new 43,000-square-foot Braun Athletic Center, which tripled the indoor recreational space on campus. Other major additions include the completion of Phase I and beginning of Phase II of the W. M. Keck Observatory in Hawaii.

■ Caltech provided $14.3 million in scholarships and fellowships, a 19 percent increase over the previous year. The cost of a Caltech education would be beyond the means of many qualified students without grant and loan assistance. Of the total spent for student aid at Caltech, 29 percent came from government sources and 71 percent came from Caltech funds. Over the past decade, Caltech's share has increased steadily, as government support declined on a relative basis. Caltech's contribution permits the Institute to continue its policy of admitting students based on their merit and promise rather than on their ability to pay. Increasing endowment for student aid and fellowships is a major objective of The Campaign for Caltech.

The following pages present a Balance Sheet, Statement of Changes in Fund Balance, and Statement of Operating Expenditures, along with Notes to Financial Statements, which comprise the Institute's formal financial statements. They provide more detail about the status at fiscal year-end and transactions during the fiscal year. Also included is Price Waterhouse's Report of Independent Accountants.

David W. Morrisroe

Vice President for Business and Finance and Treasurer

(in thousands)

September 30, 1991

Exhibit 1

	Total All Funds
ASSETS	
Cash	$ 1,124
Accounts receivable:	
United States government (note B)	171,339
Pledges (note H)	72,750
Other	4,173
Student accounts and notes receivable	13,081
Investments (note C)	587,972
Interfund advances	
Prepaid expenses and other assets	12,334
Campus properties net of depreciation (note D)	352,028
	$1,214,801
LIABILITIES and FUND BALANCES	
Accounts payable and accrued expenses (note B)	$ 178,714
Deferred student revenue	10,329
Revocable trust funds and agency funds (note E)	15,307
Annuities payable	1,553
Revenue bonds payable (note I)	50,000
Fund balances	958,898
	$1,214,801
Fund balances (Exhibit 2):	
United States government grants refundable	$ 5,052
Institute funds—	
Unrestricted	9,488
Discretionary endowment:	
Unrestricted	62,767
Restricted	70,946
Endowment principal	312,286
Other restricted	193,988
Invested in plant	304,371
	$ 958,898

See accompanying notes to financial statements

September 30, 1992

Total All Funds	*Current Funds*	*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*	*Agency Funds*
$ 369	$ 103	$ 44		$ 216		$ 6
172,196	172,196					
47,550					$ 47,550	
1,386	1,302			39		45
14,667	5,057	9,610				
613,660	31,799	2,580	$448,722	75,959	52,024	2,576
	17,628		4,437		(22,065)	
11,156	7,963		3		3,181	9
390,119					390,119	
$1,251,103	$236,048	$12,234	$453,162	$76,214	$470,809	$2,636
$ 181,018	$178,470		$ 295	$ 272	$ 1,925	$ 56
11,275	11,275					
17,642				15,062		2,580
2,728				2,728		
50,000					50,000	
988,440	46,303	$12,234	452,867	58,152	418,884	
$1,251,103	$236,048	$12,234	$453,162	$76,214	$470,809	$2,636
$ 5,387		$ 5,387				
16,071	$ 4,830				$ 11,241	
63,114			$ 63,114			
68,773			68,773			
320,980			320,980			
179,920	41,473	6,847		$58,152	73,448	
334,195					334,195	
$ 988,440	$ 46,303	$12,234	$452,867	$58,152	$418,884	

Exhibit 2

(in thousands)

	Year Ended September 30, 1991
	Total All Funds
Fund balances at beginning of year	$810,062
Revenues and other additions:	
Student tuition and fees	24,394
Investment income	34,553
Net gain (loss) on disposal of investments	28,822
Gifts	145,923
United States government grants and contracts—	
Reimbursement of direct costs	79,328
Recovery of indirect costs and management allowance	48,042
Other grants and contracts	4,241
Auxiliary enterprises revenues	10,933
United States government advances	396
Campus property acquisitions (including $25,280 in campus operating expenditures)	48,819
Retirement of indebtedness	26,350
Other	11,918
Total revenues and other additions	463,719
Expenditures and other deductions:	
Campus operating expenditures (Exhibit 3)	(230,213)
Campus property acquisitions and renewals	(29,249)
Retirement of indebtedness	(26,350)
Retirement and disposal of campus properties	(2,305)
Interest on advances for plant purposes	(1,589)
Interest on revenue bonds payable	(2,048)
Payment to life beneficiaries	(3,075)
Depreciation of campus properties	(19,438)
Other	(616)
Total expenditures and other deductions	(314,883)
Transfers among funds:	
Gifts allocated	
Investment gains and discretionary endowment allocated	
Investment income allocated	
Allocations for plant purposes	
Terminated trust and annuity agreements	
Other	
Total transfers among funds	
Increase for the year	148,836
Fund balances at end of year (Exhibit 1)	$958,898

