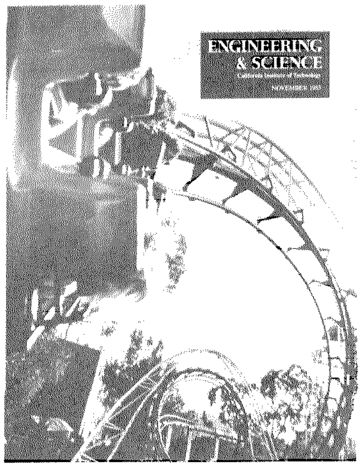
# ENGINEERING & SCIENCE

California Institute of Technology

NOVEMBER 1983

# In This Issue

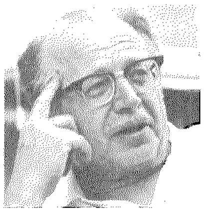



**Circular Motion**
On the cover — a participant's view of a ride on the Corkscrew at Knott's Berry Farm. This kind of visceral experience with what it means to go around in circles is the take-home lesson for Program 9 of Caltech's venture into educational television. For more, see "Physics on the Tube," which begins on page 14.

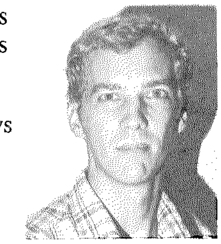
**Then and Now**

For 35 years the Hale Telescope at Palomar has been one of the world's leading astronomical instruments, though activities at the observatory have changed a lot in that time. "A Night on Palomar Mountain — 1983," which begins on page 10, describes some of the current research. For contrast it is accompanied by some quotations from the first "A Night on Palomar Mountain," published in *E&S* in 1969.

The author of the 1969 article was Jesse Greenstein, now Lee A. DuBridge Professor of Astrophysics, Emeritus.



The author of the second is John Gustafson, who spent the summer at Palomar as an intern in science writing. His assignments there included writing news releases, revising copy for a Palomar booklet, and completing this article for the magazine. Gustafson has a BS in astronomy from the University of Arizona and an MA in astronomy and astrophysics from UC Santa Cruz, where he also earned a graduate certificate in science writing. He is currently a publicist for the Lick Observatory.



**Earthquake Engineering**
The expertise of some of Caltech's engineering faculty about the effects of earthquakes on structures is well known. So it was natural to seek out one of them after the Coalinga earthquake of last May. Paul Jennings, professor of civil engineering and applied mechanics, visited Coalinga the day after the quake, and he was interviewed by Dennis Meredith, director of the News Bureau, to find out the state of the town. "Lessons from the Coalinga Earthquake," which begins on page 6, is the result of that interview.

Jennings has a BS in civil engineering from Colorado State University and an MS and PhD from Caltech. He became a Caltech faculty member in 1966.

He has studied structural damage from major earthquakes all over the world and has served on numerous panels and advisory boards on that subject, including the Earthquake Engineering Research Council and the National Research Council Committee on Natural Disasters. He is editor of reports on the Alaskan earthquake of 1964 and of the San Fernando earthquake of 1971, and he consults on the design of high-rise buildings, offshore drilling towers, and nuclear power plants.

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# ENGINEERING & SCIENCE

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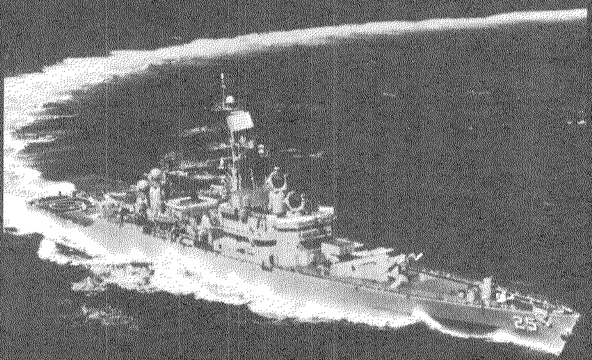
*Departments*

# The Most Sophisticated Training Ground For Nuclear Engineering Isn't On The Ground.



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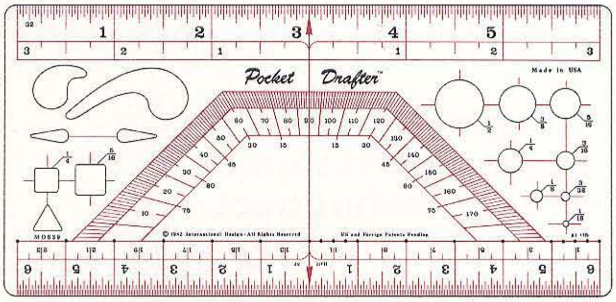

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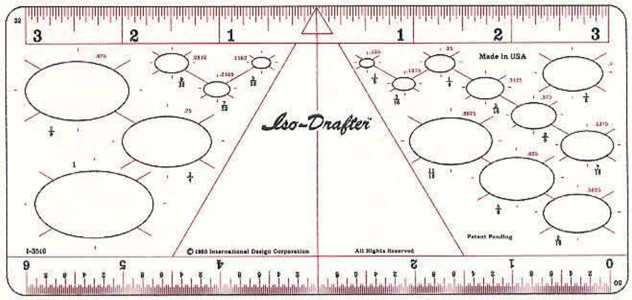

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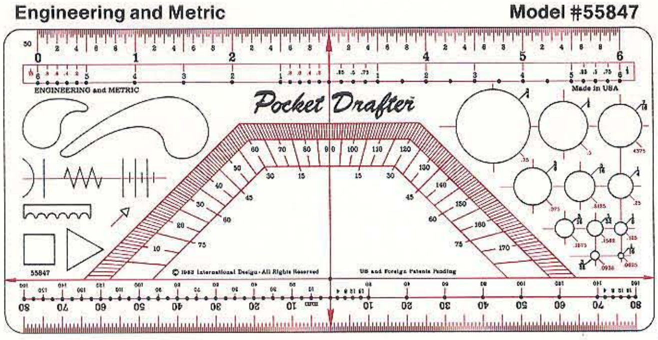

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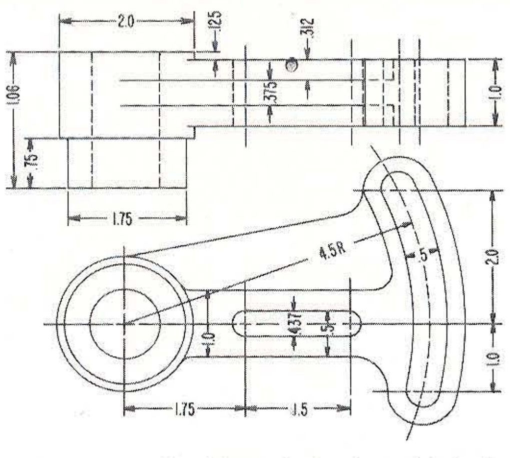


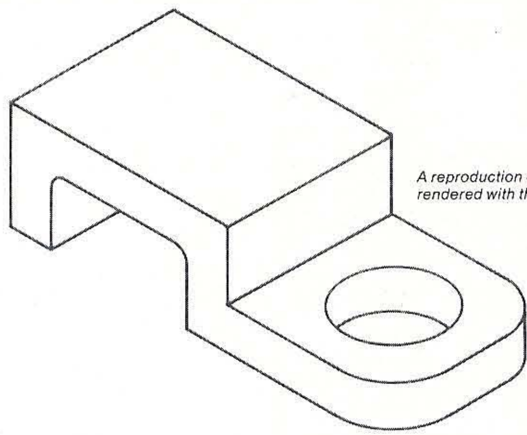

*A reproduction of a drawing rendered with the Iso-Drafter.*

The versatility and portability of the Pocket Drafter and the Iso Drafter make them a great asset when you are away from your drawing board. However you will find that the speed, accuracy, and versatility of these instruments make them valuable additions to even the most sophisticated drafting setups.

