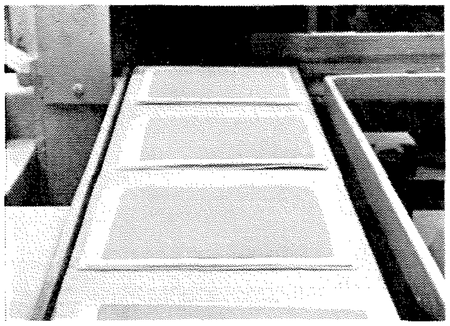
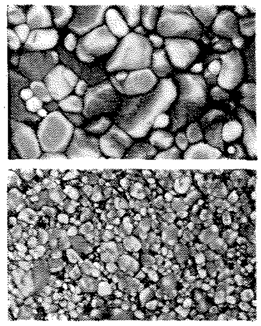
Engineering and Science

California Institute of Technology | October 1973

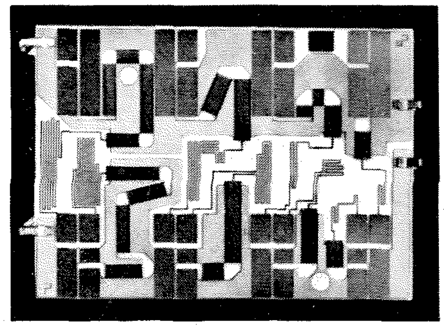
WESTERN ELECTRIC REPORTS



1500° C furnace was specially designed to fire these new substrates. The relatively low temperature results in smooth substrate surfaces for practically fault-free thin film bonding.



Electron micrographs show the great difference in grain size between new ceramic material (lower) and the previous material (upper).



Thin film integrated circuit shown here is part of a resistor network. It is one of many that benefit from the improved substrate. Metal leads on sides are bonded by thermocompression to tantalum nitride resistor film.

Smoothing the way for perfect thin film bonding.

Aluminum oxide, or alumina, is considered to have the best combination of properties for thin film circuit substrates. Until recently, however, the bonding of metal elements to gold-coated tantalum nitride resistor film on alumina was somewhat unpredictable.

Now, an advance at Western Electric has made it possible to get practically fault-free bonding of these materials.

This new perfection in bonding came through the development of finer grained alumina substrates.

The process has four basic steps: milling, casting, punching and firing.

During milling, alumina is combined with magnesium oxide, trichlorethylene, ethanol and a unique deflocculant. For 24 hours, this mixture is rotated in a ball mill. In a second 24-hour period, plasticizers and a binder are included.

The deflocculant plays a major role by dissipating the attraction forces that exist between the highly active alumina particles. This prevents thickening, which would ordinarily make an active alumina mixture unworkable.

The 48 hours of milling is followed by casting. When the material comes off the casting line, it is in the form of a flexible polymer/alumina tape, dry enough to be cut into easily handled sections.

After casting, a punch press cuts the material into the desired rectangles or other shapes. Holes can be punched at the same time.

Finally, because of the use of active alumina, the material is fired at an unusually low temperature which results in smooth substrate surfaces for reliable thin film bonding. The finished substrate is then ready for the various processes of thin film circuit production.

In developing this new process, engineers at Western Electric's Engineering Research Center worked together with engineers at the Allentown plant.

Conclusion: *This new way to produce substrates is a truly significant contribution for thin film circuit production.*

The ultimate gain from this smoother substrate is for communications itself. For through the achievement of nearly perfect bonding of metal leads to tantalum nitride, thin films can be produced with even greater reliability and economy.

Western Electric

We make things that bring people closer.

Conversation Pieces

Technically intriguing items from TRW, guaranteed to add luster to your conversation and amaze your friends.

Tornadoes, Rockets and Sonja Heine

So far, 1973 has been a banner year for tornadoes. By mid-year, more than 750 of these violent storms had swept down on the United States, killing 59 people and causing millions of dollars in property damage. Scientists expect the existing tornado record of 928 (set in 1967) to be easily shattered before the year is over.

Recently, tornado research has received help from an unexpected source — namely, studies made by TRW scientists of flow patterns in the propellant tanks in ICBM missiles. When you pump fuel out of a liquid rocket tank, much the same thing happens as when you pull the stopper out of your bathtub — a radial flow pattern develops (the particles move in spiral paths toward the center) and a vortex appears. To find out how swirling fluids behaved in propellant tanks, TRW scientists made some fundamental studies of the formation and behavior of vortexes. Further research has extended their analyses to the behavior of the large vortical patterns in the atmosphere we know as tornadoes, waterspouts, dust devils, and fire whirls.

A tornado begins with a thermal instability in the atmosphere, e.g., large mass of warm moist air under a layer of cold dry air. Under such conditions, violent updrafts may begin, around which the surrounding air begins to flow radially inward, in a swirling, spiral pattern. As particles get closer to the center of the flow pattern, their velocity increases. Some readers will recall the startling rotational speeds Sonja Heine achieved as she drew her extended arms closer to her body. Particles of air experience this same increase in rotational velocity as they get closer to the center of the system.

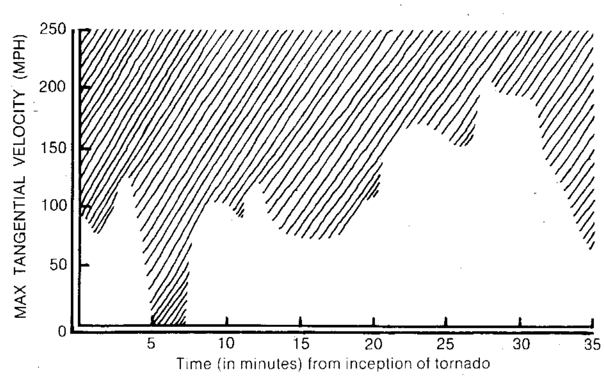
Ordinarily, turbulent diffusion opposes the swirling, and relaxes the disturbance — i.e., friction prevents Sonja from bringing her arms inward. However, in rare circumstances the radial inflow overwhelms turbulent diffusion, and a tornado develops. Actually, in a killer tornado much of the radial inflow is eventually confined to a layer near the ground, because at greater heights the increase of swirling ultimately creates a large centrifugal force that counteracts further radial inflow.

While dust and debris are being swept upward, the funnel of the tornado appears to descend. The latter occurs because the faster the air swirls, the more its temperature drops and the less moisture the air can contain. The resulting condensation of water vapor is seen as the funnel of the tornado, snaking down from the ominous cloud deck. Using these facts, TRW scientists have developed a formula which enables them to calculate the maximum velocity of winds in a tornado.*

TRW scientists have estimated the maximum wind speed in the funnel of a major tornado at around 225 m.p.h. Much of a tornado's destructiveness, however, stems not from the speed of the swirling wind, but from the radically low pressures inside the funnel. As a tornado engulfs a building, air trapped inside the building causes it to explode.

While much remains to be learned about large vortical storms, TRW's work with swirling liquid rocket propellants has lead to an important meteorological understanding of the behavior of destructive rotational storms.

**Maximum velocity, $V = (kgh)^{1/2}$, where h is the altitude of the cloud deck, k the fraction of the distance between cloud and ground the funnel cloud tip has descended, and g the acceleration of gravity.*



Using Weather Bureau data from the tornado of April 2, 1957, TRW scientists calculated the above time-history of estimated maximum wind speeds.

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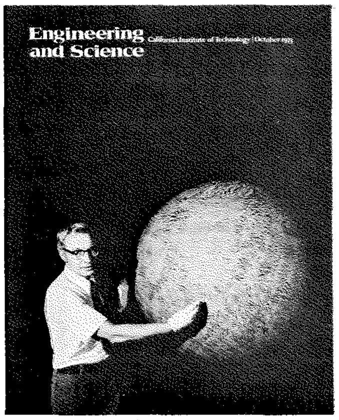


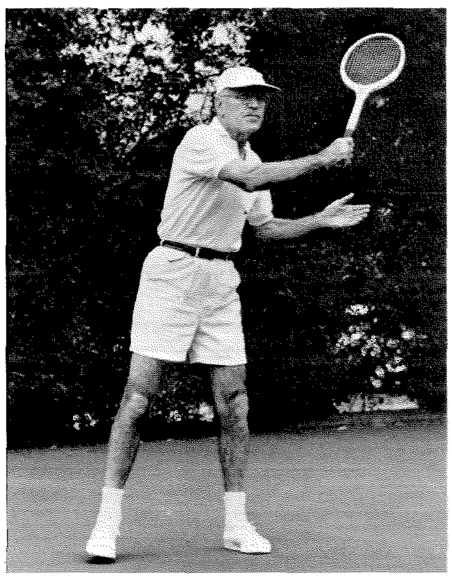
New Worlds

On the cover—JPL's latest answer to the problem of how to mount and display prize photographs. "Martian Map Makers" (page 8) tells how, under the direction of project scientist Elmer Christensen, some of the more than 7,000 Mariner 9 pictures of Mars are being used to produce scientifically accurate and esthetically exciting global maps of our neighboring planet.

Old Times

One feature of the annual faculty dinner on May 10 was Ernest Swift's nostalgic reminiscences of his early days at Caltech—before, in fact, it *was* Caltech. "The End of the Olden Days" (page 10) is adapted from that talk.

When Swift came to Throop College of Technology in 1919, he was a graduate student and teaching fellow in chemistry; by 1920 he had been promoted to instructor; and the promotions continued until, in 1967, he became professor of analytical chemistry, emeritus. In the interim he performed a multitude of services for the Institute, including being division chairman for five years. Former President Lee DuBridge once described him as "a distinguished and effective teacher, who has maintained a continuous pace in effective research. And he has been an outstanding campus citizen. He inherited from Dr. Noyes a devotion to the ideals on which Caltech was founded, and he has pursued these ideals with vigor, devotion, and enthusiasm for over 40 years."



It has been 52 years now—and he's still at it.

Looking Ahead

William H. Pickering, director of Caltech's Jet Propulsion Laboratory, professor of electrical engineering, and Caltech alumnus (BS '32, MS '33, PhD '36), can speak with some authority on today's and tomorrow's technological demands upon men. On June 5 he spoke on this subject at the annual installation and awards banquet of the San Gabriel Valley section of the Institute of Electronic and Electrical Engineers. "Technology in the Waning Century" (page 15) is adapted from that talk.

Peripatetic Professor

Harrison Brown has been a member of the Caltech faculty since 1951, first as professor of geochemistry; then, after 1967, as professor of science and government as well. Since 1962 he has been foreign secretary of the National Academy of Sciences. Appropriately, he describes his current interests as problems in science and public policy, population, and the environment. "Chinese Junket" (page 28) reports some of his pertinent observations from his recent trip to China.

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Engineering and Science

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Books

SOME RECENT ONES BY OR ABOUT
CALTECH PEOPLE

Autobiography of A Physicist
by Jesse W. M. DuMond

Jesse DuMond, professor of physics emeritus at Caltech, wrote this "intellectual" autobiography at the request of the Center for History and Philosophy of Physics at the American Institute of Physics. The two-volume manuscript was completed last year. It has not been published commercially, but copies are available in the AIP library and in the archives of the Millikan Library at Caltech.

The greater part of the 390-page manuscript is, of course, devoted to DuMond's distinguished career and accomplishments as a physicist and his work in the field of x-ray and gamma-ray spectra. But he provides a bonus for the general reader in the first 50 pages of the book, which are devoted to a lively, personal account of his early years.

Born in France to American parents, he was brought up by his grandfather, first in Rochester, New York, then in Monrovia, California. Jesse entered Throop College of Technology in 1912 and was one of eight members of the graduating class of 1916. He went to work in the testing department at the General Electric Company in Schenectady, New York, and earned an MS in electrical engineering at Union College there. In 1918 he enlisted as an engineer in the U.S. Army and served with the AEF in France. After a postwar stint with the Bureau of Standards in Washington, he came to Caltech in the fall of 1921 as a physics graduate student and teaching fellow. His subsequent distinguished career in physics at the Institute covered almost 50 years. He became professor emeritus in 1969.

INFORMAL EDUCATION: An excerpt from **Autobiography of a Physicist**

Since one of the purposes of this autobiography is for the information of a group of historians of science especially interested in the history of recent (twentieth century) physics and physicists in the United States, I believe I should mention at this point that Professor Paul Ehrenfest from Leyden had been invited to lecture at Caltech in 1930, shortly before my three-month sojourn at Stanford. I was indeed sorry that the Stanford sojourn obliged me to miss a large part of his lectures which dealt chiefly with his "Adiabatic Hypothesis," Statistical Mechanics and Thermodynamics.

This friendly but eccentric and most remarkable man had created a strong impression upon all of us at Caltech with the vivid and extremely original style of his lectures* and indeed his general behavior. For example, he had explained to me that, at Leyden, he had taken pains to see that none of his children should be permitted to have any formal education whatever.

**I recall that one of these was entitled, "Which one of us likes plum pudding better, you or I?" It was given to illustrate the indispensability of some degree of arbitrariness in the formulation of fundamental definitions, even in the so-called exact sciences. He was essentially a Bridgmanian operationalist.*

In order to circumvent the educational laws of Holland, his practice was to choose one of his own graduate students in physics as a nominal tutor for his children, but would instruct the young man strictly to teach them *nothing whatever*, save at most to suggest to them where they might *themselves* be able to find the answer to any question they might ask of him.

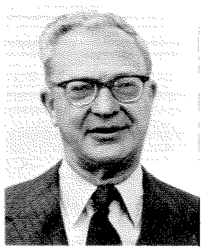
Professor Ehrenfest had brought with him to California his youngest daughter, Anna Galjia (Galinka, for short), a completely charming and very intelligent girl, then about aged 15, if I recall correctly. Once, in her father's absence she had said to me, "Doctor DuMond, isn't it just dreadful that our Daddy would never let any of us children go to school? I feel so ignorant!" (She was by no means ignorant. She spoke four languages fluently and could converse fascinatingly on *any* subject one wished to propose.) Later, in conversation with her father, I told him of what his daughter had said and he looked at me with an enthusiastic smile, slapped his knee and said, "Yes, isn't it wonderful, DuMond; they think they are ignorant and so now they are going to study all their lives!"

Mars and the Mind of Man
by Ray Bradbury, Arthur C. Clarke, Bruce Murray, Carl Sagan, Walter Sullivan
Harper & Row $7.95

On November 12, 1971—the day before Mariner 9 went into orbit around Mars—Bruce Murray, professor of planetary science at Caltech and one of the co-investigators on the Mariner 9 television team, organized a panel discussion on campus on "Mars and the Mind of Man." In addition to Murray himself, the distinguished panel included two science fiction writers, Ray Bradbury and Arthur C. Clarke; Walter Sullivan, science editor of *The New York Times*; and Carl Sagan, who was then at Caltech as a visiting associate in planetary science from Cornell University.