See accompanying notes to financial statements

Year Ended
September 30, 1992

Total All Funds	*Current Funds*		*Loan Funds*	*Endowment and Similar Funds*	*Life Income and Annuity Funds*	*Plant Funds*
	Unrestricted	*Restricted*				
$958,898	$ 3,666	$ 39,537	$10,928	$445,999	$54,239	$404,529
26,868	26,851					17
35,515	11,173	17,172	348		3,281	3,541
10,933				10,326	667	(60)
56,506	8,158	19,222	168	12,101	5,627	11,230
77,762		77,762				
50,618	50,618					
4,879	1,131	3,748				
11,180	11,180					
447			447			
62,988						62,988
473						473
9,946	2,705	6,693	170			378
348,115	111,816	124,597	1,133	22,427	9,575	78,567
(236,634)	(113,257)	(123,377)				
(46,656)						(46,656)
(473)						(473)
(4,266)						(4,266)
(1,752)						(1,752)
(3,006)						(3,006)
(3,281)					(3,281)	
(20,631)						(20,631)
(1,874)			(237)		(1,637)	
(318,573)	(113,257)	(123,377)	(237)		(4,918)	(76,784)
	(2,538)	(172)		2,710		
	12,917	3,561		(16,478)		
	4,132	(4,132)				
	(10,373)	(26)		(2,173)		12,572
			369	375	(744)	
	(1,533)	1,485	41	7		
	2,605	716	410	(15,559)	(744)	12,572
29,542	1,164	1,936	1,306	6,868	3,913	14,355
$988,440	$ 4,830	$ 41,473	$12,234	$452,867	$58,152	$418,884

(in thousands)

Exhibit 3

	Year Ended September 30,	
	1991	*1992*
Educational and general:		
Instruction and departmental research	$ 79,459	$ 81,666
Organized research	83,082	79,929
Scholarships and fellowships	12,055	14,296
Institutional and student support	31,331	36,125
Plant operation, maintenance and utilities	14,765	15,034
Total educational and general	220,692	227,050
Auxiliary enterprises	9,521	9,584
Total campus operating expenditures (Exhibit 2)	$ 230,213	$ 236,634
Direct costs of sponsored research at Jet Propulsion Laboratory (fully reimbursed by the United States government)	$1,071,292	$1,124,305

See accompanying notes to financial statements

September 30, 1992

Note A — Summary of Significant Accounting Policies

Basis of accounting and reporting
The financial statements of the California Institute of Technology, 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 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.

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, less accumulated depreciation, computed on a straight-line basis over the estimated useful lives. The depreciation method of accounting for campus properties was adopted by the Institute in fiscal 1991 (note D). 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.

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 the Statement of Operating Expenditures (Exhibit 3).

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. These contracts gave rise to a substantial portion of the accounts payable and accrued expenses in the current funds at September 30, 1992 and 1991, and in turn to accounts receivable from the United States government. Accounts payable and accrued expenses (and related receivables) for JPL amounted to approximately $169,000,000 and $163,000,000 at September 30, 1992 and 1991, respectively.

Note C — Investments

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

	September 30,	
	1991	*1992*
Marketable securities—		
Debt securities (approximate market value of $242,301,000 in 1991 and $260,291,000 in 1992)	$232,765,000	$244,218,000
Equity securities (approximate market value of $335,737,000 in 1991 and $387,333,000 in 1992)	233,341,000	260,102,000
	466,106,000	504,320,000
Short-term commercial obligations	31,983,000	46,161,000
Settlements in process—		
Receivables for securities sold	28,060,000	165,000
Payables for securities purchased	(9,675,000)	(2,585,000)
Real estate	36,190,000	36,945,000
Mortgages, notes, and other securities	35,308,000	28,654,000
	$587,972,000	$613,660,000

Investments shown above include the investment pool as follows:

	September 30,	
	1991	*1992*
Investment pool assets at year-end—		
At carrying value	$395,657,000	$401,436,000
At approximate market value	$489,024,000	$523,373,000
Pool share value at market	$ 21.89	$ 23.02
Annualized income earned per pool share	$ 1.05	$ .95

The Institute also manages a major foundation's investment portfolio with an approximate market value of $173,000,000 at September 30, 1992. These investments are not included in the amounts shown above.