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# SCIENCE/SCOPE

A Very High Speed Integrated Circuit chip has been produced at Hughes Aircraft Company, marking a significant step toward the use of advanced semiconductor technology in military systems. The chip, built after less than two years of development, contains 72,000 transistors in an area the size of a thumb tack. The VHSIC program is being conducted by the U.S. Department of Defense to develop chips that will give military electronic systems a tenfold increase in signal processing capability. The high-speed, compact VHSIC chips will be more reliable and will require less power than integrated circuits now in use.

An advanced antenna farm designed with the aid of a computer will be carried into space by Intelsat VI communications satellites. The system will provide many different kinds of coverage -- beams transmitting to entire hemispheres, "global" beams, focused regional beams, and very narrow spot beams for broadcasting high-speed data. Hundreds of computer patterns were created to predict antenna performance. These studies led to the choice of transmit reflectors 3.2 meters in diameter instead of 4 meters. The larger size was rejected because it offered only slight improvement at the cost of being much heavier, larger, and more complex. Hughes heads an international team building Intelsat VI for the International Telecommunications Satellite Organization.

The F/A-18 Hornet's radar undergoes searing heat and piercing cold as part of its reliability tests. During one demonstration, two AN/APG-65 radars operated 149 hours without failure, the equivalent of almost five months of flight time. The units were run through repeated cycles consisting of 90 minutes at -65°F, then 90 minutes at -40°F, and six hours of continuous operation at temperatures up to 160°F. By comparison, the lowest and highest temperatures ever recorded in North America were -81°F in 1954 at Snag in Canada's Yukon Territory, and 134°F in 1913 in California's Death Valley. The APG-65 is the first multifunction radar for both air-to-air and air-to-surface missions. Hughes builds it under contract to McDonnell Douglas for the U.S. Navy and Marine Corps.

The new AMRAAM missile will be good at evading enemy detection through a clever improvement to its radar system. The improvement, now patent pending, is done simply and with only a little extra hardware. It greatly reduces inaccuracies caused when the missile jumps from one radar frequency to another en route to its target. Frequency hopping makes it extremely difficult for enemy radar-detection equipment to get a fix on the missile. Hughes designed and developed the Advanced Medium-Range Air-to-Air Missile for the U.S. Air Force and Navy.

More than 20 nations throughout the free world guard their skies against enemy attack with automated air defense systems developed by Hughes. Since pioneering the electronically scanned 3-D radar more than 20 years ago, Hughes has produced or managed systems for Japan, Switzerland, NATO countries, Spain, Canada, and the United States. Air Defense Ground Environment (ADGE) systems are comprised of air defense radars, computers, displays, and other electronic subsystems. Data links relay detections to data processing centers where computers identify, automatically track, and report the aircraft's speed, altitude, and course.

# Lessons from the Coalinga Earthquake

*by Dennis Meredith*

By the standards of seismologists, this earthquake rated only a "moderate," but to most of the 7,200 residents of Coalinga, California, last spring's disaster was a terrifyingly violent episode. At 4:43 on the afternoon of May 2, 1983, this small San Joaquin Valley town was wrenched by the strong shaking from a magnitude 6.5 earthquake. Just 10 seconds later the town had sustained some $33 million in damage that varied in severity from a few minor cracks in some buildings, through foundation failure in others, to total collapse in still others. Some 45 people were injured, a few seriously, but — almost miraculously — no one was killed.

No major earthquake is without its aftermath, most of which is an unhappy reminder of the tragedy. There are, for example, the continuing aftershocks, the care of the injured and homeless (the Red Cross served over 53,000 meals in the three weeks after the quake), and the rebuilding of houses and businesses. The one long-term consolation is that seismologists, earthquake engineers, and planners extract as much knowledge as possible from each seismic calamity in the hope of making the consequences of the next one less tragic. Thus, after any sizable earthquake dozens of experts arrive with instruments, cameras, and note pads, ready to gather relevant data. Paul Jennings, Caltech professor of civil engineering and applied mechanics, is one of the more than 50 such experts examining the Coalinga earthquake for the lessons it offers.

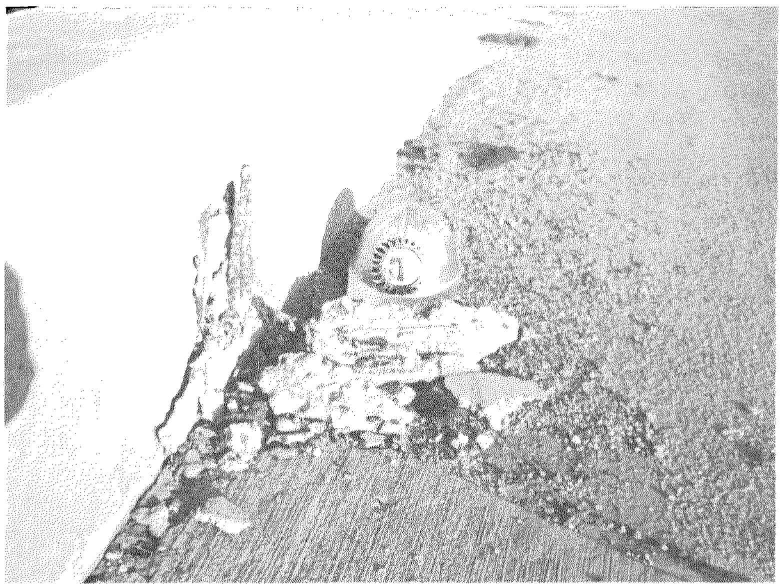
The work of Caltech engineers and seismologists began within a few hours of the main shock, when Assistant Professor John Hall, engineer Raul Relles, and several Caltech graduate students arrived in the area to install strong-motion instruments to capture records of aftershocks. (One distinguishing feature of this earthquake is that there were more aftershocks in the magnitude 5 to 6 range than are normally expected.) In addition, students from Caltech's Seismological Laboratory went to the area, primarily to look for evidence of fault movement near Coalinga and on the nearby San Andreas fault. On May 3, the day after the quake, Jennings arrived with another student group to survey the damage to structures. Interestingly, in some places it took a really practiced eye to spot it.

"Until we got into downtown Coalinga, which is the older part of town," says Jennings, "it was not obvious that there had been any earthquake damage at all. We could see some very minor damage to the freeway bridges — some spalling (chipping) and cracking — but only an experienced observer could tell that it wasn't just normal wear and tear. When we came to the first stopping point on the way into the city, where the patrolmen were issuing passes, on one side of the street was the Cambridge Motel open for business, and on the other side was the office of the county sheriff. There was no damage to either place. It wasn't until we reached the older part of the town that we could really see the damage, and it confirmed what engineers have known for a long time — that modern construction practices really make a difference."

Jennings feels that the Coalinga earthquake was a clear test case of the resistance of older commercial and residential construction versus newer commercial and residential buildings. It's obvious to him that modern construction practices, codes, and engineering combined in varying degrees to make the newer buildings perform much better. Old commercial buildings, which were primarily of unreinforced masonry, suffered heavy damage or were totally demolished, and modern commercial buildings emerged practically unscathed.