That freewheeling discussion now serves as an introduction to this book for the general reader. It presents the thoughts, opinions, and reflections of the five panelists more than a year later, after Mariner 9 had finally expired, having sent us more than 7,000 pictures and a plethora of scientific data on Mars.

This fascinating book also includes about 50 of the most spectacular Mars pictures, selected and captioned by Murray and Sagan.



Is There Life on Mars?
The Incredible Photographic Mission of Mariner 9
by Graham Berry
The Ward Ritchie Press $4.95

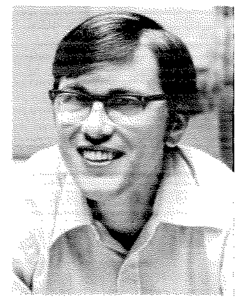
If *Mars and the Mind of Man* is a book for the general reader, then Graham Berry's *Is There Life on Mars?* is for the even more general reader. Berry, who is director of Caltech's News Bureau, is an old hand at interpreting science for the layman, and his book is a crystal-clear account of the Mariner 9 Mars mission. Short, concise, and complete, it contains about 25 of the best Mars pictures, with extremely informative captions. As to the answer to the question proposed in the book's title—check it out for yourself.

Geothermal Energy
Edited by Paul Kruger and Carel Otte
Stanford University Press $17.50

Geothermal Energy contains the proceedings of a special symposium held at the annual meeting of the American Nuclear Society in June 1972. Co-editor Carel Otte (MS '50, PhD '54) is a vice president and manager of the geothermal division of the Union Oil Company of California.

Systems Concepts: Lectures on Contemporary Approaches to Systems
Edited by Ralph F. Miles Jr.
John Wiley & Sons $13.50

Ralph Miles, a member of the technical staff of the Jet Propulsion Laboratory and a Caltech alumnus (BS '55, MS '60, PhD '63), organized an extremely successful series of lectures on systems engineering in 1971, when he was serving at Caltech as a visiting assistant professor of aeronautics and environmental engineering science. The ten lectures in that series, edited by Miles, have now been collected in this volume in the Wiley series on Systems Engineering and Analysis.

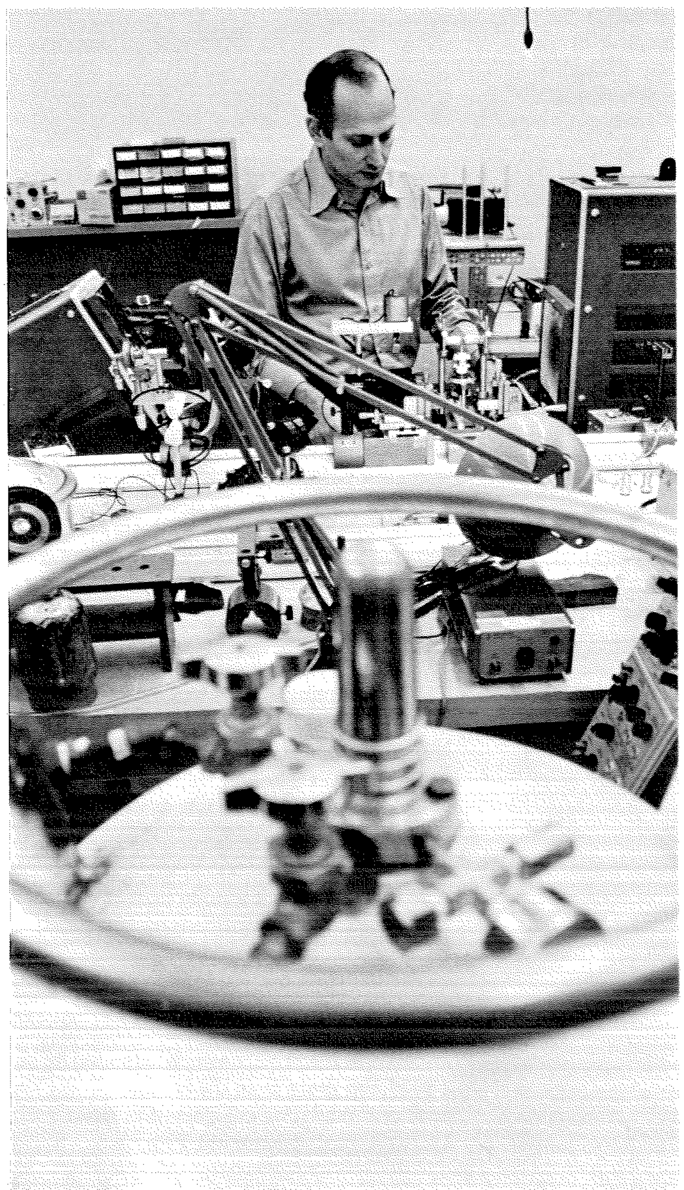


Economic Aspects of Television Regulation
by Roger G. Noll, Merton J. Peck, and John J. McGowan
Brookings Institution $8.95

Economic Aspects of Television Regulation is a painstaking economic analysis of the television industry and a study of how government policies (and most specifically the Federal Communications Commission) shape the performance of the industry. The book is the seventh in the Brookings Institution series of Studies in the Regulation of Economic Activity. This program of research focuses on public policy toward business. It is supported by a Ford Foundation grant, and its co-director (and co-author of this volume) is Roger Noll. A Caltech alumnus, BS '62, and a member of the Caltech faculty from 1965 to 1971, Noll served as a Brookings senior fellow from 1970 to 1973. This summer he rejoined the Caltech faculty as a professor of economics.

One of Noll's activities during the coming year will be to direct a study to determine whether the federal government can effectively increase the pace of technological innovation in the United States—and if so, how. Ten Caltech economists, historians, and political scientists will be involved in the project, which is funded by a $127,800 grant from the National Science Foundation as a part of its new Technological Assessment Program.

A Revolution in Communications



Amnon Yariv and his Caltech co-workers are producing small, simple devices to process light the way electronic circuits now process electricity.

Ours is a civilization based largely on the ability to communicate, process, and use vast amounts of information. But our communication needs, and the volume of information we produce, keep outstripping our capability to cope with the load.

Miniaturization has saved us in the past. Transistors and integrated circuits have made it possible for us to build extremely small electronic devices, which in turn let us handle more and more information in less and less space. But now it is clear that we are going to have to find a new way to handle even more information.

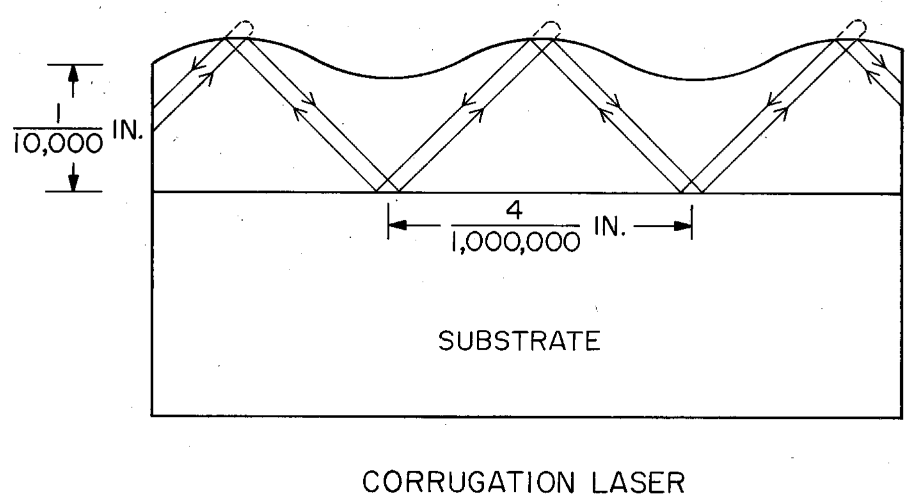
Light waves, in theory, can carry 10,000 times more information than electrical signals in electronic circuits. Today, the shafts that carry telephone, computer, and radio messages in skyscrapers are often as large as those needed for elevators. But "optical cables" of glass or plastic, carrying information-laden laser light, could handle the same amount of information in about one square inch of space.

For such a laser communication system to work, miniaturized optical terminals are needed to launch, remove, distribute, and otherwise process the light as it travels through the optical cables. But this requires a new technology that does not now exist—integrated optical microcircuits.

Amnon Yariv, professor of electrical engineering, and a group of co-investigators at Caltech have worked for almost five years to develop such an optical circuit. Already the team has developed detectors, switches, amplifiers, couplers, and the like to duplicate for optics the array of components available in integrated electronic circuits. Now, with the construction of the latest and most crucial element, the researchers have demonstrated that optical microcircuits are a practical possibility within the near future.

Their latest achievement is probably one of the world's smallest lasers. It uses tiny surface corrugations for continuous operation rather than end mirrors. A step toward reducing the size of present optical systems, this miniaturized corrugation laser is less than an eighth of an inch long, four-hundredths of an inch wide, and ten-thousandths of an inch thick.

Instead of mirrors, the laser uses a grating of 27,000 corrugations, each four-millionths of an inch wide, etched on the upper surface of a thin-film waveguide made of gallium arsenide. These corrugations reflect light back and forth until it reaches the proper power and intensity—lases. This occurs because the depth of the waveguides is so small that the corrugations exert a strong influence on the light traveling in the guides. If the light has the



The corrugation laser is a crucial element in optical microcircuits. One of the world's smallest lasers, it is less than an eighth of an inch long, four-hundredths of an inch wide, and ten-thousandths of an inch thick. Instead of mirrors, it uses a grating of 27,000 corrugations, each four-millionths of an inch wide, to bounce light beams back and forth until they lase.

right mathematical relationship to the corrugations, its direction is reversed; that is, it is reflected as if there were a mirror in its way.

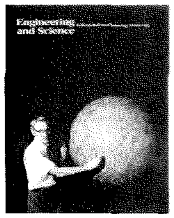
The corrugation laser was originally devised because it is amenable, like transistor circuits, to photolithographic fabrication techniques. These processes, which are something like those used to develop photographs, are what makes it so easy to mass-produce transistors. But the corrugation laser is also potentially more efficient, and this may provide the solution to one of the problems that has dogged the designers of lasers for optical communications: the unreliability of traditional gallium arsenide lasers. The enormously high currents required to trigger laser action cause destructive heating that reduces their operating lifetime to the point where they are not practical economically.

To excite the gallium arsenide to the lasing point, a corrugation laser has to be pumped externally by a beam of red light from a "dye" laser. But work is now in progress on a simpler system that would allow the Yariv team to stimulate the corrugation laser electrically.

Working with scientists at the Hughes Research Laboratories for the past five years, the Caltech team has used gallium arsenide as the basic building material for all the elements they have developed for an integrated optical circuit—lasers, switches, detectors, waveguides, distribution networks, and modulators to place information on the light. Over the short term, it would have been easier to build each of these components out of whatever material would do the job best and then attempt to "glue" the disparate elements together into an optical circuit. Instead, the researchers took a clue from integrated electronics and decided to build all the components out of the same material, thus increasing the likelihood that they will all operate together as an integrated unit.

With the construction of the corrugation laser, it now appears likely that one of a number of research groups across the country will build a complete miniaturized optical circuit. Eventually, when the technology is worked out, long-distance optical communication systems between cities—with miniature integrated optical circuits to transmit, amplify, and receive the light signals—should be possible.

In addition to Yariv, the group working on integrated optical microcircuits at Caltech includes Elsa Garmire, senior research fellow in applied science; Michihara Nakamura, research fellow in electrical engineering; graduate students Sasson Somekh, Harold Stoll, Avraham Gover, and H. W. Yen; and Desmond Armstrong, a member of the technical staff. The Hughes scientists participating in the project are Drs. Robert Hunsperger and Hugh Garvin. □

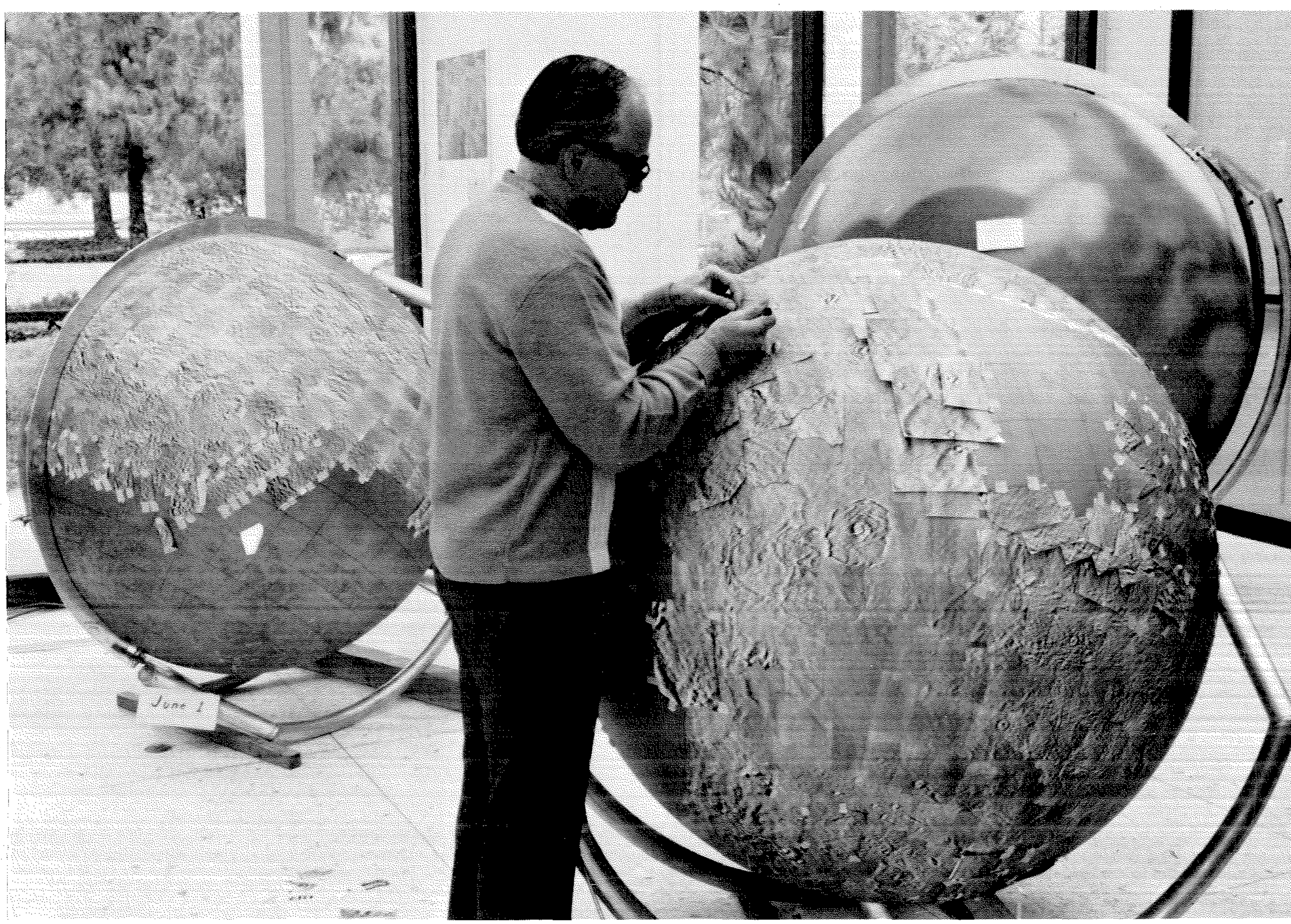


Martian Map Makers

Everyone knows Mariner 9 did a remarkable job of photographing the whole surface of Mars—and nobody knows it better than the scientists at Caltech's Jet Propulsion Laboratory. So, even before the end of the Mariner 9 mission, they began to think about the best way to display their spectacular pictures.