Note D — Campus Properties and Plant Funds

Campus properties consist of the following:

	September 30,	
	1991	*1992*
Land	$ 10,761,000	$ 12,064,000
Land improvements	8,617,000	8,697,000
Buildings	282,170,000	311,721,000
Equipment	234,374,000	262,162,000
	535,922,000	594,644,000
Less accumulated depreciation	(183,894,000)	(204,525,000)
	$352,028,000	$390,119,000

Depreciation has been calculated, using the straight line method, with life years of 20, 40, and 10 for land improvements, buildings and equipment, respectively. Depreciation of $19,438,000 was recorded for fiscal 1991 and $20,631,000 for fiscal 1992.

The W. M. Keck Foundation previously provided funding of $70 million toward the construction of a 10-meter telescope in Hawaii. The telescope has been essentially completed at a cost of approximately $92 million, which is included in campus properties and will be operational in 1993.

In 1991, the Foundation awarded the Institute $74.6 million toward the construction of a second telescope at the same location. As of September 30, 1992, $33.8 million had been received and approximately $17.5 million had been expended and included in campus properties. The unexpended portion of $16.3 million is included in plant funds investments. The balance of the pledge of $40.8 million is shown as a receivable in accordance with the policy indicated in note H.

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 $18,500,000 and $17,200,000 at September 30, 1992 and 1991, respectively. The income derived from these funds amounted to approximately $795,000 for the years ended September 30, 1992 and 1991. This income has been included as investment income in the Statement of Changes in Fund Balances (Exhibit 2).

In addition, the Institute is the trustee for several revocable trusts, valued at trustor's basis at date of establishment, or at cost, if purchased by the Institute, totaling $15,062,000 and $12,971,000 at September 30, 1992 and 1991, respectively, in which it has a remainder interest and for which it makes income payments for life to the grantors of the trusts.

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 compensation 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.

The net pension cost for the year ended September 30, 1992, and the funded status at September 30, 1992, for the defined benefit plans are as follows:

Note F — Retirement Plans (continued)

	Campus	*JPL*
Net Pension Cost		
Service cost—benefits earned during the year	$ 2,510,000	$ 10,807,000
Interest cost on projected benefit obligation	3,275,000	15,204,000
Actual return on plan assets	(3,648,000)	(16,674,000)
Net amortization and deferral	380,000	1,390,000
Net pension cost	$ 2,517,000	$ 10,727,000
Funded Status		
Actuarial present value of benefit obligations—		
Accumulated benefit obligation, including vested benefits of $59,308,000 and $290,581,000	$60,557,000	$295,414,000
Projected benefit obligation	$65,843,000	$316,749,000
Plan assets at fair value	61,434,000	299,138,000
Projected benefit obligation in excess of plan assets	4,409,000	17,611,000
Unrecognized net gains (losses)	(4,415,000)	(12,786,000)
Unrecognized net asset at October 1, 1987, being amortized over 16 and 18 years, respectively	59,000	585,000
Accrued pension cost	$ 53,000	$ 5,410,000

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 7.25% (1991–7.75%) 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, 1992, were $5,091,000 for the Campus, and $19,116,000 for JPL.

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

Note G — Deferred Compensation Plan

The Institute has a deferred compensation plan whereunder eligible employees elected 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 $31,550,000 and $32,040,000 at September 30, 1992 and 1991, 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 records as a receivable and as revenue in plant funds, unconditional pledges received with respect to funding of major construction projects approved by the Board of Trustees and deemed fully collectible. The recording of these pledges is in substantial conformity with the accounting standard proposed by the Financial Accounting Standards Board. Of the $72,750,000 recorded in fiscal 1991, the Institute had $47,550,000 remaining to be collected as of September 30, 1992.