An equally strong contrast was evident in the behavior of older residential housing, particularly old wooden housing built before 1933, versus modern housing. Before 1933, a common method of constructing a wood frame house was to build the floor level of the house two or three feet off the ground with a front porch and steps leading up to the floor. The perimeter of the box-like house rested on a mud sill of concrete, and the floor was supported with 14- to 18-inch-long four-by-four studs, each of which rested on a small concrete pad. Typically, such a house has a skirt of clapboard or siding around the outside. In the 1933 Long Beach earthquake and in virtually every large earthquake since, houses like those — if they

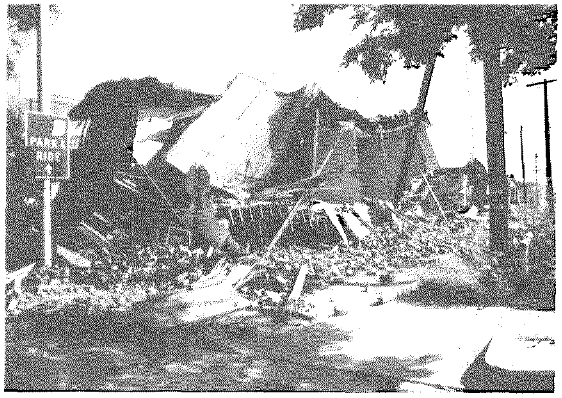

*The two pre-1933 residences at the left show the effects of a magnitude 6.5 earthquake — one losing much of its front wall and the other shifting off its foundation.*

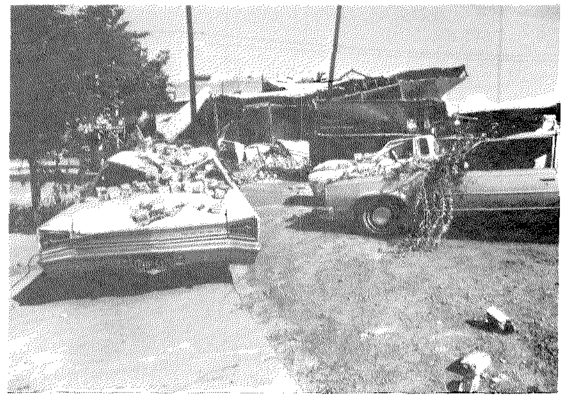



*Damage to freeway bridges was fairly minor. An example of spalling is shown at the left and of cracking, above.*


*The older part of Coalinga suffered major damage. Just 10 seconds of shaking created this kind of havoc in the downtown area.*

*The advice to "Park and Ride" may have been good for some people, but the shakeup was hard on buildings and cars left in the area.*



haven't had any additional bracing — have fallen off their foundations. This happened in the Coalinga earthquake too. The damage isn't necessarily hazardous to life or limb, but it's terribly expensive to repair.

"What wasn't tested in Coalinga," says Jennings, "was the structural integrity of the intermediate-height concrete buildings built in the 1950s and 1960s, before there were codes for ductile concrete. Nor were tall skyscrapers and various types of industrial and large commercial structures tested, because there weren't any in the area. There was, for example, no building in Coalinga like the Imperial County Services Building, which was damaged so severely in the Imperial County earthquake in 1979 that it had to be taken down. If there had been a building of that size and construction in Coalinga, it wouldn't have done well either, because the shaking was comparable in the two earthquakes."

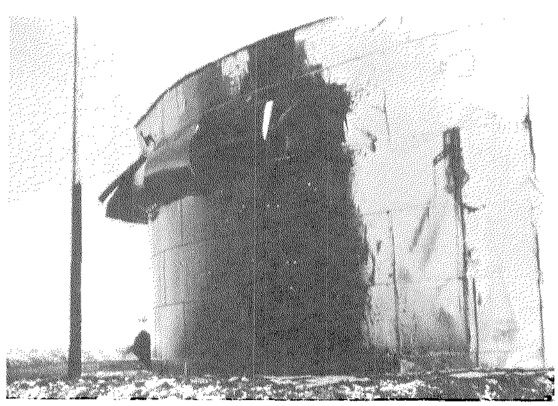
But could the effects of the Coalinga earthquake be taken as a milder, smaller version of the effects of a truly large earthquake on Los Angeles?

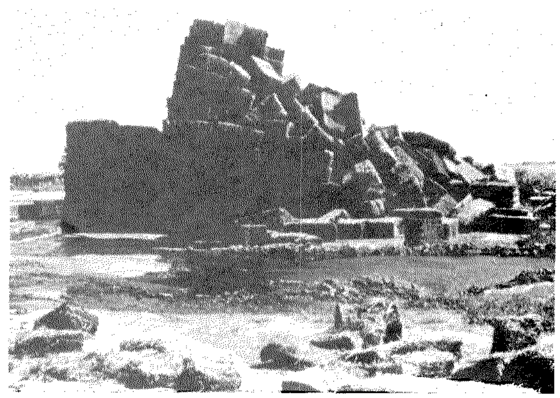
"Not really," says Jennings. "I don't expect the picture of damage in a large earthquake in L.A. to be so black and white. I'm definitely convinced that, as a class, new buildings are much better than old buildings. I'm also sure that we're moving strongly in the right direction in our construction practices. But there are tens of thousands of buildings in the Los Angeles metropolitan area, and even some of the newer ones were built when the understanding of earthquake-resistant design wasn't what it is now. We also have to realize that it's impossible to prevent construction and design errors completely. So we have to expect that both the old buildings and some of the newer buildings are going to have trouble.

"Also, Los Angeles has larger, more complicated structures. These buildings use their materials at closer to their capacity than the typical one- or two-story residential or commercial building, which has a lot of resistance to shaking that's independent of the calculations made in the design. In the bigger structures, on the other hand, the materials are used more efficiently, so their properties are being pushed nearer the limits. The structural engineers are still meeting all building codes in these buildings, but because of the volume, cost, and size of the structures, some don't have the built-in margin of safety that most one-story commercial structures have."

The Coalinga earthquake also offered valuable lessons about how well utilities can withstand earthquakes, providing added understanding of what needs to be done to protect

*Storage tanks are a familiar sight in and around Coalinga. The chief damage was buckling and seepage of the contents, as in the oil tank at the right. At the far right, a toppled stack of baled hay sits in a lake of molasses that leaked from a cattle food tank.*





electrical distribution, telephone, and water systems. By and large these came through very well. Their performance added to engineers' knowledge of what kinds of problems to expect and what kinds of solutions seem to work best.

"The lessons aren't clear yet," says Jennings, "but I think the Coalinga earthquake is going to provide very good case studies for the people who are interested in the mitigation and disaster relief processes. The situation in Coalinga was unlike that in the San Fernando earthquake of 1971, in which a part of a major urban community was damaged, but the rest was not. In Coalinga, there were no surrounding communities, and so it should be simpler to understand how various agencies interacted with one another. There were fewer actors involved in the roles, making them easier to understand. In my opinion, the public officials in Coalinga responded well. I was particularly aware, visiting the day after the earthquake, that the people in charge of trying to control the influx of persons into the affected area were doing a very good job. They were a sensible, well-organized group."

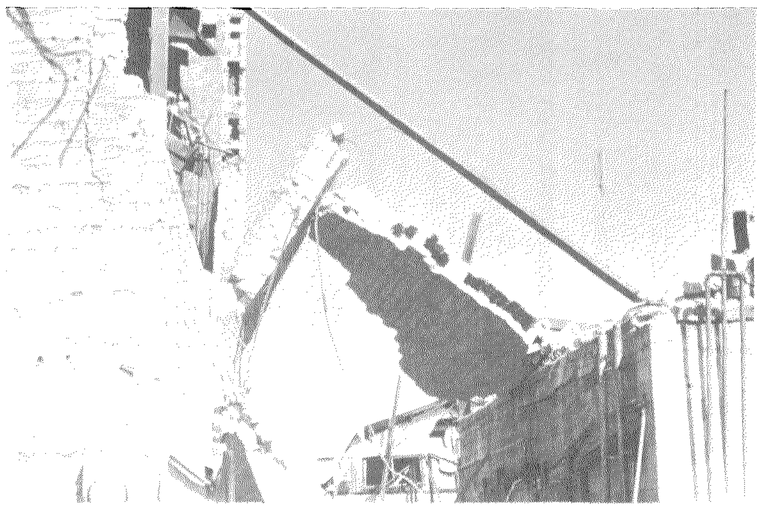
The Coalinga earthquake, and other such damaging tremors around the world, are being actively studied by earthquake engineers. But serious gaps still remain in the data they must use to design earthquake-resistant buildings.

"First," says Jennings, "we've not yet recorded the strong shaking close to the fault in a truly great earthquake, one of magnitude 8-plus. Second, we don't really know very much about the near-field motions for earthquakes of magnitude 7 and above. We think that the motions saturate; that is, that a magnitude 8 isn't going to give much stronger shaking than a magnitude 7 near the fault, although it will last longer. And, finally, for a variety of buildings we don't have measurements of shaking strong enough to cause serious damage or failure. Those kinds of readings are necessary to find out the real shaking capacity of the buildings. Such information has to be complemented by full-scale testing of buildings plus laboratory work, of course, but we still need records of buildings shaken so strongly by earthquakes that they are really tested to their limits."