The result is a photomosaic—a detailed spherical map constructed from Mariner's photographs of the Martian surface. In fact, there three of these photomosaics—two 4-foot ones now completed and a 6-foot sphere still being worked on.

Making a photomosaic may sound easy, but this was not a simple matter of gluing black-and-white photographs on an aluminum sphere. In the first place, the photographs returned by the spacecraft could not be used directly because they were almost all shot at an angle—and for this purpose views from straight overhead were required. So each photograph had to be altered by a computer process



It took Earl Zimmerman and his co-workers eight months to complete the first photomosaic globe of Mars at the left. Work went faster on the second one; after photomosaics were positioned on the first globe, they were photographed and copies were put on the second. Photographs of the second globe are now being enlarged for use on the third globe in the background.

to an overhead view. Also, all the photographs required to cover a globe—1,500 of them—had to have the same scale, contrast, and shading. The originals varied enormously, of course, so once more the computer had to work them over. Finally, it turned out that rectangular photographs were useless because they couldn't be fitted properly to a spherical surface. The computer couldn't help with this part of the project; so the irregular pieces needed for actual gluing on the globes were laboriously cut by hand from the large photos.

Most of the work on the globes was done by the project scientist, Elmer Christensen, aided by mathematician Sally Rubsamen, photomosaicist Earl Zimmerman, and photographer Duane Patterson. The team started to work late in 1971, after the Mariner 9 mission was completed. One of their 4-foot spheres will be on display at the National Aeronautics and Space Administration headquarters in Washington, D.C. The other goes to NASA's Lewis Research Center in Cleveland, Ohio. The 6-foot globe will be on exhibit at JPL. And although they were originally prepared for display only, the globes are so accurate in their geological and geographical relationships that scientists are using them as references for current studies and for the planning of future missions to Mars.

Gluing down a section is perhaps the most delicate step in the whole process. To do exact matching, a scalpel-like blade is used to trim overlapping sections along feature lines, so that each blends imperceptibly with the others around it.

Because each section of the global photomosaic has to be oriented precisely in longitude and latitude, Elmer Christensen, right, and Earl Zimmerman, take great pains in positioning the photographs. Outsize photo sections are first taped into place so that orientations and shading can be adjusted. Final positioning is done by matching the images on overlapping portions of each photograph.

The End of the Olden Days

A MEMOIR BY ERNEST SWIFT

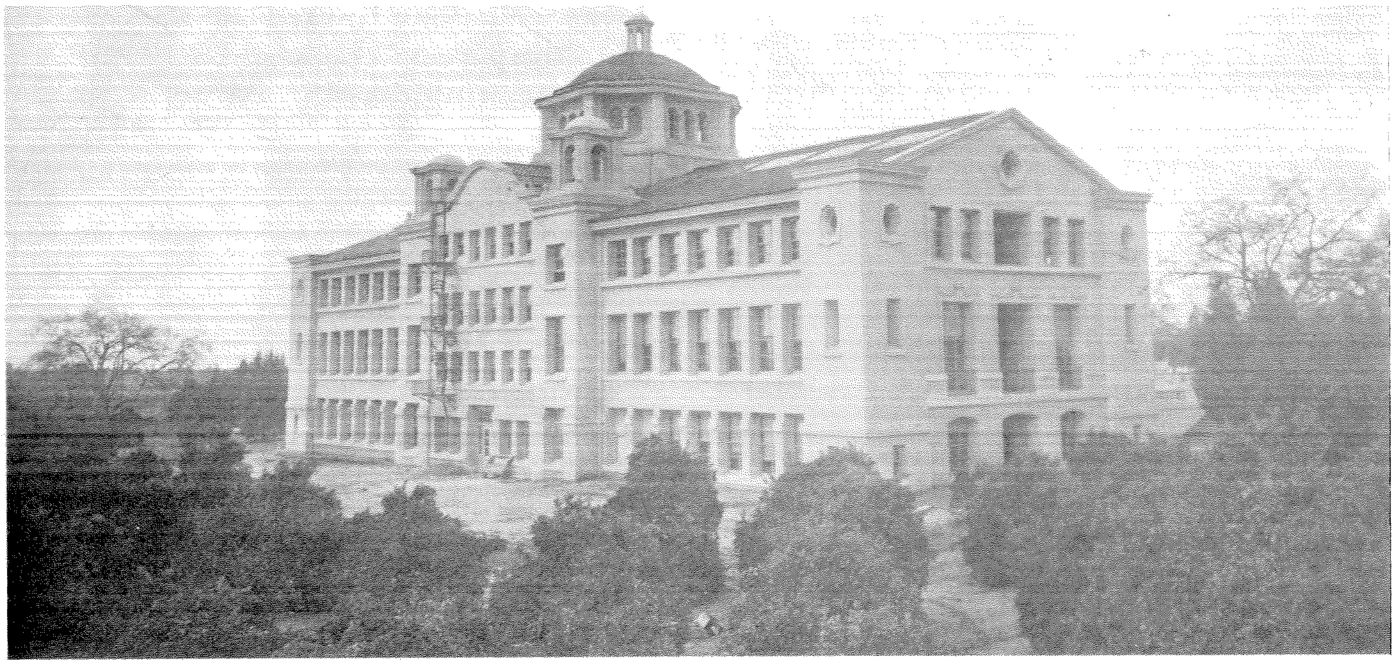
Whenever I reminisce in public about the early days at Caltech, my feelings are similar to those engendered when our daughter was young and when discussion of some past event would cause her to ask, "Daddy, what was it really like in the olden days?" Regardless of these feelings, I will attempt to tell you a little about what Caltech was like in the olden days—or at least when I arrived here.

To begin with, it may be in order to explain how my association with the Institute originated, because it illustrates the informality of administration in those days and the influence of pure chance on one's career.

During World War I, I served valiantly for a few months in an officers' training camp, then in January of 1919 returned to the University of Virginia, where I had been given a BS degree in the previous year. There I began working a wonderful racket toward obtaining a master's degree. The University, in the usual fervor of wartime patriotism, had offered a full year of academic credit toward a degree to any serviceman entering in January and successfully taking a normal course load until June. By May I was well along toward obtaining a very cheap and very meaningless MS.

In addition to the reduced residence time, the chemistry faculty had been so depleted by wartime activities that few remained competent of directing a graduate program. Realizing this, the University had invited A. A. Noyes to visit the campus as a consultant regarding reorganization of the department. During his visit Dr. Noyes mentioned to my research supervisor that he was spending part of his time at Throop College of Technology, and that Throop was looking for graduate students in chemistry. He asked if there was anyone who might be interested. This information was relayed to me.

I had never heard of Throop College of Technology, but upon having been told that it was in southern California, I was interested. I had never been west of the Blue Ridge Mountains of Virginia; therefore, this appeared to be a wonderful chance to see the unknown West. An interview was arranged, during which Dr. Noyes mentioned that he was revising his qualitative analysis text, that he needed a laboratory assistant during the coming summer to help with that work, and that he was leaving from Washington for Pasadena the next week. I think that anyone who, like myself, has agonized over graduate admissions in interminable committee meetings will be quite interested when I mention that within ten minutes I had been appointed, first, a graduate laboratory assistant for the summer, and second, a teaching fellow (equivalent to the present graduate teaching assistant) for the following academic year. Administration *was* simpler in the olden



Pasadena Hall, later known as Throop, amid the orange groves in 1917.

days. (In fact, I have sometimes wondered if that appointment was not *unique* in that it was offered without benefit of application forms of any kind and accepted without benefit of a catalog.)

A few days later I left by train with Dr. Noyes from Washington for Pasadena, and after five and a half days of travel, which included a detour to the Grand Canyon, we arrived in Pasadena around eight o'clock one evening. Dr. Stuart Bates took me to his home for that night.

I still remember vividly that evening. The weather was beautiful, and the air balmy. (Remember that this was what could be called the B.S. era—before smog and before subdivisions.) The southeast section of Pasadena was still predominantly orange groves, and the smell of orange blossoms was almost overwhelming. I thought I had arrived in a veritable lotus land and felt quite smug over my move.

The next morning we walked over to the campus, and with my first view all my smugness vanished. At that time Spiro Agnew could have characterized me as an "effete easterner." I had been conditioned to the academic environment of the traditional eastern campus—buildings with ivy-covered walls surrounded by shade trees and expanses of green lawns. Naively, I had expected something similar, plus waving palm trees and lush semitropical landscaping.

What I saw was—well, something different. No ivy

World War I view of Gates, with slit trenches where Millikan Library now stands.

anywhere (not at that time), no lawns, and just two permanent academic buildings of uncertain architectural parentage. They were Pasadena Hall (Throop to most of you) and the first unit of Gates.

Extending westward from Pasadena Hall to Wilson Avenue was a dirty, dusty, unkempt expanse of dried weeds, interspersed here and there with strange mounds of dirt which on subsequent investigation I found to be slit trenches from the World War I Student Army Training Corps.

Extending eastward from Pasadena Hall was a run-down, scaly orange grove which terminated in an equally run-down, scaly frame house among some small scrub oaks where the Athenaeum now stands.

I was well along toward obtaining a very cheap and very meaningless MS.

When I did obtain a catalog, 1919 edition, I found Pasadena Hall described as "a majestic building comprising 800,000 feet of cubic contents." I am still baffled as to what was meant by those cubic contents. (I must interject that in spite of my reactions at that time, it was with a poignant feeling of nostalgia that I saw that iron ball crunch against the cupola of Throop and bring it crumbling down.)

I had noticed slightly east and north of Pasadena Hall a brown frame two-story structure which was unpleasantly reminiscent of my army barracks. On reference to my catalog I found it described as "a modern dormitory, of California bungalow type with large, airy, and well-lighted rooms." I was told that this "modern" structure was in fact temporary and soon to be replaced; it *was* replaced—42 years later, prior to erection of the student center.

I remember being puzzled by not finding in my catalog, even in the index, any mention of either *athletics* or *physical education.* I finally found in the text a short, two-paragraph section entitled "Hygienic Supervision." The first paragraph stated: "Dr. James H. McBride . . . is the hygienic adviser for students, and will address them during the year on personal hygiene." The second paragraph stated: "The physical exercise and athletic activities of the college are under the supervision of a physical director; the object of the college authorities being to make the good health of all students a matter of scientific care rather than the specialized development of intercollegiate athletic 'teams'."

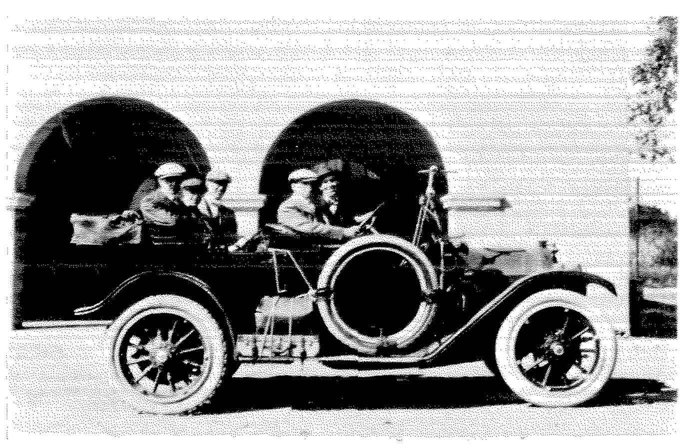
There *were* intercollegiate teams, and although Tournament Park was then city owned, it was available for college use. I noted with interest that it contained two modern asphalt tennis courts—at least they were the first asphalt courts I had seen; and I mean chemically pure asphalt, not the asphalt-cement composition developed later. They were adequate in winter, but had liabilities in summer. Being jet black they could become so hot as to be sticky and to quickly blister your feet. Then, in addition, some civic group decided that they would be just dandy for dances under the stars. One trial showed, however, that dancing on that asphalt was more effort than fun. Undaunted, they covered the surface with a slippery powder of some kind and had a fine surface for dancing. But trying to play tennis the next day brought comments from the tennis players that I will not repeat here.

That, then, was the campus—the physical plant—of that date. Now a few observations regarding personnel. My catalog listed a faculty, professors through instructors, of 34 members. In our current catalog I counted 60 full professors—in the division of engineering and applied science alone. These figures do represent growth, but I must warn Francis Clauser that in certain areas his division has lost ground. Thus I found listed in that 1919 catalog:

3 instructors in mechanical drawing
1 instructor in wood working
1 instructor in pattern making
1 instructor in shop forging.

I find no reference to any of these fundamental courses in our current catalog.

That catalog listed three teaching fellows, all in chemistry. This was the title of my appointment and was the equivalent of the present graduate teaching assistant. My annual stipend was $750 with the annual tuition of $150 included. Near the end of my first year, George S. Parks, who was teaching sophomore analytical chemistry, accepted an appointment at Stanford. To my astonishment I was assigned his duties for the next year and promoted to the rank of instructor—with a raise in salary of $150. I found it quite depressing in scanning the personnel of that faculty to note that at the present time only two of those names remain in our present catalog: William Michael and William Lacey, emeritus professors.