At September 30, 1992, the Institute had additional pledges on hand (principally for restricted purposes), but not recorded, totaling approximately $47,000,000, of which $15,000,000 is expected to be collected in 1993. It is not practicable to estimate the net realizable value of these pledges.

Note I — Revenue Bonds

On May 29, 1991, the Institute issued $50,000,000 in California Educational Facilities Authority Revenue Bonds for the purpose of financing and refinancing the acquisition, construction, and completion of certain educational facilities, and to advance refund the outstanding principal amount of the Institute's Series 1985 bonds. The Series 1991 bonds are repayable with interest, from the general revenues of the Institute over a 30-year period. Interest rates vary from 4.8% to 6.4%. Required principal and interest payments are approximately $4,000,000 a year for the fiscal years 1992 through 2005, approximately $3,000,000 a year for fiscal years 2006 through 2016, and approximately $2,000,000 a year thereafter until 2021, when the bonds will be fully redeemed.

Note J — Postretirement Benefits Other Than Pensions

The Institute provides certain health and life insurance benefits to retirees. In December 1990, the Financial Accounting Standards Board issued Standard No. 106, "Employers' Accounting for Postretirement Benefits Other Than Pensions." The standard is effective for the Institute's fiscal year 1994 and requires the accrual basis of accounting for recognizing the cost of postretirement benefits other than pensions. The Institute does not believe that the implementation of this standard will have a material effect on its financial condition.

Note K — 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 (the "Institute") at September 30, 1992, 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, 1992

Officers of the Board
Ruben F. Mettler, *Chairman*
Thomas E. Everhart, *President*
William F. Kieschnick, *Vice Chairman*
Benjamin M. Rosen, *Vice Chairman*

Trustees
John F. Akers
Chairman of the Board
International Business Machines Corporation
George L. Argyros
Chairman and Chief Executive Officer
Arnel Development Company
Victor K. Atkins
President
Atkins Company
Donald R. Beall
Chairman of the Board and Chief Executive Officer
Rockwell International Corporation
Stephen D. Bechtel, Jr.
Chairman Emeritus and Director
Bechtel Group, Inc.
Donald L. Bren
Chairman of the Board
The Irvine Company
Eli Broad
Chairman, President and Chief Executive Officer
SunAmerica Inc.
Harold Brown
Counselor
Center for Strategic and International Studies (CSIS)
Walter Burke
President
Sherman Fairchild Foundation, Inc.
Jewel Plummer Cobb*
President Emerita
California State University, Fullerton
Trustee Professor
California State University, Los Angeles
Harry M. Conger
Chairman and Chief Executive Officer
Homestake Mining Company
Richard P. Cooley
Chairman of the Executive Committee
Seafirst Bank
Thomas H. Cruikshank
Chairman and Chief Executive Officer
Halliburton Company
Thomas E. Everhart*
President
California Institute of Technology
Richard M. Ferry
President
Korn/Ferry International
Camilla C. Frost
Chairman of the Executive Committee
Los Angeles County Museum of Art
Charles C. Gates
Chairman of the Board and Chief Executive Officer
The Gates Corporation
Donald E. Guinn
Chairman Emeritus
Pacific Telesis Group
Philip M. Hawley
Chairman and Chief Executive Officer
Carter Hawley Hale Stores, Inc.
Shirley M. Hufstedler
Partner
Hufstedler, Kaus & Ettinger
Bobby R. Inman
Private Investor
Eli S. Jacobs
E. S. Jacobs & Co.
William F. Kieschnick
President and Chief Executive Officer (Retired)
Atlantic Richfield Company
Yuan T. Lee
Nobel Laureate and Professor of Chemistry
University of California, Berkeley
Ronald K. Linde*
Chairman of the Board
The Ronald and Maxine Linde Foundation
Ruben F. Mettler*
Retired Chairman and Chief Executive Officer
TRW Inc.
Gordon E. Moore
Chairman
Intel Corporation
Peter W. Mullin
President and Chief Executive Officer
Management Compensation Group, Los Angeles, Inc.
Stephen R. Onderdonk*
President and Chief Executive Officer
Econolite Control Products, Inc.
Pamela B. Pesenti
Trustee
Santa Barbara Museum of Natural History
Sidney R. Petersen*
Chairman and Chief Executive Officer (Retired)
Getty Oil Company
Stanley R. Rawn, Jr.
Private Investor
Arthur Rock
Principal
Arthur Rock and Company
Benjamin M. Rosen
Chairman
Sevin Rosen Management Company
Richard M. Rosenberg
Chairman and Chief Executive Officer
BankAmerica Corporation and
Bank of America NT&SA
Robert J. Schultz
Vice Chairman (Retired)
General Motors Corporation
Dennis Stanfill*
Co-Chairman of the Board and
Chief Executive Officer
Metro-Goldwyn-Mayer Inc.
Walter L. Weisman
Former Chairman and Chief Executive Officer
American Medical International, Inc.
Frank G. Wells
President and Chief Operating Officer
The Walt Disney Company
Albert D. Wheelon
Chairman and Chief Executive Officer (Retired)
Hughes Aircraft Company