So Coalinga was not an "ideal" earthquake from the engineers' point of view. Nevertheless, warns Jennings, its lessons must not be lost on California. "Every city in the state should look at Coalinga and say, 'There but for the grace of God go I.' All the major cities in California have older buildings like those in Coalinga, and if they experience an earthquake like Coalinga, they can expect to suffer similar damage.

"Most cities have some time to do something about their major hazards — their old, unreinforced buildings. And they also have time to help homeowners strengthen the old pre-1933 wooden houses. Such efforts would only cost a few hundred dollars per house, less if the homeowner does it himself. It might only take some nails and one-by-sixes, and in some cases bolts drilled into concrete."

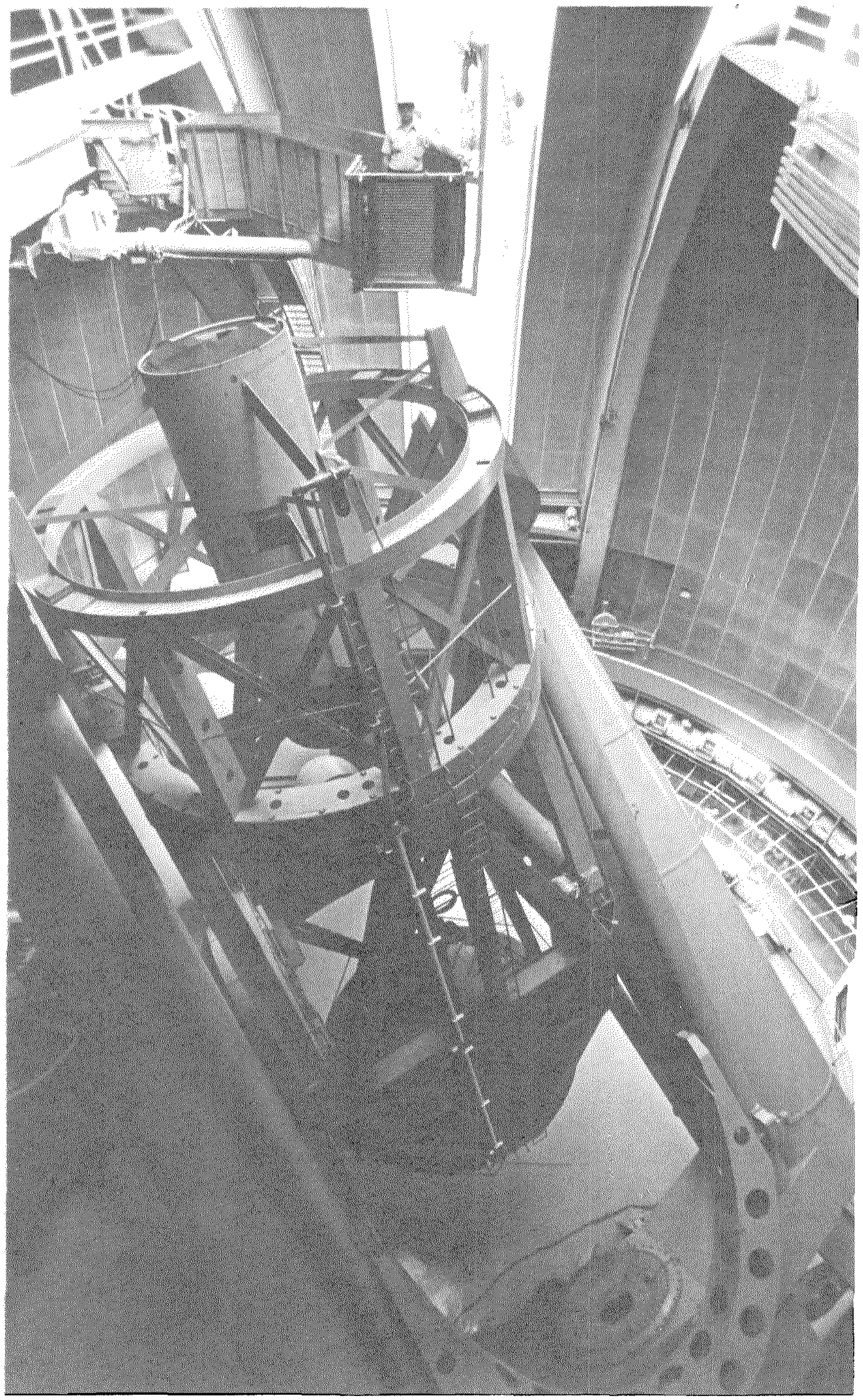
Earthquake engineers know that there will always be damage from earthquakes, because it will seldom make sense to make all buildings totally earthquake resistant. But the buildings *can* be made safe for their occupants in an earthquake, and there remain inexpensive measures that can yield large paybacks in reduced damage. This is the really important take-home lesson from Coalinga's experience. □



*Some structures, of course, didn't fall down completely, though the long-term integrity of the two above is doubtful. The benefits of modern construction are demonstrated below by Coalinga's Elks Club, complete with undamaged statuary.*

# A Night on Palomar Mountain — 1983

*by John Gustafson*



*Back in 1969,* E&S *printed its first version of "A Night on Palomar Mountain." The article was written by Jesse Greenstein, now DuBridge Professor of Astrophysics, Emeritus, and it later appeared in* the 1970 Yearbook of Science and the Future. *But John Gustafson, who spent this summer at Palomar as an intern in science writing, noted that much about observing has changed in the last 14 years, and he wanted to describe some of those changes. His article appears below, accompanied by a few quotations from the original.*

THE MASSIVE shutter doors, nearly half a football field long, part quietly in response to the touch of a button by the telescope operator. The fading light of dusk fills the cavernous dome of the 200-inch Hale Telescope. The telescope itself, a mammoth steel construct at the moment more silhouette than substance, waits silently amid a flurry of activity — the astronomers are making the final preparations for the night's observing. When finished, they will aim the telescope at a chosen spot in the sky, and the giant glass mirror will gather and focus light that may have been streaming across space for billions of years.

Billion-year-old starlight is what tonight's astronomers — J. Beverley Oke of Caltech, James Gunn of Princeton and Caltech, and John Hoessel of the Space Science Telescope Institute — are, in fact, collecting and studying. They are investigating distant groups of galaxies, galaxy clusters at the extreme limit of detectability. These galaxies, whose existence could only have been guessed at a decade ago, can be studied today because of sensitive electronic light detectors that have almost entirely replaced the astronomer's traditional aid, the photographic plate.

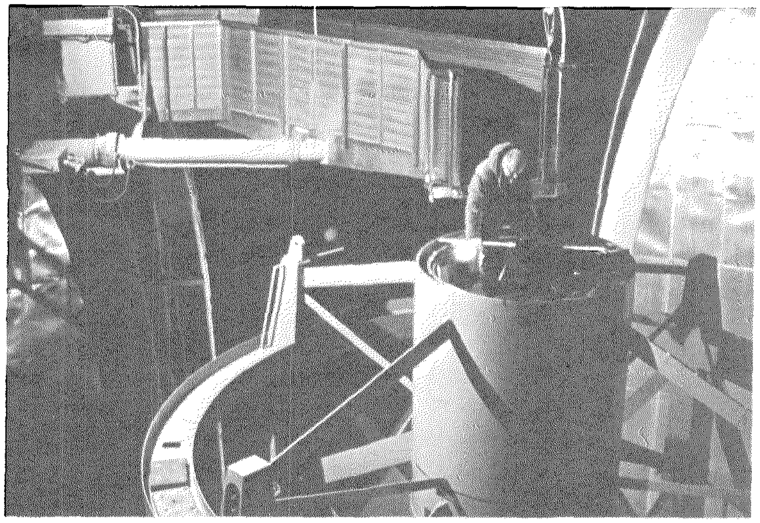
To a certain extent, modern light detectors — mainly the charge coupled device (CCD) — have changed the character of an astronomer's nighttime experience. For example, a single astronomer used to make the trek to the telescope to observe. Now it is more common for a team of astronomers — two, three, sometimes more — to work together through the night. Besides trading worried words about the clouds on the horizon, or opinions about recent research results, the team shares the variety of tasks that modern observing requires.