Noyes and friends out for a ride in his vintage Cadillac. The car was known as Mossie—short for Demosthenes, because it was afflicted with a sensational stutter.

Quite naturally, my first personal contacts were with the members of the chemistry faculty. (I purposely did not say division because there was no hint of divisional organization shown in my catalog.)

I found the chemists to be very cordial, friendly, and helpful. The senior members, Drs. Noyes, Bates, Bell, Lucas, and Lacey, were—as might be expected—quite conventional in most ways. However, there were two younger members, James Ellis and Roscoe Dickinson, who had been recently brought from MIT by Dr. Noyes. They fascinated me because I think it reasonably correct to say that they were, over 50 years ago, prototype hippies. Ellis had a beard, treated his clothes as a matter of necessity, and was completely functional toward social conventions; but with it all was very friendly, likable, and a promising scientist.

His office was in the basement of Gates and was totally dark unless a light was turned on. One morning the—perhaps I should be more explicit and say the *one*—chemistry secretary started to enter his room to leave a note. She immediately came tearing out screaming that there was a man on the floor of Dr. Ellis's office. There *was*—Dr. Ellis. He had been working late, gotten sleepy, so he spread his sleeping bag and went to sleep.

The board of trustees at that time consisted of only seven members, and the chairman was Arthur A. Fleming. Mr. Fleming, who later had an office on campus, had some rather contradictory traits. Although he had his chauffeur drive him to school in a Hispano-Suiza (the foreign super luxury car of those days) and although he was generous in his gifts to the Institute (these including the original campus and subsequent financial support during the expansion of the twenties), he had a compulsive drive to minimize any inefficiency or waste however minor in the operation of the campus, and he is reputed to have prowled the buildings in this effort.

There is a story, somewhat indelicate and perhaps apocryphal, but so typical that I dare to repeat it. One day on one of his campus surveys he realized that the toilets were equipped with roll paper dispensers. To him that represented a possible source of extravagant waste; therefore, in a short time there appeared in all toilets locked dispensers which bore the trade mark "Onlione!" (Perhaps I should advise Arnold Beckman that not too long ago these Onliones were replaced by *double* roll dispensers.)

There were no female students at that time and a serious lack of feminine personnel. I can recall only four female administrative assistants: Miss Spining, librarian; Miss Howard, secretary to the president (then James A. B. Scherer); Miss Sage, in charge of general accounts; and Miss Allen, secretary to the treasurer (then E. C. Barrett). Miss Allen, who is now Mrs. Swift, tells me that her duties also included balancing the financial books of the college,

The appointment was offered without benefit of application forms of any kind, and accepted without benefit of a catalog.

assisting with the bookstore, handling the telephone exchange, collecting student loans, and in her leisure time taking dictation from senior faculty members. She still remembers her embarrassment when, prodded by Mr. Barrett, she had to ask Frank Capra if he could make a small payment on his student loan.

Scanning the student lists, I found three who are associated with the Institute at present: Frank Capra, now an Associate; Arthur Klein, then of the junior class, now professor emeritus; and Howard Vesper, then a freshman, now a trustee.

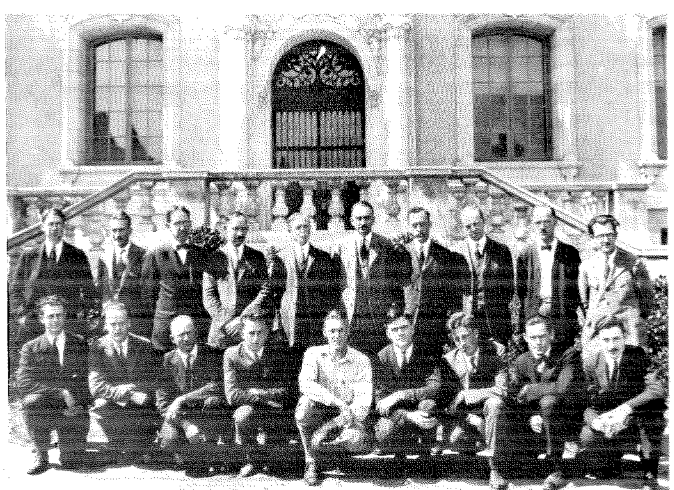
When I read through the section in my catalog regarding student conduct, I could not but wonder if our present director of student affairs and deans have not fallen victims to the terrible permissiveness of the modern age. Summing up several pages of specific rules I found the following statement (said to be "emphatically endorsed as the general policy of the college"): "For the conduct and character of its students a college assumes a far more intimate responsibility than a university. Toward mere thoughtlessness and exuberance of animal spirits it will be lenient. But towards vice in its three dread forms, drunkenness, gambling, and licentiousness, it will exercise a severity unknown to universities. It will not ferret out evil by spies, nor cultivate the acquaintance of the scandalmongers of the town, nor encourage students to testify against each other, nor take unfair advantage of medical or quasi-medical information given in confidence. But though it fights fairly, it will fight these vices every chance it gets. When these evils come fairly and squarely

This was what could be called the B.S. era–before smog and before subdivisions.

to its attention, as when carried to excess they inevitably do, the school counts no cost too high, whether in removing students or alienating families and friends, to pay for keeping its moral atmosphere clean and wholesome."

I am inclined to attribute that passage, as well as certain others in that catalog, to the influence of President Scherer, who had quite a way with words and who had been president of a small denominational college in the South before being brought to Throop by Dr. Hale.

The definition of exuberance of spirits was evidently more restricted in those days. I am told of an incident in which a group of students became so exuberant that they embellished the statue of Apollo with red paint in a manner any gentleman would resent, especially Apollo, who then stood quite prominently in the main entrance of Pasadena Hall. Their act was judged as *vice*, not exuberance, and they were "removed" forthwith. Three of the group later returned and subsequently became valued faculty members.



Caltech's chemistry faculty in 1923-24. Top row: Charles Prescott, Richard Badger, James Bell, Howard Lucas, A. A. Noyes, Richard Tolman, Will Lacey, Stuart Bates, Ernest Swift, Roscoe G. Dickinson. Bottom row: Linus Pauling, Ernest White, Reinhardt Schuhmann, William Holton, Joseph Mayer, Paul Emmett, Vincent Manchee, Oliver Wulf, L. Merle Kirkpatrick.

Again, in looking through my catalog, I am inclined to wonder if our present catalog as eloquently presents the local attractions as they are set forth in the 1919 edition under the section entitled "Environment." I quote in part: "Pasadena is not only one of the most beautiful of cities, but it is noted for the morality, refinement, and culture of its citizens. Being notably a residential town—it is surrounded by safeguards and privileges that fit it for the guardianship of youth. Saloons are prohibited by charter. Boys under age are shut out by statute from questionable places of amusement, of which there are few . . . Pasadena is known as 'the city of churches and schools,' and is also frequently called 'the most beautiful town in the world.' To be surrounded by an atmosphere of purity and beauty is no hindrance to a training in utility."

The environment of that day, before smog and before subdivisions, did not need such hucksterism. To some of us it was southern California at its best. The deserts were free of people and of paved roads—not to mention off-road motorcycles. Las Vegas was a place with a railroad station where one could obtain food when traveling the desert at night. In 1920 I was part of a two-car caravan that became lost trying to cross Death Valley. One could hike the Sierra for days without seeing a human.

Spiro Agnew could have characterized me as an effete easterner.

Pasadena was a nice small town—even on New Year's Day. I remember my first one. Hearing quite a commotion in Tournament Park I wandered over. I was told that a football game had just begun and that Harvard was playing Oregon, so I walked up to a ticket window, bought a ticket, and saw the game.

Also, even when I first arrived, there were the beginnings of a stimulating ferment within the campus community—intimations of coming changes and developments. These were given substance by the arrival of Dr. Noyes on a permanent basis early in 1920. Later in that year the present name of the school was adopted; and construction of Bridge and Culbertson was started; A. A. Michaelson was conducting experiments on the campus; it was rumored that Millikan would arrive the next year; President Scherer resigned; and the catalog was revised. Then in 1921 Millikan did arrive, and the present statement of educational policies was adopted. I am inclined to think that those events marked the beginning of an exciting new era—but the ending of the olden days. □

Technology in the Waning Century

BY WILLIAM H. PICKERING

After the technological bonanza of the 1960's, science and technology changed almost overnight from hero to antihero. What are the prospects now?

Science, no less than other fields of human endeavor, has always had its germinal periods that have left indelible bench marks along the paths of history.

We like to look at Newtonian physics as such a landmark in establishing the concept of law and order in the universe, leading to the emergence of modern science and the application of the experimental method in research. The industrial revolution of the last century, by harnessing power to the production of goods, became another dynamic force in the evolution of our modern technological civilization. Today, we are experiencing what has been called the cybernetic revolution, in which we are adapting automatic control and electronic computing devices to simulate some of the complex switching network functions of the human brain and nervous system.

These years since World War II are in many ways remarkable decades. The advent of the Atomic Age in the late 1940's unleashed the dream of science, promising to remake the world in a new image. Technology would find a solution to the postwar problems that followed the troubled peace after Hiroshima. All mankind would coexist without war, without want, without fear.

But first, it was necessary to achieve security if we were to follow the men of science along the path to lasting peace. And that meant developing an intercontinental missile capability to counter the Russians, who by now also had the Bomb.

During the 1950's, we entered a period of frantic technological growth, an era largely dominated by the rocket engine makers, who were attempting to adapt the visionary experiments of Goddard and Malina to the harsh realities of the launch pad at Cape Canaveral.

Then, as we seemed to be approaching a kind of missile and warhead parity, the Soviets orbited Sputnik in October of 1957. An emotional trauma shook the land. For the first time, we realized that American science and tech-

In the new world of science and technology, the engineer will find that the responses are not Newtonian, but Darwinian.

nology were not supreme in the world, and that what we had regarded as a land of lumbering peasants could beat us into Earth orbit.

Our confidence was deeply disturbed. We searched in desperation for ways to revamp our scientific, industrial, and educational establishments. Because we had never shunned a challenge and our honor was presumably at stake, in 1961 President John Kennedy set as a national goal the landing of American astronauts on the Moon before the end of the decade.

What followed in the 1960's was a technological bonanza unique in all history. The thrust of the space program was felt in almost all areas of science and technology. Researchers who had spent most of their careers cloistered in isolated laboratories suddenly found themselves in great demand. Technological innovation spawned projects of unprecedented complexity. It seemed as if any conceivable technical undertaking could be developed and demonstrated. The difficult took a year or so; the impossible—men on the Moon—took eight years.

The obvious way to erase the bitter memory of Sputnik was to beat the Russians with men for lunar exploration and with instruments to probe the planets. We unveiled Apollo—possibly the most ambitious peaceful, technical undertaking in the history of the race. NASA became much more than an agency largely confined by its aerodynamic research mission. Now it would launch tons of rockets, spacecraft, and men into the Florida sky, looking toward a Moon landing a quarter of a million miles away.

This was a time when it seemed as though engineers and scientists were almost given blank checks on the federal treasury. There was no apparent limit to the promises of science and technology. The only constraint to be reckoned with was imagination. The laws of Newton and Maxwell governed an enormous variety of hardware projects, and the government was a ready customer.

Then, and quite without warning, something began to happen as the 1960's reached their midpoint. Vietnam began to develop into something more than a gunboat incident. Riots wracked our major cities; the campuses became hotbeds of demonstration and destruction. Ethnic groups found power they had never before exercised. Climactically, a new word was dredged out of the dictionary—ecology became the battle cry. Science and technology became the villains.

Suddenly, the glamor of space declined. Even Congress became less enthusiastic. The federal bounty, which had seemed endless during the glory years, began to dry up. We realized that the public had turned against the fountainhead; science and technology changed almost overnight from hero to antihero.

What had happened? Had technology been too successful? Had the public recoiled from the prospect of the Orwell syndrome coming to term before 1984? Had the New People, the uninhibited young, revolted against the computerized society, the era of solid-state electronics?

Perhaps the concern most loudly articulated was over the expenditure of billions of dollars to explore the solar system while millions of Americans were underprivileged and even on the fringes of starvation. Congressman and constituency alike wanted the money spent "here on Earth" where it could be immediately beneficial.

Among many intellectuals, there was a concern that space projects were really of interest only to the technicians, who worried over how their systems would perform in the vacuum beyond Earth's atmosphere while thousands died in Vietnam. They suspected that scientists were merely carrying on an esoteric dialogue with other scientists.

It was plain as the 1960's wore on that the era of technological *laissez-faire* had come to an end. Research could no longer be based only on the search for pure knowledge. There had to be an immediate fallout that could be measured in dollars and cents in the marketplace, that could be equated with the betterment of society.

What is the prospect for the scientific and technological establishment as we enter the last quarter of the century? Perhaps we should attempt to make a sober assessment of what seems to lie ahead beyond the Bicentennial of 1976.

We must recognize that we have lived in a time of rapid change and that change will continue. In the recent past, to a very considerable degree, change was largely dependent on science and technology for its motive power. In the future the driving force may be different, but we as engineers and scientists should not regret this fact, nor regard it as catastrophic.

Ours is the most advanced nation in the world, and most of our material progress stems from a steady flow of innovative technology as the fallout of a free and intellectually untrammeled science. Yet, isn't it ironic that ours is the only country in which a considerable portion of the liberal intellectual community would scuttle the technological base from which most of the nation's affluence and a major part of its power for good in the world have come!

In terms of the norm, perhaps the more sedate pace that has so far characterized the 1970's is preferable. There have been serious suggestions from responsible sources that science might take a well-earned holiday while society catches up with the breakneck technological productivity of the last two or three decades. Some even see the cure for our social, political, economic, and environmental ills in a reversal of the flow of time, in an effort to recapture a simpler, more innocent past.

There is something good and something bad in all of these suggestions. The only reality is that the problems are there and they will not vanish, even under the impact of a computer-backed study.

Garrett Hardin has pointed out that the engineer is schooled in a Newtonian world of physical reality, with exact cause-and-effect relationships, and a precise predictability to controlled events. Planck and Einstein modified these concepts, but only slightly. Newton remains the demigod in an ordered universe.

Now, it would seem that, in the future, the technologist will be dealing more with social problems—those of the urban sprawl, transportation, the environment, the troubles of the people. He will be confronting the quality of life more than the reliability of an electronic circuit.

Society will be his customer more than the government. And he will soon find that society is an amorphous assemblage of humans with widely divergent motivations and noncharacteristic reactions to stimuli.