Senior Trustees
Robert Anderson
Chairman Emeritus
Rockwell International Corporation
William R. Gould
Chairman of the Board Emeritus
Southern California Edison Company
Ralph Landau
Listowel Incorporated
Chauncey J. Medberry III*
Chairman of the Board (Retired)
BankAmerica Corporation and
Bank of America NT&SA
Harry Wetzel
Chairman and Chief Executive Officer (Retired)
The Garrett Corporation

Life Trustees
Robert O. Anderson
President
Hondo Oil & Gas Company
R. Stanton Avery
Founder and Chairman Emeritus
Avery Dennison Corporation
Arnold O. Beckman
Founder Chairman
Beckman Instruments, Inc.
Benjamin F. Biaggini
Chairman (Retired)
Southern Pacific Company
Mrs. Norman Chandler
Honorary Life Chairman of the Board
The Music Center
Lee A. DuBridge
President Emeritus
California Institute of Technology
Gilbert W. Fitzhugh
Chairman (Retired)
Metropolitan Life Insurance Company
William A. Hewitt
Former Chairman, Deere & Company
Former Ambassador to Jamaica
Earle M. Jorgensen
Chairman of the Board
Earle M. Jorgensen Company
L. F. McCollum
Retired Chairman
Continental Oil Company
Robert S. McNamara
President (Retired)
The World Bank
Rudolph A. Peterson
President (Retired)
Bank of America
Simon Ramo
Co-Founder and Director Emeritus
TRW Inc.
James E. Robison
President
Lonsdale Enterprises, Inc.
Mary L. Scranton
Nonprofit Consultant
Charles H. Townes
Nobel Laureate and University Professor Emeritus
University of California, Berkeley
Howard G. Vesper
Director and Vice President (Retired)
Chevron Corporation
Richard R. Von Hagen
President Emeritus
Lloyd Management Corporation
Lew R. Wasserman
Chairman and Chief Executive Officer
MCA Inc.
Thomas J. Watson, Jr.
Chairman Emeritus
International Business Machines Corporation
William E. Zisch
Vice Chairman of the Board
Science Applications International Corporation

* *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
(as of March 9, 1993)

Thomas E. Everhart
President
Paul C. Jennings
Vice President and Provost
John N. Abelson
Chairman
Division of Biology
Thomas W. Anderson
Vice President for Institute Relations
Fred C. Anson
Chairman
Division of Chemistry and Chemical Engineering
David L. Goodstein
Vice Provost
John O. Ledyard
Chairman
Division of the Humanities and Social Sciences
Gary A. Lorden
Vice President for Student Affairs
David W. Morrisroe
Vice President for Business and Finance and Treasurer
Gerry Neugebauer
Chairman
Division of Physics, Mathematics and Astronomy
Robert L. O'Rourke
Assistant Vice President for Public Relations
John H. Richards
Chairman of the Faculty
John H. Seinfeld
Chairman
Division of Engineering and Applied Science
David J. Stevenson
Chairman
Division of Geological and Planetary Sciences
Edward C. Stone
Vice President and Director
Jet Propulsion Laboratory
Mary L. Webster
Executive Assistant to the President and
Secretary, Board of Trustees
Harry M. Yohalem
General Counsel

Design: Denton Design Associates

Photography: cover, 1, 4-5, 10-11, 16-17, 22-23, Robert Paz; 27, Sunny H. Sung; 29, Svenskt Pressfoto. Photos on pages 7, 8, 12,15,19,20, and 25 represent research in Caltech's academic divisions and Jet Propulsion Laboratory.

California Institute of Technology
Pasadena, California 91125