Tonight's team is using PFUEI (pronounced "phooey"), an acronym for Prime Focus Universal Extragalactic Instrument, which was designed by Gunn and James Westphal of Caltech. PFUEI has an optical arrangement that concentrates the converging beam of light from the 200-inch mirror onto a CCD, and electronics linking the computer that reads and controls the CCD. The device fits into the instrument holder in the prime focus observing station. John Hoessel is this night's choice to ride in the prime focus cage, a somewhat cramped metallic cylinder, suspended at the top of the telescope's frame 55 feet above the mirror, with displays and equipment lining its perimeter.

The 34-year-old Hale Telescope was the first astronomical instrument large enough to carry an observer at the primary focal point, and a night in the observing cage is seen by some as an essential initiation into astronomy's inner orders. Others view the prime focus experience as one of professional astronomy's last remaining romantic aspects. Hoessel looks upon it as a necessary chore: "It was fun the first time I did it, but I quickly outgrew that." As Hoessel makes the trip above, Gunn and Oke take up their places in front of a variety of television monitors, instrument displays, and computer keyboards in a comfortable, well-lit room on the main observing floor. A few feet away from the astronomers, the telescope operator, Juan Carrasco, sits in front of his own bank of displays and controls, waiting to point the telescope toward the first object.

From the control room, besides offering Hoessel friendly jibes over the intercom, Gunn and Oke operate the computer that controls PFUEI and interprets the data it accumulates. The very nature of the dime-sized, light-sensitive CCD silicon wafer lends itself to on-site data reduction. A CCD contains thousands of individual cells that convert impinging photons to an electric charge. Each cell, or pixel, builds up a charge until the exposure ends. Then the computer records the charge level and position of each pixel on magnetic tape. Since the computer's presence is necessary to read the CCD, it's a simple matter to add another program that interprets the stored information and recreates and displays the captured image on the television monitor.

## Palomar — 1969



*Jesse Greenstein steps into the observing cage — in 1969 — from an elevator that climbs 60 feet up the inside curve of the observatory dome.*

By unbreakable tradition, each astronomer makes his own observations at a large telescope. He is surrounded by engineering marvels and advanced electronic technology. But making a critical and delicate observation is still, ultimately, a one-man struggle.

The romance and beauty of the night, of the half-seen, faint glow of starlight, promise excitement and mystery. The observing process is an irresistible adventure for me, even after 30 years. I am a telescope addict, and in love with a 500-ton steel and glass monster, at Palomar.

The telescope slides a few degrees; I look down the tube at a black pool filled with tiny lights, the mirror 55 feet away catching starlight. Then, in the eyepiece is a strange, pale, white glow, shaped like a comet; at its tip, a star is being born. Our view is as old as civilization; the light is 5,000 years old.

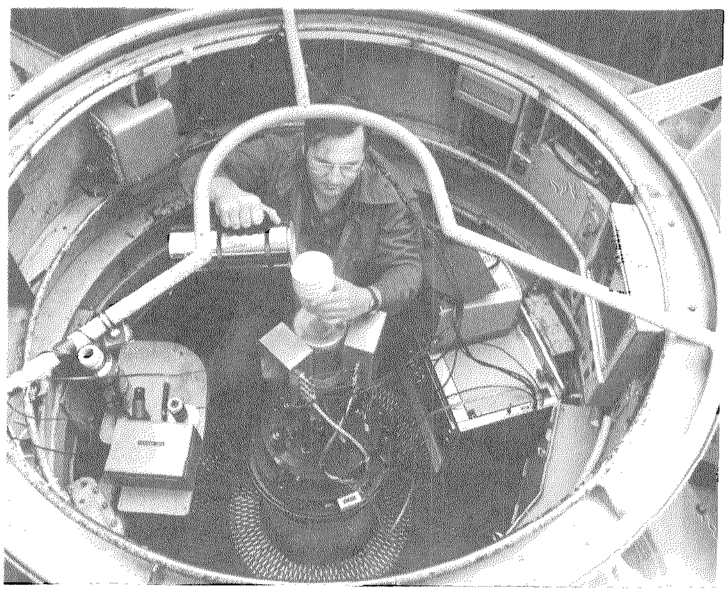
A bustle of final settings, calibrations, data for the observing record; I pull out the camera-cover slide, and the exposure begins. Then silence, only the distant pumps, and the passage of time. The telescope is turning 15 feet an hour to follow a star $3 \times 10^{16}$ miles away! The star stays frozen on the spectrograph slit, but every few minutes I check and reset the fine motions of the telescope, perhaps a thousandth of an inch, to maintain centering.

The process of exposing a photographic plate, carrying it to the dark room, developing it, and scrutinizing it through an eyepiece seldom occurs now. These nights, the quick data display lets astronomers know immediately if their efforts were successful or not.

The nature of the CCD also determines some of the chores that face the astronomers when they arrive at the dome. After riding the elevator to the prime focus, Hoessel first fills a reservoir surrounding the CCD from a thermos of liquid nitrogen. Within the light detector's chamber, the temperature chills to 150 degrees below zero. A warm CCD spontaneously liberates electrons, which would mix with the real signal generated by the light. A cold CCD, however, looses substantially fewer extraneous electrons and has a correspondingly cleaner signal. After topping off the reservoir and sending the elevator back down, Hoessel tells his colleagues below that he is ready to take some "flats."

Flats are necessary because each CCD has its own unique response; some pixels are more, some less sensitive than average. When the device is exposed to a flat, uniform field of light, the resulting image will show light and dark spots. By storing this image in the computer, the chip's own response can be subtracted later from an actual exposure, called "flattening" the exposure, and so accurately reproduce what the CCD "saw."

Taking flats is a brief procedure, so soon after Hoessel has climbed into the cage, everything is set to go. In the control room, Oke leans back in his chair and asks, "Juan, can you give us a bright star near the meridian, please?" Carrasco, with anticipation born from years of experience, already has a star chosen. He types the star's designation into the computer, which displays the proper, updated coordinates on a monitor. With these as a guide, Carrasco presses buttons, and as the dome shutters spread open, the telescope swings over a few degrees.



*Astronomers are not the only scientists who occupy the prime focus cage of the 200-inch Hale Telescope. Here, Edward Danielson, senior scientist on the planetary sciences staff, cools the CCD by pouring liquid nitrogen into it.*

"It claims we're there," Carrasco says after aligning the telescope with the displayed figures.

And they are. A two-second exposure on PFUEI shows that the telescope has pinpointed a bright star. The astronomers use the star's image to make the final, precise adjustments to the telescope's focus.

Finally, all preparations are complete, twilight has faded into night, and the real observing begins.

"First object please, Juan," says Oke.

Carrasco refers to the prepared list that Oke gave him earlier and directs the telescope to object number one. High up in the dark dome, Hoessel has already been alerted to the upcoming motion and sits tight during the few-minute ride. Carrasco says the aiming is done. From above, Hoessel calls over the intercom that he has located a guide star, with which he will make minor corrections in the telescope's position and so keep the field centered on the CCD.

"OK, we're going to take a 150-second exposure," Gunn announces. He types rapidly at the terminal, giving the computer the appropriate commands, and then relaxes while the computer takes charge of the exposure.

Shortly, the image of the field unrolls on the monitor. Oke, holding a photograph of the desired field, leans forward to look at the screen. Comparing monitor and photograph he declares, "Looks like we've got it. Lets go with the red filter, a 900-second exposure."

Hoessel inserts the filter, Gunn keys the computer, and they're in business. Oke writes in the log all the pertinent information: the cluster's name, the time the exposure began, duration of the exposure, and what filter they're using. Then he takes advantage of the 15-minute exposure to go check the weather. Carrasco, who must shut the dome if weather conditions threaten, offers to go along.