In this world of people, the engineer will find that the responses are not Newtonian, but Darwinian. Cause and effect exist but only in a probabilistic manner. Experiments cannot be isolated in controlled environments; they must always be part of a larger world. The small and remote cannot necessarily be neglected. The inverse square law is replaced by the laws of exponential growth. An item as small as a single germ in a man's throat can change the entire course of history.

We are saying that the engineer and scientist must realize that they are no longer dealing with the immutable laws of Newton and Maxwell, but with the patterns of biological growth, of politics, economics, sociology, and psychology. When the engineer moves into this arena, he must doff his Newtonian cap and adjust to the Darwinian mode. This may be a difficult process indeed but, in the 1970's, the 1980's, and the 1990's, it will become more and more necessary.

Although we recognize that society has many problems that the engineer cannot solve, there is still much to be done in the sense of the high technology of the 1950's and 1960's, but at a materially slower rate of growth. The challenges will still be there: the exploration of the outer planets, the overwhelming question of extraterrestrial life, the solution of the energy crisis, the utilization of the ocean for food and mineral resources. We have succeeded in forcing back the door of our ignorance just a bit, and it is inconceivable that we will completely abandon further pursuit of these fascinating ponderables.

In the future, the technologist will be dealing more with social problems. He will be confronting the quality of life more than the reliability of an electronic circuit.

In dealing with human problems, the engineer of the future will find that the customer is no longer a single autocratic government office with a billion dollar project, but comprises an infinity of humans, whose thought processes are legion, shattering completely his concept of logic. Consensus is a term dear to the poll makers, but it hardly exists in a pragmatic sense outside the political arena. The engineer will find little of the beauty of mathematics or the predictive behavior of the machine.

Patently, the engineer, working from a broader base and dealing with the intangible as well as the tangible, will find the rules of the game dramatically different. The solution to the problem may be software, not the sophisticated hardware of space. Defining the problem and establishing the hierarchy of responsibilities and interface relationships may be impossible, or, at best, imperfectly defined. Most frustrating, the extent of success may be difficult to measure. A social project of 1987 cannot be demonstrated by a test flight landing on target; an extensive statistical analysis of several years of data is required, showing, for example, a reduction in the incidence of sickle cell anemia in the black belt of Detroit.

Tomorrow's scientists and technologists will be needed to assist in solving the most profoundly complex problems facing society. They must, without loss of professional integrity, focus their attack on problem areas with a definite technological component that cannot ordinarily be resolved by social, political, and economic philosophers alone.

There will have to be an early recognition that these projects of the future will be quite different from those NASA/Department of Defense programs of the 1950's and the 1960's. They will involve systems interfaces with nearly all segments of society and many diverse political and ethnic groups. Technical managers will have to structure their teams to include the capabilities of behavioral as well as technical experts. They will have to refocus their efforts on social and environmental conditions that are largely open-ended, which cannot be so precisely defined and scheduled as a space project. They must often do this without being able to demonstrate success on a finite time scale. The manager of tomorrow must be a man of Job-like patience, of great flexibility, highly skilled in the ordered world of science and in the disorder of human behavior.

We have achieved a sort of virtuosity in working with hardware. Now we must apply our skills to those elusive factors that dominate human affairs.

We have seen the idea of the mechanized world of Galileo and Descartes developing as a philosophical thesis, finally merging with Newton's rational universe and leading directly to the high technology of today. Now we see the prophets of technocratic doom predicting that the mega-machine will displace man in his own culture, that expanding science and technology are the root causes of most of man's problems.

As scientists and engineers, we do not agree with these pessimistic predictions. We can learn to integrate the sciences with the arts—to cross-pollinate the classical technical disciplines with the humanistic approach to the problems of society. We can learn to better the human condition with technological means. We have achieved a sort of virtuosity in working with hardware. Now we must apply these skills of analysis, synthesis, and management to those elusive factors that dominate human affairs.

The engineer and the scientist freed man from the constraints imposed by the use of human or animal labor and the industrial revolution ensued. No longer was it necessary for the great mass of mankind to work from dawn to sunset to obtain the essentials for survival. The use of cheap energy made possible all of the material advancements we take for granted.

Recently the engineer and the scientist have taken the next step and freed man from the drudgery of simple and repetitive intellectual labor, the cybernetic revolution. Cheap information processing is having just as profound an effect as cheap energy.

Science and technology must now show society that we can join the hardware of the industrial revolution with the software of the cybernetic revolution and bring mankind up still another step toward achieving its ultimate potential. That is the challenge of the closing decades of the century. □

Earthquakes: Pattern For Prediction

Since February 9, 1971, scientists have learned a lot about the possibility of predicting earthquakes. At Caltech, six seismologists have been using the avalanche of information about the thoroughly recorded San Fernando quake to look for telltale signs that might precede such events. In particular, they have been looking at the phenomenon of "dilatancy" and its effect on the primary (P) and secondary (S) waves generated by earthquakes.

Dilatancy is a curious process in which a material under stress expands when it is near its breaking strength because of the formation of cracks. It is what happens when you press your foot into wet sand and the sand lightens in color. The stress of the foot rearranges the grains of sand, increasing the space between them, which makes the sand appear dryer. While under stress, the sand is firmer and less apt to shift.

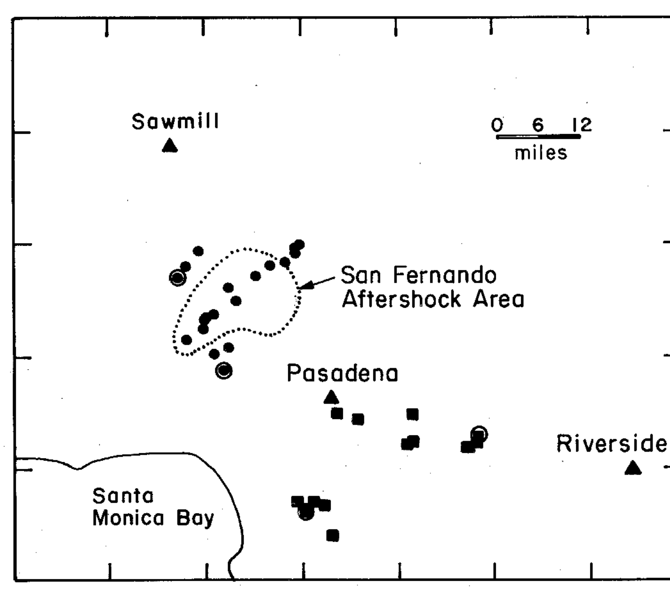
On a much larger scale, something of the same sort takes place in the earth's crust. The rocks under stress in the ground strengthen temporarily, but their strength decreases again as water and steam flow into the newly opened cracks. The dilatancy theory was generalized by Don Anderson, professor of geophysics and director of the Seismological Laboratory, and his colleagues.

Dilatancy explains phenomena that were detected by seismologists when they started reviewing seismic recordings for earthquakes in the San Fernando Valley for the ten years before the 1971 earthquake. These records showed that until three and a half years before the quake, the seismic wave velocities were relatively constant. Then, suddenly, they dropped sharply and began moving slowly back up until they reached their previous "normal" level a few months before the quake hit Sylmar. Similar results had been found by Soviet seismologists in the Garm region of the USSR.

In comparing the way the P and S waves change velocity when passing through a seismically active zone, the Russians found that when the P-wave speeds were divided by the S-wave speeds and plotted on a chart, the curve that resulted followed a curious path. Beginning at a relatively constant normal value, the ratio of the two speeds dropped sharply and then slowly rose until it reached its original level. Shortly thereafter an earthquake occurred.

This pattern is remarkably similar to what happened in 1971, and it led James Whitcomb, research associate in geophysics, and Jan Garmany, research assistant, to take a closer look at the P- and S-wave components in the seismic records of 19 other earthquakes in southern California between 1961 and 1970. These quakes were chosen because their epicenters fell on a more or less straight line between two Caltech recording stations at Pasadena and Riverside, making it possible to measure P- and S-wave velocities with some precision, as well as the velocity ratio.

Comparison of the two kinds of waves in these records showed patterns similar to those observed by the Russians. By measuring both waves separately, the two



Nineteen earthquakes whose seismic waves passed near the epicenter of the 1971 San Fernando Valley quake (dots) between 1960 and 1970 have been analyzed by Caltech seismologists. The old records reveal a pattern that might possibly have been used to predict the 1971 disaster. Analysis of another 12 quakes whose seismic waves passed *through* the epicenter between 1966 and 1970 (squares) shows they followed a similar pattern.

researchers found that it was the P wave that was changing velocity rather than the S wave, as some scientists had previously thought. And the only theory that satisfactorily explains a change in the P-wave velocity is dilatancy.

A series of complex events takes place beneath the earth's crust just before an earthquake:

Far below the surface of an active fault, where two massive land blocks strain against each other, there are small, hairline, water-filled cracks in the rock layers. As the rocks grind against each other, these microscopic cracks begin to expand; the water no longer fills them. And as the volume of the partially filled cracks increases, the velocity of the P waves begins to fall off and the ratio of P to S drops.

More water and steam percolate into the zone and fill the enlarged cavities. As this happens, the velocity of the P waves bottoms out and starts increasing. When the velocity is back to normal, it means that the cracks have filled completely with water. And because the cracks are now larger and hold more water than they did before, the rocks are weakened and are less able to stand the unrelenting pressure of the opposing blocks. Eventually, the rocks shatter, and an earthquake rips through the crust above.

Anderson, Whitcomb, and Garmany have found a correlation between the length of time it takes for the P wave to return to its normal value and the magnitude of the ensuing temblor. It also appears that by plotting the variations in P-wave velocities it may be possible to predict the day or week an earthquake is likely to strike.

One question that needs to be answered, however, is whether rocks change in this manner in all seismic areas, or whether the change is peculiar to thrust-fault regions such as those of the east-west ranges like the San Gabriel Mountains in southern California. During a quake in a thrust-fault region, two land blocks are locked head to head, and as one block tries to vault up and over the second block, the second is trying to slip under the first.

The 1971 San Fernando Valley quake occurred in this kind of region. During quakes in strike-slip fault regions, such as along the San Andreas fault, the two blocks are trying to slide past each other. It is not yet clear whether earthquakes in strike-slip fault regions give off the same kind of warning signals as those in thrust-fault regions.

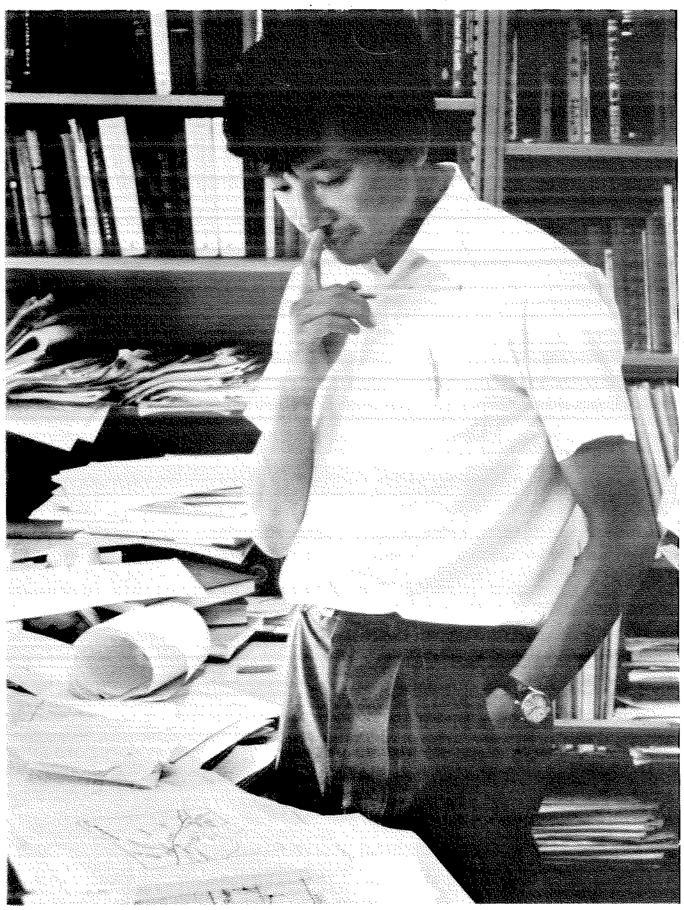
Seismological Laboratory scientists are now looking over records collected during the past 30 years on Caltech's southern California seismograph network. They want to see if dilatancy and precursory phenomena occurred before other earthquakes, and to look for abnormal patterns that may exist right now.

There may be such an abnormal pattern occurring beneath the city of Riverside. The seismic wave velocity in the earth's crust there has been changing for several years, and Hiroo Kanamori, professor of geophysics, is attempting to determine whether it is due to earthquake-related activity, to changes in the flow and distribution of underground water, or to something else.

Kanamori discovered the variations by measuring the changes in the velocities of seismic waves under the Riverside area produced by nuclear explosions in the Aleutian Islands in 1965, 1969, and 1971; by dynamite blasts in a cement quarry in the neighboring city of Corona; and by distant earthquakes. Using old seismic records, he measured the velocity of the waves produced from these sources by comparing the time it took them to activate various southern California seismographs.

He found that the recorded velocities had not changed

Seismologists James Whitcomb, Don Anderson, and Tom Hanks review the records of one of the many earthquakes monitored by Caltech seismometers—this particular one from Chile. Recent detailed analysis of such records reveals the existence of warning signals that may precede quakes.



Hiroo Kanamori, formerly professor of geophysics at the Earthquake Institute of Tokyo University, joined the Caltech faculty in November 1972. In Japan his most recent work was on the mode of strain release associated with major Japanese earthquakes, particularly as it relates to quake prediction. He is now conducting similar research along the San Andreas fault near the city of Riverside.

significantly over the years at any of the stations except the one at Riverside. The seismic velocities were constant between the 1965 and 1969 nuclear explosions, but at the Riverside station the waves from the 1971 detonation had increased in velocity about 14 percent. The records of waves from dynamite blasts and distant quakes corroborated the finding. In addition, seismic records from these two sources show that since 1971 the seismic wave velocities in the Riverside area have returned to "normal." Kanamori is also studying the change in velocity of surface waves that cross this region.