Gunn, meanwhile, marvels at the image from the last exposure, which remains displayed on the monitor. There are a few bright stars scattered about the screen, and lying in the center about a dozen small, faint smudges —

the galaxy cluster under study. Such an image is a good reason for marveling. The new instrumentation has made it routine to examine galaxies with look-back times about half the age of the universe. Once that would have been unthinkable, as would the ability to study galaxy evolution not by inference but by direct observation. Astronomers can actually see the effects of the evolution of the universe in a few blots of light barely brighter than the background sky — vivid testimony to the power of modern light detectors.

Oke and Carrasco return before the exposure is done, having circled the dome's exterior catwalk, three stories above the ground. Oke bends over to the microphone and calls to Hoessel:

"The clouds seem to be getting higher in the sky."

"Yeah, my guide star keeps disappearing from time to time."

"Oh, you're just getting tired," Oke replies, and exchanges a grin with Gunn.

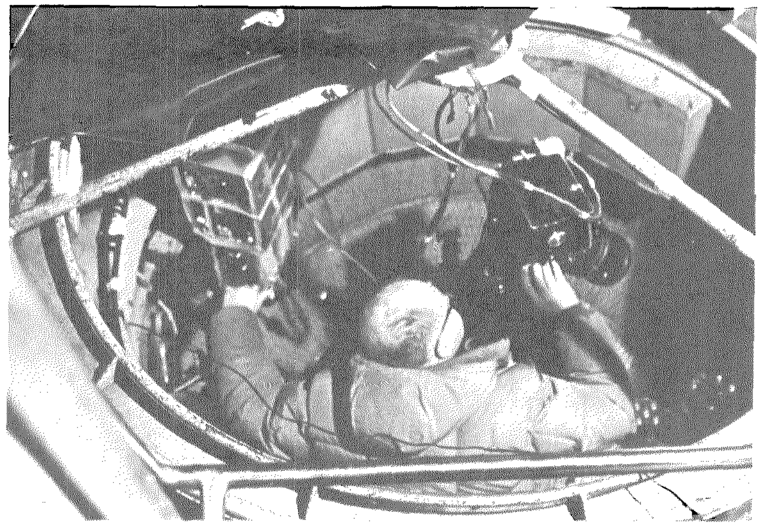
After the 15 minutes elapse, a buzzer signals that the shutter has closed, and lights on a wall panel flash to indicate that the computer is reading the CCD. By the time Hoessel has changed filters, the computer, primed by Gunn, is ready to start the next exposure. They observe this galaxy cluster through three different filters, examining each exposure on the monitor to ensure that all continues to function properly, before going on to the next object.

And so the night goes: an intense but efficient bustle of activity between the end of one exposure and the start of the next, and then a relaxed period — except for Hoessel, peering through the guider and manipulating the telescope — of contemplation and planning as the minutes of the next exposure slowly pass. For the faintest objects, exposure times of an hour or more are not uncommon.

This night the astronomers are fortunate — the clouds never become sufficiently bothersome to halt the observing. They work steadily through the night, until the approaching dawn begins to brighten the sky. Although the time often drags through a long exposure, with the coming day the night suddenly seems brief.

The elevator is sent to retrieve a stiff prime focus observer, and the trio strolls back to the monastery, pleased with their efforts and ready to sleep the morning away. They need to be well-rested for the next night's work, collecting and analyzing billion-year-old light in a continuing quest to decipher some of the mysteries of the universe. □

Palomar — 1969 . . . *continued*



*Inside the cage, with spectrograph mounted, Greenstein adjusts his camera, checks his star charts, and settles in for a few cold hours of observation.*

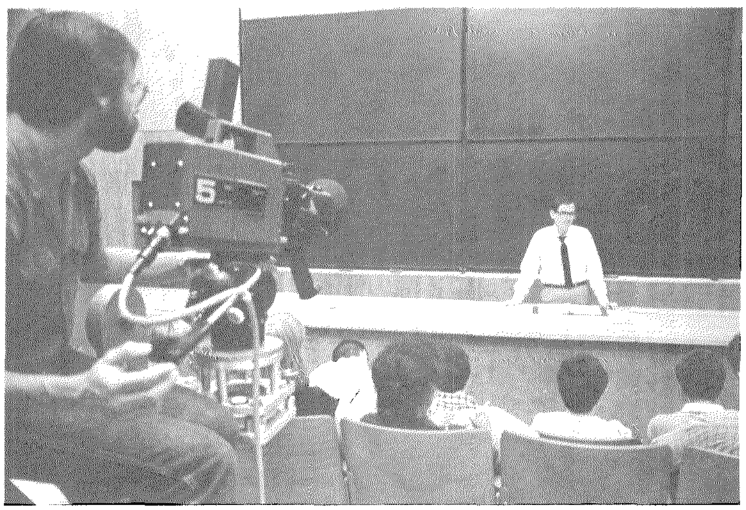
I retilt the seat. Once I climb on it to look out at the nearby sky; 42 degrees F feels cold if you sit still near midnight. What do I think of? Usually of nothing, hypnotized by the dulling reality of chill and fatigue, or of what I might have done incorrectly, or about the next exposure. But sometimes I think of what may be creating the dim glow I see.

After midnight I climb out of the tube, to the elevator, to descend to the darkroom, and have lunch. The plates, still wet, show the nebula spectrum was well exposed. The faint white dwarf gave a narrow streak of blackened silver grains that tells me something new. Up the elevators to the cage, to new objects and another four hours. At the end of the last exposure, dawn begins; the telescope is set vertical; the motors stop. . . . By dawn I am in the monastery, completely darkened and quiet, to sleep five hours till breakfast.

To the darkroom again at 1 p.m. to prepare for the next night. Are these objects interesting? Shall I change the program? It is the first of my four nights of this run. Tonight might be crucial; last night's plates suggested something new. I will be more tired; if there were only more time! Were I sensible, would I be an astronomer again? Of course, because next year, science will be better; new objects and instruments will be found; new ideas already are boiling, and there is so much unknown. What were all those flying specks of light in the mirror? What new marvels are waiting?

# Physics on the Tube

"The Mechanical Universe" is in production at Caltech and Knott's Berry Farm




*Although the TV physics course begins in the lecture hall, it departs after a couple of minutes to more exciting locations, for example, the Corkscrew at Knott's Berry Farm.*

"OKAY, STUDENTS, walking positions, please," says the director. "Take it all the way through this time. Remember to take notes. Stand by . . . action."

The camera rolls. Students file into the physics lecture hall, 201 Bridge, more brightly lit than usual, and take seats in the first two rows. The next several rows have been removed to accommodate the cameras, lights, and other equipment. David Goodstein, professor of physics, who has been drawing circles on the blackboard as the students entered, begins his lecture.

"I don't know who invented the wheel, but the circle was discovered independently by primitive peoples all over the world. Often it had mystical significance, associated with the horizon, the sky, and the gods. Gradually, myths acquire complicated traditions and fancy language. Then they become known as philosophy."

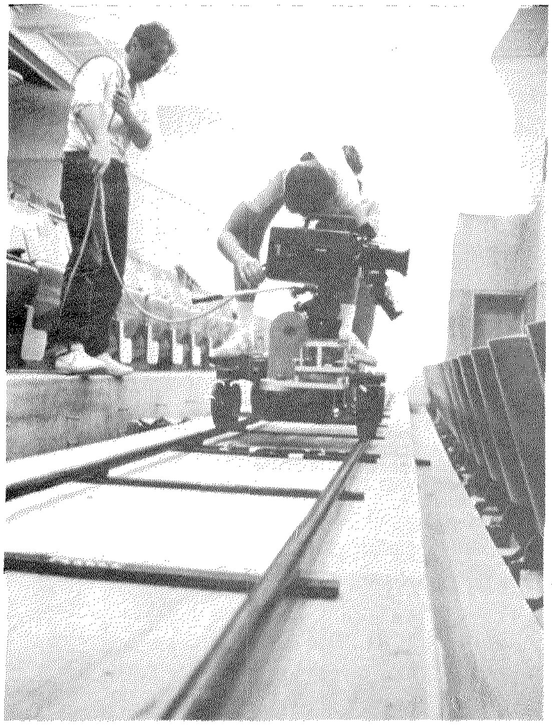
Goodstein goes on to Plato and the idea, which "stopped astronomy dead in its tracks for 2000 years," that the heavenly bodies move around the earth in perfect circles at uniform rates. The subsequent effort to explain actual observations led to the contrivance of epicycles, or circles centered on circles . . .