Of course, it is possible that the velocity change takes place without any association with an earthquake. Underground water can move around, and seismic waves passing through it react in the same way they do in a quake-prone area. But if the velocity change is related to a possible future earthquake, the dilatancy phenomenon may be common to all quakes and not just to those occurring in thrust-fault areas. (Riverside is near the southern end of the central segment of the San Andreas fault, which is in a strike-slip fault area, but it is still subjected to compressive stresses as well because it is so close to the big bend in the San Andreas fault.) To determine if dilatancy is the cause of the velocity changes, Kanamori is now measuring the seismic waves at different angles across the fault. If the measurements indicate some directional change of seismic waves with respect to the fault, it would strongly imply dilatancy, as shown theoretically by Anderson and two graduate students, Bernard Minster and David Cole.

Two other Caltech seismologists—Thomas Hanks, research fellow in applied science and geophysics, and graduate student James Hileman—have approached the prediction problem on a slightly different tack. Rather than reviewing records of past quakes, they are looking for an area with a high probability of earthquake activity in the future. They will then set up equipment to study what goes on underground prior to an expected earthquake.

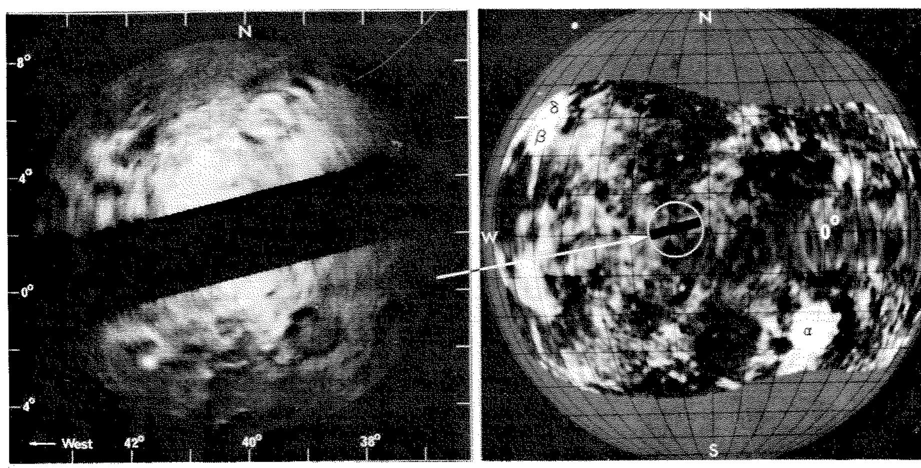
Two likely sites for their study are Lytle Creek, northwest of San Bernardino, and Anza, northwest of Borrego Desert. Both are on the San Jacinto fault, in a strike-slip fault region that extends for more than 200 miles southeast from Lytle Creek in the San Bernardino Mountains, through Hemet, Borrego Springs, Anza, and Mexicali, and then to the Gulf of California. Small quakes of about magnitude 4 have shaken the Lytle Creek and Anza areas frequently in the past 40 years, and the seismic habits along this branch of the San Andreas fault indicate that larger temblors—of magnitude 6 or greater—are likely to occur where smaller quakes are active.

Even before this vital research is finished, Caltech and the U.S. Geological Survey are taking steps to set up an earthquake prediction system. In a cooperative project they will install a large number of seismographs within the next two years in southern California; many of them will be placed along the San Andreas and San Jacinto faults. Seismic recordings from these stations will be continuously transmitted to the Caltech Seismological Laboratory. About 40 seismograph stations now ring southern California. But with this limited number, there are only certain places where dilatancy can be detected and used to spot potential earthquakes. If the Caltech-USGS project is successful, however, within five years seismologists may be able to predict earthquakes in areas that are heavily instrumented to monitor seismic activity. □

Research Notes

Craters on Venus

At least three planets in the solar system —Earth, Mars, and the Moon—are known to be scarred by craters resulting from some sort of cataclysmic collisions over the past several million years. Now it appears that a fourth—cloud-shrouded Venus—is marked by this kind of cratering too. The surprising discovery was made by radar astronomers at Caltech's Jet Propulsion Laboratory, who pierced the 13-mile-thick Venusian cloud layer with high-intensity radar beams sent from the Goldstone Deep Space Station in the Mojave Desert. A dramatic map assembled from these radar measurements reveals a 910-mile swath (about the size of Alaska) pitted with a dozen huge shallow craters. The largest is about 100 miles in diameter; others are between 20 and 65 miles across. All of them are relatively shallow—less than 1,200 feet deep. In fact, the whole area seems to vary by no more than 3,300 feet in altitude, and the presence of any craters at all is surprising.



A close-up of JPL's radar map (left) reveals an area near the equatorial region of Venus that is almost as cratered as the Moon. The black bar through the center of the area is a section that could not be scanned by radio telescopes at the Goldstone Deep Space Station. The photograph on the right shows the location of the cratered area in relation to bright sections mapped in previous JPL radar scans, marked α, β, and δ.

It has usually been assumed that the surface of Venus would have to be relatively smooth because it is shielded by an atmosphere 100 times more dense than Earth's. With this protective mantle, meteors on a collision course with Venus normally should have burned up before hitting the surface as meteorites. Nevertheless, the size and shallow nature of the craters defined by the JPL radar measurements suggest that they were created by impact and have somehow survived the erosion processes on the super-heated planet.

The JPL team is headed by Richard M. Goldstein, who has been radar-mapping Venus for a decade ("Mapping a Mystery" —*E&S*, November 1971). Manager of JPL's communications systems research section, he is also a research associate in planetary science at Caltech. The scientists used signal-processing equipment designed by Senior Research Engineer Richard R. Green (BS '64, MS '65, PhD '69) and George A. Morris, a group supervisor. The cratered map of Venus was assembled with the aid of computer techniques devised by Senior Research Engineer Howard C. Rumsey Jr. (BS '57, MS '58, PhD '61).

For the first time, Goldstein and his co-workers were able to scan the planet with two huge dish antennas—one 210 feet wide and the other 85 feet across—located 14 miles apart near Goldstone. The stereoscopic view that resulted made it possible to determine elevation differences on Venus to within 600 feet and distances on the surface to within six miles. These results are five times better than those of the last Venus radar experiment in 1970, which used only one of the Goldstone antennas.

The project scientists hope to get a closer look at Venus when JPL's Mariner 10 flies by the planet in February 1974 on its way to Mercury. They are now studying the results of the six radar scans of the last decade to help decide just where to point the Mariner 10 cameras, and they have also planned further radar probes in conjunction with the Mariner flight. Even though the spacecraft's television cameras may not be lucky enough to find holes in the Venus cloud curtain, the radar beams should be helpful in interpreting the close-up spacecraft data.

A New Telescope for Big Bear

Caltech's Big Bear Solar Observatory got a new three-barreled, four-ton, million-dollar telescope this summer. It can make five observations of the sun simultaneously, and it replaces a much less versatile system. Workers are still sorting out the miles of wires necessary to connect the electronic controls, but the system should be in full operation by next month, when one of its jobs will be to aid the astronauts on Skylab 3 in monitoring solar activity that is not visible from the earth's surface. A telephonic "hot line" will be maintained between the Johnson Space Center in Houston and the Big Bear Solar Observatory. When Big Bear observers spot impending interesting activity on the sun, they will notify Houston. There, the information will be relayed quickly by radio to Skylab or will be used in planning the following day's solar observations aboard the spacecraft.

Planets and Planetesimals

Scientists have a general idea of how the solar system developed, though a lot of details still haven't been completely worked out. But at least there seems to be general agreement that, in the very beginning stages of the evolution of the solar system, debris the size of dust—or even of small particles of gravel—condensed out of the slowly cooling gases in the nebula around the newly formed sun. It also seems fairly certain that, quite a bit further along in the evolutionary process, planet-sized bodies formed as the products of a series of collisions of smaller, asteroid-like objects called planetesimals. The gravitational fields of these objects would have caused them to stick together once they collided, creating a new and larger body. And this process must have continued until planets came into being.

This theory explains everything except what happened between that first evolutionary step and the end product. How did fragments no bigger than dust or gravel, and with no apparent gravitational attraction for one another, "grow" into planetesimals? Peter Goldreich, professor of planetary science and astronomy, and research fellow William Ward, have worked out a possible explanation of how the transition was made:

As gas in the solar nebula began to cool billions of years ago, the tiny solid particles that condensed out of it formed a thin, plate-like disk of debris that orbited around the sun. Although the gravitational pull of any one of these countless miniscule fragments was virtually negligible, their combined mutual attraction was enough to break the newly formed disk into separate clusters. Each cluster was composed of bits of debris—all attracting one another sufficiently to cause the space between the particles to shrink. Eventually, portions of each cluster collapsed on each other to form larger objects.

In just a few years—an incredibly fast time scale as cosmic time is measured—planetesimal bodies about half a mile thick were formed. In clusters of about 10,000 they continued to rotate around themselves in a delicately balanced equilibrium, prevented from contracting further by the strength of their rotational patterns.

Over a period of a few thousand years, however, the planetesimals interacted with the hydrogen gas that formed most of the remaining solar nebula, and the gas produced a drag that drained away the energy of the clusters. This caused them to continue to contract upon themselves until they formed still larger planetesimals about five miles in diameter.

This is about as large as these objects could have gotten by this process, but by this time they would have started colliding with each other, and their gravitational fields would have been strong enough to cause them to stick together. Eventually, they would have become planet-sized bodies.

If the process Goldreich and Ward describe is accurate, it has taken place many times—in fact, around every sun in the universe that has a solar system. And the formation of planets is very likely a natural consequence of the formation of stars.

Another Apollo

Caltech planetary scientist Eleanor Helin celebrated the Fourth of July this year in spectacular style. She discovered a five-mile-wide asteroid that whipped across the sky faster than anything but a meteor, and came to within 7 million miles of Earth. Moving at 60,000 miles an hour, if it had hit this planet—as objects of this kind occasionally do—it would have gouged out a crater 50 to 60 miles in diameter.

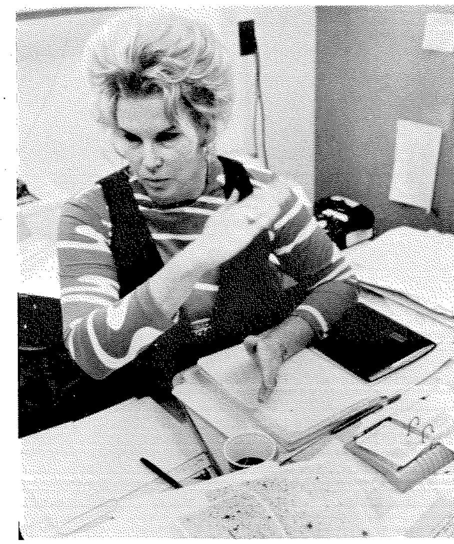
This is the 17th asteroid of its type discovered since 1932, when the first one was observed and named Apollo—a name that has since been applied to the whole group. It is the first discovered in a six-month search program now being conducted by Mrs. Helin and Eugene Shoemaker, professor of geology. The aim of the search is not only to locate Apollo objects but to find out more about them and their relationship to the processes by which the solar system was formed.

The new object was located within the constellation of Scorpius on discovery, and it showed up as a streak of light on a 20-minute exposure on a photographic plate taken by Mrs. Helin. She used the 18-inch Schmidt telescope at Palomar Mountain and was assisted by undergraduate John Smith, '74.

The asteroid travels in an elongated ellipse around the sun, coming as close as 80 million miles and swinging out as far as 290 million miles. Mrs. Helin and Shoemaker will have the honor of naming it when it returns to the neighborhood of Earth in late 1975 or early 1976.

Apollo group objects may be the residue of comets from which gases, dust, and small particles have been stripped away by close approaches to the sun. Like comets they follow up-and-down paths that crisscross diagonally through the plane of the orbits of the planets—in contrast to main-belt asteroids whose orbital inclinations are similar to those of the planets.

The most unusual thing about this particular object—and what makes it so spectacular to planetary scientists—is the extreme angle of its orbit to the plane of the earth's



Eleanor Helin

orbit: 67 degrees (an orbital inclination greater by far than any other known asteroid) as compared to the 10- to 15-degree inclinations of most other Apollo group objects. One 40-degree-inclination Apollo object was discovered last December and another earlier this year; together with the new discovery, the three appear to represent a whole new group of planetary objects.

Astronomers estimate that there are as many as 10,000 of these objects scattered throughout the space above and below the orbital plane of the planets of the solar system—space previously supposed to be empty except for the comets that travel through it. While some comets take as long as 100 million years to complete their orbits, there are also short-period comets that appear and disappear every few years. Mrs. Helin's discovery is the first solid evidence that there may be a link between the Apollo group objects and the short-period comets.

P.S. On August 27 another object was discovered by Mrs. Helin, who made seven observations, followed by observations by Richard Green, a graduate student, and Charles Kowal, research assistant in astrophysics. Preliminary orbital computations suggest that this is another Apollo group object. □

The Summer at Caltech

Campus Progress Report

The summer campus was more or less a mess. Physically, that is.

Where solid old Throop Hall used to stand like a national monument in the center of the campus, there was now a bombed-out crater. All through the summer months, though, workmen were putting in water lines, sewer lines, and electrical conduits so that construction could begin in November or December on the three new pools that will cascade down a grassy slope from the Millikan Pool to Throop Alley.

The cascading pools are pretty much the result of undergraduate student pressure. An earlier plan for the site involved long concrete steps, and it was student resistance to concrete that helped bring about the pools.

San Pasqual Street, between Wilson and Chester Avenues, was closed to automobile traffic on August 7.

In September, workmen started, at Chester Avenue, to move San Pasqual's palm trees to other locations and to tear up curbs, gutters, and paving to turn the street into pedestrian walkways.

Gates Laboratory, which revealed much of the same kind of structural weakness as Throop did in the San Fernando earthquake, has now had its interior cleaned out so that it stands, outwardly the same, but actually just a structurally sound shell. When funds, and programs, become available, the interior will be developed for central administration offices.

The Mabel and Arnold Beckman Laboratories of Behavioral Biology, across the Beckman Mall from the Donald E. Baxter, M.D., Hall of the Humanities and Social Sciences, will be dedicated in January.

The Seeley G. Mudd Building of Geophysics and Planetary Science, under construction since March 1972, is due to be completed in May 1974.

There will be a few other visible changes in the campus this fall. The age-old ivy between Guggenheim and Thomas will finally give way to turf and a new ground cover. And the service driveway between the Winnett Student Center and the Spalding-Thomas engineering buildings will be replaced by a pedestrian walk. For the information of the Page House White Horse & Railroad Company, Inc., the campus architect's office has a spot in mind at the north end of that walk for their David Smith Memorial Ramp.

Moving even one 80-foot-tall, 50-year-old palm tree requires men, machines—and belief in the value of saving trees. But multiply the job by 22, and you get a bigger idea of what it's taking to relandscape San Pasqual Street. Three of these *Washingtonia robustas* now form a small oasis on the northwest corner of Hill Avenue and San Pasqual, and most of the others are dressing up the area around the gym.

New Librarian

The office of the director of libraries on the second floor of Millikan has a new occupant this fall—Johanna Tallman. She replaces Harald Ostvold, who retired this summer.

Mrs. Tallman comes to the Institute after 28 years on the library staff at UCLA. Her most recent positions there were as head of the Engineering and Mathematical Sciences Library, coordinator of physical science libraries, and lecturer in the School of Library Service.

Born in Germany, Mrs. Tallman attended UC Berkeley, where she received both her AB and her graduate library certificate from the School of Librarianship. Her first job was at the San Marino Public Library, and

Johanna Tallman

it was followed by service at the Los Angeles County Public Library and the Pacific Aeronautical Library. She has been prominent in national and regional library affairs, and in 1966-67 held a Fulbright grant to lecture in Brazil. She has also been a consultant to such firms as Beckman Instruments, Lockheed Aircraft Corporation, and System Development Corporation—and to the University of Arizona.

The library system that Mrs. Tallman takes over in 1973 is very different from the one Harald Ostvold found in 1963 when he arrived at the Institute from New York where he had been chief of the reference department of the New York Public Library. Ostvold's first few years on campus included countless meetings with architects and faculty committees to plan Millikan Memorial Library. Then in 1967 he organized and supervised the moving of more than 130,000 books scattered in five other libraries across the campus into Caltech's first central library.

Accessions—including a bevy of Administration refugees from Throop Hall—have since filled Millikan to overflowing, and what may keep Mrs. Tallman walking a tightrope is balancing preference and practicality—specialized collections, interdisciplinary needs, and budget and space realities. But she is increasingly enthusiastic about her new job—and she's met challenges before.

Named Professors

Caltech has two new named professorships this fall—and two distinguished scholars to occupy the chairs.

New to the campus is Michael E. Levine, Henry R. Luce Professor of Law and Social Change in the Technological Society. A graduate of Reed College, where he was a science major, Levine received his LLB from Yale University. He served as an attorney for the Civil Aeronautics Board and then as a special assistant to the Task Force on Economic Growth and Opportunity. In 1967 he was offered a fellowship in law and economics at the University of Chicago, and he has been on the faculty at USC since 1968. He is a trustee of the Southern California Center for Law in the Public Interest.

His Caltech appointment is made possible by a five-year grant from the Henry Luce Foundation, and it is part of a program established by the foundation to encourage an integrative approach to the study of the humanities and social sciences.

Caltech's first IBM Professor of Mathematics is Marshall Hall Jr., who has been a member of the faculty since 1959. He is being honored for his "outstanding scholarly abilities and achievements, particularly in the fields of group theory and combinatorial analysis." In expressing appreciation to IBM for endowing the chair, President Harold Brown pointed out that Hall's work is linked with the mathematics of computers, "by happy coincidence a field in which IBM is closely associated."

Ding-a-Ling

We all know that Caltech telephone operators have to be trustworthy, loyal, helpful, friendly, courteous, kind, obedient, cheerful, thrifty, brave, clean, and reverent. But we are inclined to forget that they also have to be unflappable. (Could *you* handle a caller whose dog just swallowed a bee and what should she do? Or one who wants the Seismo Lab to investigate a strong earthquake whose epicenter is under his rumpus room?)

At any rate, Betty Bosserman, supervisor of telephone services, who works as a correspondent for a rival campus publication, has reminded us once again of how much self-control it takes to work as a Caltech phone operator. In her column in Physical Plant's lively *VIP* she reports:

Operator Nancy answered a signal from a campus phone. A pleasant masculine voice asked her for some long distance information. Nancy supplied it—but couldn't help remarking on a peculiar noise in the background.

"It sounds like an *elephant*," she said. The gentleman caller considered this for a moment.

"It isn't an elephant," he said reassuringly. "We don't have to have elephants here as long as I wear my paper hat."

He hung up after that—and it's no use pumping Operator Nancy or Chief Operator Betty. They won't even tell you what *division* the call came from.

New Options for Undergraduates

Life will be a lot different in the undergraduate student houses this year.

Faced with the possibility of an increase of as much as 50 percent in board cost, students reluctantly agreed last spring to do away with board contracts. From now on, instead of being served by waiters in their own house dining rooms, most undergraduates will eat their meals cafeteria-style in Chandler Dining Hall or in the three "new" houses—Page, Lloyd, and Ruddock. But at least one of the other houses plans to keep its former style by having dinners catered and assessing house members—in either money or time—to pay for service.

Students who prefer some other alternative can cook their meals on stoves installed in some of the alley kitchenettes. At present, each house has one or two stoves, and there are plans for putting in more. Seniors over 21 years old can now join the Athenaeum and eat there. And some students will probably patronize the commercial restaurants on Lake Avenue.

Another alternative to on-campus housing and eating exists in the co-op houses. First opened a year ago, these four Institute-owned houses are about a block north of the campus. They accommodate some 25 students, who pay rent to the Institute and share the expenses of running the houses. With their convenient location, good cooking facilities, and low rent, the co-ops are so popular that they all have waiting lists. This fall a new residence was opened on Lura Street for undergraduate and graduate women who prefer not to live in the co-ed student houses. This house is being run just like the on-campus student houses, with weekly linen exchange and rent at the student-house rate. The six-bedroom house has room for ten women, though at the start of the term only six had moved in.

Obviously, the effects of these changes on undergraduate student life won't show up for a while. But some sour seniors will tell you it's already putting an end to the old fraternity-like camaraderie that house residents enjoyed as recently as last year.

The Caltech Navy

Possibly because she can be classified as a freshman, the new—and only—member of Caltech's Navy went to freshman camp at Catalina this fall. With students and faculty aboard for cruises, she displayed her speed (20 to 25 knots), her special gear (scuba equipment and a custom ladder and storage areas), and her holding tanks (with recirculating water).

The 31-foot-long, fiberglas *Sea Urchin III* will be used by Wheeler North, professor of environmental science, for his kelp rehabilitation projects. And three scientists from the division of biology—Charles Brokaw, professor; Eric Davidson, associate professor; and Roy Britten, senior research associate—will be using her to collect sea urchins for their research. Despite her roman numeral, *Sea Urchin III* is the first Kerckhoff Marine Laboratory boat to be constructed specifically for Caltech's marine biologists; her predecessors were old Navy wooden launches. *Sea Urchin II* simply wore out in the late sixties, but in the late fifties *Sea Urchin I* met a sadder fate. Loaned to an institution which shall be nameless, her solitary occupant left her alone, and when he rose from his dive, found she had drifted to shore and been reduced to flotsam and/or jetsam.

The new boat was financed by grants from the National Science Foundation and the J. W. Kieckhefer Foundation.

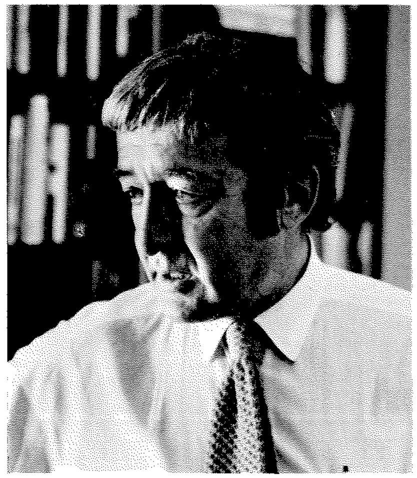
Chinese Junket

Harrison Brown, professor of geochemistry and of science and government, spent almost a month in China last spring as a member of a delegation representing the Committee of Scholarly Communication with the People's Republic of China. The delegation was jointly created by the National Academy of Sciences, the Social Science Research Council, and the American Council of Learned Societies so that almost every major field of scholarly endeavor was represented. The group made the trip at the invitation of the Chinese, to discuss scholarly exchanges. Here are some of Brown's comments on the visit:

The most impressive element of Chinese life, I thought, was their determination to develop their nation on their own, minimizing the need for outside assistance. Indeed, the amount of outside assistance they are receiving now, after the pullout of the Russians, is zero. To be sure, they are getting grain from the United States and Canada, but they are purchasing this with hard currency.

Whenever the Soviet Union was mentioned, it was in derogatory terms. Sometimes the comments were humorously put. Chou En-Lai and others stressed that the Russians could be numbered among the best teachers in the world: The most important single thing they did for China was to leave, which forced the Chinese to learn how to do things themselves. Indeed, again and again we saw examples of this; steel mills were left half completed, structures and industries of various sorts were left unfinished, and the Chinese had to learn how to put them together and get them into operation by themselves.

It is quite clear that the Chinese are developing a lifestyle that is unlike that of the West. We were told by Chou En-Lai that they do not intend to become an "automobile culture," and indeed in Peking itself, in a city of four million inhabitants, they have some 1.7 million bicycles. It's quite impressive to see the streets during rush hours; there are thousands of bicycles moving along, but it's very quiet. You occasionally hear the tinkling of bells, or conversations of people, the whizzing of the bicycle tires on pavement, but that's all.



The Chinese are making maximum use of their most abundant resource, which is people. It's surprising to see the extent to which people are prime movers; I think more carts are pulled by people than by horses, and there are quite a few horses, and mules. They have developed some very simple single-cylinder engines that are used to pull loads at low speed, and there are trucks, of course. But for the most part loads are pulled by people, and to a lesser extent by draft animals.

I was impressed with the activity on the communes. A commune is basically a small collection of four, five, or six villages. A village is now called a "work brigade." Each work brigade tries to be independent; they have separate bank accounts, they sow crops, they save their money, and they vote on how to spend their money. Several work brigades band together to form a commune, and the function of the commune is to develop facilities which no single village could afford by itself, such as a middle school, a hospital, a small industry —such as a fertilizer factory.

Each laborer on a commune receives a certain number of "work units," which are translated into local currency. A work unit depends in part upon the ability of individuals to work, and those who can work hardest can get more points than others. Men get more points than women, solely on the basis of the amount of physical energy they expend. There are differences between categories of laborers, but the difference between the highest and lowest paid is really very small.

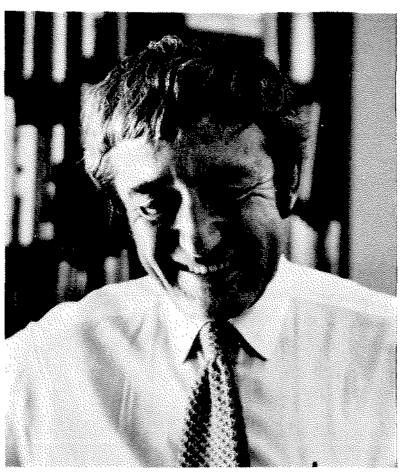
I have no idea how reliable the numbers are, but the figure for total population in China was given to me as about 750 million, give or take about 20 million persons. With respect to vital statistics, it is quite clear that the Chinese death rate has been lowered, in large part because of a tremendous effort that has been made in the field of public health. I do a great deal of traveling in developing countries, and to me one of the most impressive elements of China is its cleanliness. Almost all of the members of our delegation engaged in "fly counts," and I think I counted four flies all the time I was there, which is fewer flies than I will see around Caltech in the course of a day. Even a tropical city like Canton, which used to be noted for its dirtiness and disease, is now relatively clean—at least to the point of not having obnoxious smells noticeable to the visitor. I'm not just talking about the main streets; we were quite free to wander around.

So death rates have gone down. The Chinese have also made a tremendous effort to lower their birth rate. They have been successful in the cities, but they have a long way to go before they really reach the people in the countryside—who make up about 90 percent of the population.

The people, everyplace I went, were extremely friendly. I run every morning for exercise, and as I ran people would wave and smile and laugh. No matter where we walked, people were extremely curious, but they would always smile and wave. Not once did we experience any antagonism. The political leaders were friendly too. We spent two hours with Chou En-Lai, and he said only extremely friendly things to us. We talked about the future of exchanges, and it is clear that they want to deepen and widen the relationship between the peoples of our two countries. They are interested in engaging in scholarly exchanges, not across the board, but on selective bases. We proposed a group of 12 delegations of American scholars in different fields to travel to China. We made our proposal on the basis of examining those fields in which we feel that we have something to learn from the Chinese, and we wanted to make the overall proposal as attractive as possible to them. We told them we would be prepared to receive in return approximately equal numbers of delegations in fields of their own choosing. We were pleasantly surprised to find that they accepted 9 out of the 12 delegations we proposed. They said that they simply were not prepared yet for the other three delegations, which were in the social sciences. The delegations that they accepted were for the most part in the natural sciences. As they put it, the social scientists are still going through the process of self-criticism, which natural scientists have already gone through.

The groups going to China include one each in earthquake prediction and seismology, in child psychology and childhood learning processes, acupuncture anesthesia, modern Chinese archaeological findings, anthropology (with particular reference to early man, and new discoveries about Peking man), and plant science (which will attempt to develop an exchange of plant materials to broaden our gene reservoirs of genetic materials for crop purposes).

The groups they did not accept were those relating to modern Chinese studies, with particular reference to how they organize their communes and their cities, the political processes that take place, and so forth. The Chinese were not prepared to engage in



exchanges in those areas. They are sending over groups primarily in the natural sciences. There will be a group in earthquake prediction, and they have already sent over a group dealing with problems of water management, and a group on insect control with steroid chemicals. They are planning to send a group to study how we teach the English language to foreigners; they have a very real problem of teaching English to many people in China. One of the main limiting factors they have in receiving guests is the shortage of interpreters.

There is almost no scientific research of any consequence going on in the Chinese universities these days; most of the research takes place in research institutes, which are operated by either the Academy of Sciences or Ministries of one sort or another. Some research institutes are doing extremely good work, at the forefront of modern scientific knowledge, while others are 15 years behind the times.

I am told by my colleagues who examined the Chinese synthetic organic chemistry work that the Chinese are achieving a great deal here, particularly in the areas of steroid chemistry. For example, in their own birth control pills, the Chinese have bypassed the yam. We start off with the yam and extract steroid intermediates from it and synthesize our hormone-like contraceptives from that. They start from the beginning, apparently.

It seemed to me that the universities in China have become sort of glorified technical schools. They are used primarily to train young people in modern technological techniques. The other major difference is the admissions process. In the United States students are admitted primarily on the basis of their ability, as measured by how well they did in high school and on entrance examinations and the like. This was true at one time in China. Generally speaking, however, the sons and daughters of intellectuals tended to go to the university more often than the sons and daughters of peasants. The Chinese have made an effort to eliminate this class distinction and admit many young people from peasant villages. Some of the most important criteria for admission today relate to the applicant's political standing.