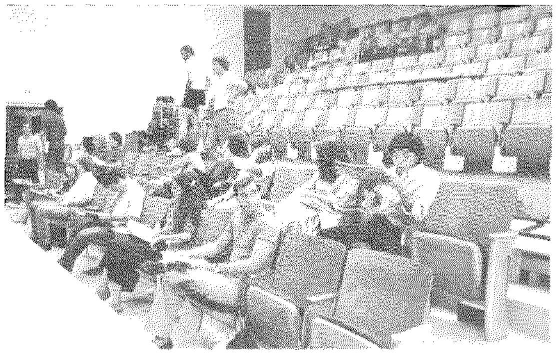
"Cut."

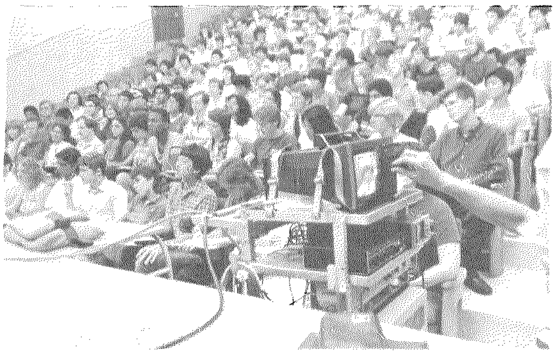
It's scene 1, take 1, of program 9 of "The Mechanical Universe," Caltech's current venture into show business — an introductory course in classical mechanics developed in cooperation with the Corporation for Community College Television. The show is being produced and directed by Peter Buffa, and Caltech's Don Delson is project manager. Funded by $2.1 million from the Annenberg/CPB Project (a joint effort of the Annenberg School of Communications and the Corporation for Public Broadcasting), the series of 26 half-hour programs is part of a plan to create innovative college-level courses using the unique capabilities of telecommunications.

These unique capabilities will enable the student viewer to flee the lecture hall for other sites that provide often amusing illustrations of physical principles (the program on the law of falling bodies begins on a window washer's scaffold high on a Los Angeles skyscraper) and dramatized historical sequences (Newton's apple orchard, for example, offers some opportunities for humor). Computer graphics by the Jet Propulsion Laboratory's James Blinn include lively ballets of equations more like a video game than the static page of a math book.

But it's not all fun and games. "The Me-







*Removing rows of seats in 201 Bridge accommodated a track for the camera (far left). For most of the classroom shooting over the summer, only two rows of "students" were necessary for the foreground. When Caltech students returned in the fall, a whole hall's worth were hired (below) for "student reaction" scenes to be spliced into the sequences taped earlier.*

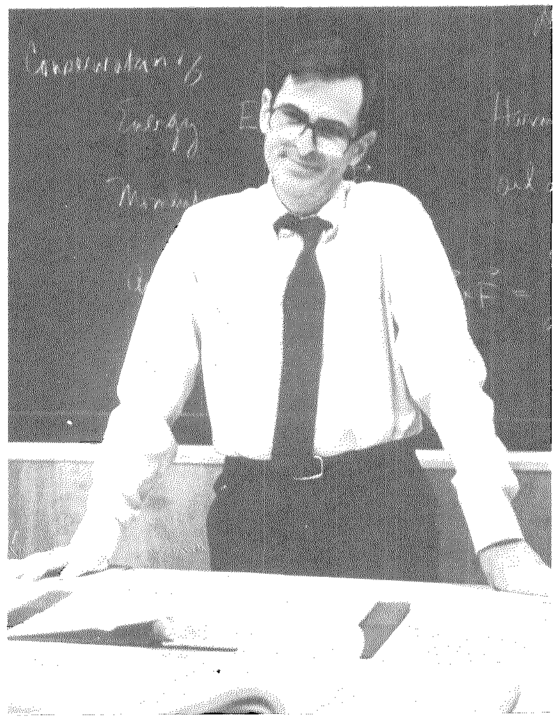
chanical Universe" will offer a rigorous semester's worth of Newtonian mechanics along with all the requisite calculus. This is, after all, Caltech. The idea sprang from Goodstein's version of Physics 1, which he taught from 1979 to 1982, and which has become a local legend for its spicing of wit along with the solid stuff. Two textbooks are being written to accompany the program — one for students in nontechnical fields and the other for engineers and science majors. Early chapters of the latter, in manuscript form, made their debut this fall in Caltech's Physics 1, currently taught by Steven Frautschi, professor of theoretical physics. Frautschi, Tom Apostol, professor of mathematics, who received one of the 1983 undergraduate awards for outstanding teaching, and Richard Olenick, visiting associate in physics from the University of Dallas, are the authors of the text.

Each of the TV programs will begin and end in 201 Bridge with Goodstein in his accustomed place at the blackboard — for example, drawing circles in program 9, "Moving in Circles." But the lecture introduction lasts only two minutes ("the audience falls asleep after two minutes"), and then the narrator and picture show take over.

"Moving in Circles" must put across the concept of the derivative of a vector, worked out by application to uniform circular motion. Derivatives, vectors, and integrals will have already been introduced in earlier programs, as well as universal gravity and Newton's law, which determine planetary orbits (which are almost uniform and almost circular). Program 9 puts all of that together and introduces concepts necessary to understand later programs on rotating bodies and angular momentum — not an easy task in half an hour. How do you get such complicated abstractions across and make them entertaining as well?

Ideas come from a number of sources. Since the format of the series is based on a Caltech course, the starting point for each of the programs is Goodstein's "phantom" lecture on the subject — phantom because most of the program isn't really a lecture at all. Goodstein oversees the evolution of the script and makes all final decisions. His phantom lecture for "Moving in Circles" moved on from epicycles to Copernicus, whose revolutionary idea, says Goodstein, was actually an attempt to make the universe more Platonic, the motion more uniform. From there Goodstein launched into the math — the position of an object in uniform circular motion expressed as a vector quantity and its velocity and acceleration as derivatives of vectors.

The TV program, however, takes off into the mystical significance of the circle in primitive cultures, sneaks into vectors via computer animation, returning later to Copernicus. Story editor Jack Arnold assigned the script of program 9 to Deane Rink, one of six professional writers working on the show. For guides the



*Program 9 of "The Mechanical Universe" will star amusement park rides as well as David Goodstein.*

writer had the phantom lecture, the relevant chapter of the textbook, and a program content outline developed by the Caltech team suggesting the major concepts to be conveyed, real-world examples, existing film footage, and computer animation possibilities.

"From a physics/math/historical standpoint, the key work has been done for you," Arnold wrote to Rink. "So you 'merely' have to understand and to implement the scholars' blueprint . . . Use (your creativity) to take the blueprint and create a magnificent structure. A story line that flows, a narration that enlightens, provokes, entertains, a collection of pictures that illustrate, captivate, make circular motion spin in the viewers' mind."

Meanwhile, back at Caltech, other imaginations were also busy with the problem. In a science writing course taught three terms last year (and again this year) by Ed Hutchings, lecturer in journalism and former editor of *E&S*, undergraduate veterans of Physics 1 offered their own ideas of communicating physics in a visually entertaining manner. Their treatments and scripts were mainly exercises for the course, but occasionally student-generated ideas were assimilated into the show. For "Moving in Circles" several students wanted to illustrate vectors with a slingshot — a dramatization of a Grecian warrior or David and Goliath, with the whirling sling fading into animated equations. Goodstein, who usually sat in on the class, thought this idea was "good pedagogically," but "the TV people will want more scenery than a swinging sling. They have to fill up 23 minutes with pictures."