Everything is aimed at the development of China. This is the number one priority. Everyone must work on something connected with the development of the country. This is a basic rule of behavior in China these days. The leaders have done everything they can to eliminate class, to eliminate wealth, to minimize the difference between the richest and the poorest. Thus far they seem to have been successful in this.

Chemical Change

Administration of the division of chemistry and chemical engineering is under new management this fall. The recently appointed new chairman, John Baldeschwieler (*E&S*, January), arrived on campus during the summer. And two new executive officers were appointed.

Fred Anson, professor of analytical chemistry, is the new executive officer for chemistry, replacing Norman Davidson, who has held the job since 1967. Anson is a 1954 graduate of the Institute. He got his PhD at Harvard in 1957 and came back to join the Caltech faculty that same year. In 1964 he spent eight months studying in Belgium as a Guggenheim fellow, and last year he spent four months in Italy as a Fulbright scholar. He is particularly interested in chemical substances which adsorb on the surfaces of metal electrodes, where they facilitate the efficient conversion of chemical energy directly into electrical energy.

John H. Seinfeld, associate professor of chemical engineering, has been named acting executive officer for chemical engineering. He takes the place of C. J. Pings, who has held the job since 1969. Seinfeld received his BS at the University of Rochester in 1964 and his PhD from Princeton in 1967. He came to Caltech in 1967 as assistant professor of chemical engineering and became associate professor in 1970. Last year he was one of 17 young American scientists to be awarded a grant from the Camille and Henry Dreyfus Foundation for achievements in teaching and research. His research fields are optimization and control of chemical systems, and air pollution simulation and control.

Honors, Awards, and Appointments

Stirling L. Huntley, associate dean of graduate studies, has been appointed to a pair of additional positions. He's now also director of admissions and financial aid and a lecturer in drama.

Huntley's experience and training qualifies him for both of these assignments. For two years before coming to the Institute in 1971 he served as head of admissions, alumni, records, and community relations for the University of Hawaii's East-West Center. For ten years before that he was on the staff of the admissions office at Stanford. And for five years before that he was a member of the speech and drama faculty there. His BA and MS degrees are from UCLA, and his PhD is from Stanford.

W. Henry Weinberg, assistant professor of chemical engineering, has received the Victor K. LaMer Award of the American Chemical Society's Division of Colloid and Surface Chemistry. The prize of $1,000 is given biennially to a young chemist or chemical engineer. Weinberg is 28.

Before coming to Caltech in 1972, Weinberg did postdoctoral work at Cambridge University in England. He received his BS from the University of South Carolina and his PhD from UC Berkeley. He is studying—both experimentally and theoretically—the way gases interact with solid surfaces and the problems of chemical adsorption and heterogeneous catalysis.

Ray Owen, professor of biology, has been appointed to the President's Cancer Panel. The three-member group, established by the National Cancer Act, supervises the National Cancer Program and reports directly to the President.

Owen has been a member of the American Cancer Society's panel on the etiology of cancer and the special grants committee of the society's California division. He has also served as chairman of the National Science Foundation's advisory committee for biological and medical sciences, and was a member of Governor Reagan's Cancer Advisory Council.

Pol Duwez, professor of materials science, who is internationally known for his research into the development of new alloys with unusual superconducting and thermoelectric properties, received the 1973 Albert Sauveur Achievement Award of the American Society for Metals. The award, presented annually since 1934, is given "to recognize pioneering metallurgical achievements which have stimulated organized work along similar lines to such an extent that a marked basic advance has been made in metallurgical knowledge."

Roy W. Gould, professor of electrical engineering and physics, has been named to a four-man advisory committee of the Electric Power Research Institute. EPRI was formed recently by the nation's electric power industry to develop methods of providing adequate electric power in the future. The new advisory committee's responsibility will be to accelerate research and development of controlled nuclear fusion to provide large amounts of power at low total cost. Gould, who is an alumnus of the Institute, has been a member of the faculty since 1955. He recently returned to the campus from a two-year leave of absence during which he was director of the Atomic Energy Commission's division of controlled thermonuclear research.

Faculty and Administrative Changes 1973-1974

ADMINISTRATION

FRED C. ANSON—*executive officer for chemistry*
JOHN D. BALDESCHWIELER—*chairman of the division of chemistry and chemical engineering*
ROY W. GOULD—*executive officer for applied physics*
NORMAN H. HOROWITZ—*acting chairman of the division of biology* (January 15 to August 31, 1973)
MAARTEN SCHMIDT—*executive officer for astronomy*
JOHN H. SEINFELD—*acting executive officer for chemical engineering*

PROMOTIONS

To Professor, Emeritus:
C. HEWITT DIX—*geophysics*

To Professor:
ROBERT G. BERGMAN—*chemistry*
JAMES O. MC CALDIN—*applied science*
MARC-AURELE NICOLET—*electrical engineering*
MICHAEL A. RAFTERY—*chemical biology*

To Senior Research Associate:
ROY J. BRITTEN—*biology*
CLAIR C. PATTERSON—*geochemistry*

To Associate Professor:
LEROY E. HOOD—*biology*

To Research Associate:
JAMES E. BROADWELL—*aeronautics*
JUSTINE S. GARVEY—*chemistry*
BOZENA HENISZ-DOSTERT—*linguistics*
RICHARD E. MARSH—*chemistry*
STEN O. SAMSON—*chemistry*
CHANG-CHYI TSUEI—*applied physics*

To Assistant Professor:
JOEL H. ANDERSON—*mathematics*
COLIN BENNETT—*mathematics*
WILLIAM H. PRESS—*theoretical physics*
ROBERT M. STROUD—*chemistry*

To Senior Research Fellow:
THOMAS H. ANDERSON—*geology*
STEVEN J. BARKER—*aeronautics*
WEI-KAN CHU—*electrical engineering*
ALLEN T.-Y. CHWANG—*engineering science*
GEORGE J. DICK—*applied physics*
ERI HELLER—*chemistry*
ARTHUR H. HUFFMAN—*physics*
HARUMI KASAMATSU—*biology*
FRANK A. PODOSEK—*planetary science and physics*

STEVEN H. SMALLCOMBE—*chemistry*
ELLEN G. STRAUSS—*biology*

NEW FACULTY MEMBERS
Professor:
JOHN D. BALDESCHWIELER—*chemistry*
ROGER C. NOLL—*economics*

Research Associate:
RICHARD M. GOLDSTEIN—*planetary science*

Senior Research Fellows:
MICHAEL A. BERTA (Major, USAF)—*aeronautics*
A. GERALD BRADY—*earthquake engineering*
RICHARD C. BROWER—*theoretical physics*
GLENNYS R. FARRAR—*theoretical physics*
MICHAEL G. HAUSER—*physics*
AURORA M. LANDEL—*biomedical engineering*
RICHARD J. POWERS—*physics*
HANS-PETER VOSBERG—*biology*

TERMINATIONS
E. RICHARD COHEN—*research associate in engineering science*
A. R. DZIERBA—*senior research fellow in physics*
JAMES W. GREENLEE—*assistant professor of French*
ROBERT S. HARP—*assistant professor of electrical engineering*
GORDON L. HARRIS—*assistant professor of aeronautics*
ALAN J. HODGE—*professor of biology*
JAMES F. KORSH—*senior research fellow in applied science*
HAROLD LURIE—*professor of engineering science*
HITOSHI MIZUTANI—*senior research fellow in geophysics*
TSE-CHIN MO—*senior research fellow in electrical engineering*
YORIKIYO NAGASHIMA—*senior research fellow in physics*
JAMES W. PRAHL—*senior research fellow in biology*
BORJE I. PERSSON—*assistant professor of physics*
DONALD G. REA—*research associate in planetary science*
LAWLOR M. RECK—*coach*
RICHARD H. STANFORD JR.—*senior research fellow in chemistry*
SANDOR TRAJMAR—*senior research fellow in chemistry*
MICHAEL D. WATERFIELD—*senior research fellow in biology*
MYONGGEUN YOON—*senior research fellow in biology*
B. D. ZABLOCKI—*senior research fellow and lecturer in sociology*
JOHN S. ZEIGEL—*assistant professor of English*

RETIREMENTS
BERT F. LA BRUCHERIE—*coach*
HARALD OSTVOLD—*director of libraries*

CHECK OUR SPECS BEFORE YOU BUY THEIR 4 CHANNEL RECEIVER.

	Sylvania	Pioneer	Sansui	Fisher	Harman-Kardon	Marantz
Model	RQ 3748					
Continuous (RMS) Power[1] **4 channels** **Stereo Bridge**	50W x 4 125W x 2					
THD at rated output	<0.5%					
IM Distortion at rated output	<0.5%					
FM IHF Sensitivity	1.9μv					
50 db signal to noise ratio	2.8μv					
Capture Ratio	1.5db					
Price	$549.95[2]					

[1]All powermeasurements taken at 120 volts/60 cycles, 8 ohms, 20Hz-20kHz, all channels driven simultaneously.
[2]Manufacturer's suggested list price which may be higher in some areas.

If you're in the market for four channel, you already know you've got to spend a good bit of cash for a receiver. So it'd be a good idea to spend a good bit of time checking specs on everything available just to make sure you get the most for your money.

To make your search a little easier, we've prepared the blank comparison chart above with spaces for some of the best-known brands and most important specs. Just take it with you to the store, fill it in, and you'll be able to tell at a glance what you get for what you pay.

We took the liberty of filling in the Sylvania column with specs for our RQ3748 four channel receiver. We did it because we know we're not the best-known name in four channel, and we didn't want you to overlook us for that reason.

Because we think the RQ3748's specs are really worth remembering.

50 watts of RMS power per channel at 8 ohms, 20-20kHz, with all four channels driven. 125 watts per channel in stereo bridge mode. A THD and IM of less than 0.5% at rated output. An FM sensitivity of 1.9 microvolts. A discrete four channel receiver with matrix capabilities so you can use either type of quadraphonic material. And much, much more[3]

We can offer so much because we have so much experience. We were one of the first in the audio field. And now we're applying all our knowledge, all our engineering skill to four channel.

Once you've proven to yourself which receiver has the best specs, move on down to that last line in the chart and compare Sylvania's price with all the others. Find out which one gives the most for your money.

We feel pretty confident you'll discover that the best-known names aren't necessarily your best buy.

[3]So much more that it won't all fit here. So send us a stamped, self-addressed envelope and we'll send you a four-page brochure on our four channel receivers.

GTE SYLVANIA

Sylvania Entertainment Products Group, Batavia, N.Y.

Now that you've decided to be an engineer, how do you decide what kind?

Trying to figure out the exact kind of engineering work you should go into can be pretty tough.

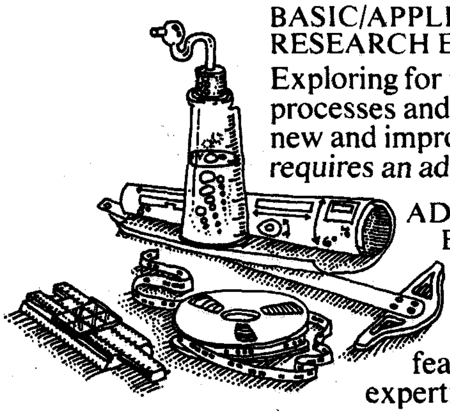
One minute you're studying a general area like mechanical or electrical engineering. The next you're faced with a maze of job functions you don't fully understand. And that often are called different names by different companies.

General Electric hires quite a few engineers each year. So we thought a series of ads explaining work they do might come in handy. After all, it's better to understand your options before a job interview than waste your interview time trying to learn about them.

Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems. Manufacturing products. Selling and servicing products.

This ad is a brief outline of the most common engineering functions at GE. In future ads we'll cover individual functions in more detail.

Development and Design



BASIC/APPLIED RESEARCH ENGINEERING
Exploring for new materials, processes and systems for making new and improved products. Usually requires an advanced degree.

ADVANCE PRODUCT ENGINEERING
Thinking up ideas for new or improved products, then proving their technical feasibility. High technical expertise required.

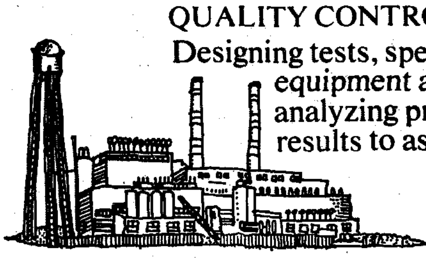
PRODUCT DESIGN ENGINEERING
Transforming the product idea into a design that meets given specs and can be manufactured. Following through to production.

ENGINEERING MANAGEMENT
Planning, organizing and supervising engineering work in a product business or project operation.

Manufacturing

MANUFACTURING ENGINEERING
Planning exactly how a product will be manufactured. From consulting with designers to creating tools and machinery to planning production flow.

QUALITY CONTROL ENGINEERING
Designing tests, specifying test equipment and procedures, analyzing production test results to assure product quality.



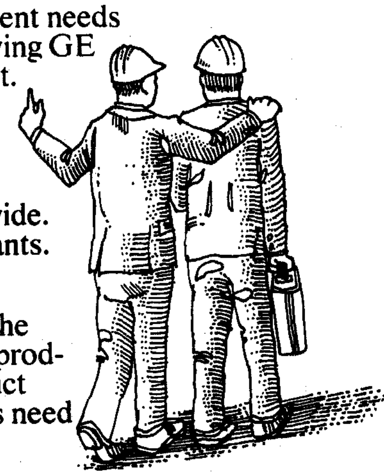
FACTORY MANAGEMENT
Supervising a factory's people and machines. Making sure all the many elements run smoothly.

MATERIALS MANAGEMENT
Designing materials flow systems to make sure vital parts and materials are at the right place, at the right cost, at the right time.

Sales and Service

SALES ENGINEERING
Identifying the needs of GE's utility, industrial and governmental customers and recommending the products and services to fill them.

APPLICATION ENGINEERING
Analyzing special equipment needs of customers, then specifying GE products and systems to fit.



FIELD ENGINEERING
Installing and servicing large machinery systems for GE customers worldwide. From motors to power plants.

PRODUCT PLANNING
Marketing. Determining the need for new or modified products. Making sure a product line offers what customers need at competitive prices.

GENERAL ELECTRIC
An Equal Opportunity Employer