Tracy Furutani, now a senior, wrote a complete script for program 9 with suggestions for narration, dramatization (which facetiously included Copernicus's mistress and Plato in his native ambience surrounded by "scantily clad slave chicks"), computer animation, music ("Circles" by rock musician Peter Townshend), and location footage (a machine shop used in an earlier program, which would cut production costs). Furutani's script wasn't used, but it was especially confident and correct on the math, according to Goodstein, and this — not the nearly nude slaves — earned him a summer job as a math consultant to the professional writers.

The final "concept sequence" (the setting for the major portion of location filming) for "Moving in Circles" actually did come out of the class. David Sahnow, also a senior, suggested an amusement park: "Show rides that have circular motion: merry-go-round, Ferris wheel . . . the one where the rider sits in a swing and is spun around, and the one where the riders are strapped into a rotating cage, which is turned vertically."

Sahnow's amusement park was written into the script. Completion of the script, which was assigned in May, was supposed to take 50 days. The writer's first of several drafts elicited from Goodstein: ". . . it seems to me the main problem is that the sweep of the history is so grand that the math and physics come off as annoying intrusions. The point of the program should not be the importance of the circle in human history, but rather how to master circular motion with the mathematical tools in our arsenal.

"The point of the amusement park is to put us into circular motion so that we can sense the effects. Another more subtle and entertaining point is the role of the circle in ancient religion and mythology played off against its use in our modern secular religion of pleasure. It can also get us into and out of computer animations of the mathematics.

"The circle in astronomy connects this program to the rest of the series. It also sets up one of the payoffs of the program: Once we realize that uniform circular motion involves constant acceleration toward the center, we have a simpler, more effective description of the point Newton worked out with great difficulty in program 8: how gravity keeps the moon in motion around the earth."

In the final script the scene cuts from the lecture hall to the rising sun and its symbolism to ancient peoples from Assyrians to American


*Caltech's newest Nobel Prize-winner proudly displays another award — a sweat shirt awarded him this week by colleagues at Yerkes Observatory in Wisconsin.*

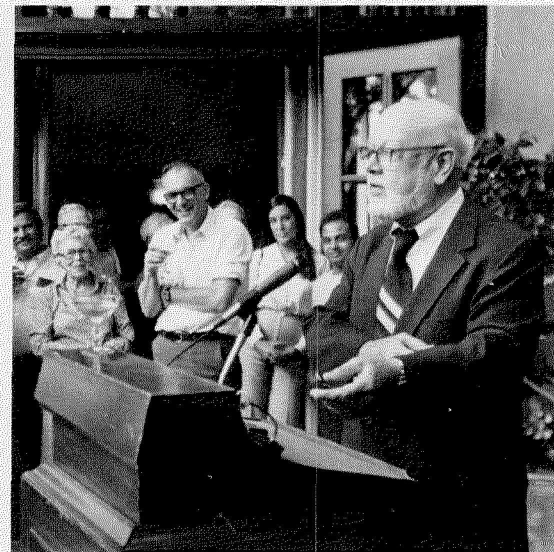
# William A. Fowler

## Nobel Laureate 1983

For his "theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe," William A. Fowler received the Nobel Prize in Physics on October 19. He is considered the driving genius behind the present theory of nucleosynthesis — the origin of the elements and their isotopes mainly in the nuclear furnaces in the core regions of stars.

The importance of Fowler's contribution lies in his recognition toward the end of the 1930s that "with the growing knowledge and understanding of nuclear physics, it should be possible to make quantitative statements about the rate at which nuclear reactions occur in stars," according to his colleague Charles Barnes, professor of physics. "He had the wisdom to foresee that the depth of our theoretical knowledge of nuclear physics would for a very long time remain insufficient to predict the rates of nuclear reactions purely from theory, and so he set up a program with his colleagues to measure accurately the rates of astrophysically important nuclear reactions in the laboratory. This was the beginning of a whole sub-branch of physics that has had an impact on studies of every aspect of stellar evolution and the synthesis of the chemical elements."

*Champagne and smiles were the order of the day in Dabney Garden on October 21 — with his wife, Ardiane, and at the podium to tell his colleagues (including Provost Rochus Vogt) how it happened.*

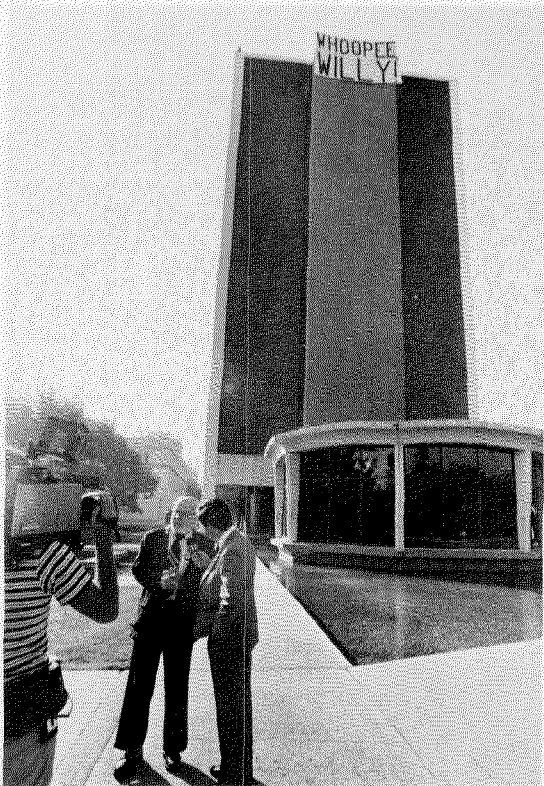


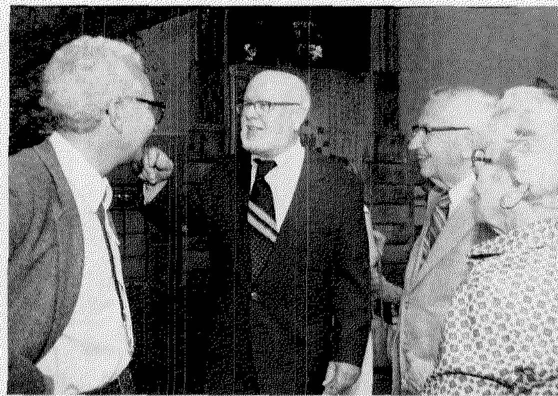
Fowler becomes the 20th Caltech faculty member or alumnus (and the 12th physicist) to win the Nobel Prize, and he is, as Provost Rochus Vogt described him, "the archetype of the Caltech citizen." His Caltech career spans 50 years. He came here after receiving his bachelor of engineering physics from Ohio State University in 1933, immediately following what Fowler calls "the golden year of classical nuclear physics," 1932, when Urey discovered deuterium, Chadwick discovered the neutron, Anderson discovered the positron, and Cockcroft and Walton succeeded in producing nuclear reactions far below the Coulomb barrier — work that served as the foundation for the growing body of new ideas of nuclear structure. Fowler joined Charles Lauritsen's team in the newly established W. K. Kellogg Radiation Laboratory and earned his PhD in physics in 1936 with a dissertation on radioactive elements of low atomic number. Between 1936 and 1946 he climbed the academic ranks from research fellow to full professor and in 1970 was named the first Institute Professor of Physics. He became emeritus in 1982 — a few months after the 50th anniversary of Kellogg Lab.

Fowler identifies his career and work closely with the history of the laboratory and said on receiving the Nobel Prize that "it's really a prize for Kellogg in my book." He drew a distinct contrast between his own research and that of Barbara McClintock, who had won the Nobel Prize in Medicine the previous week. McClintock did her work entirely by herself, while Fowler sees himself as part of a group of "many, many people who have made major contributions in the field of astrophysics." He singled out Barnes and Ralph Kavanagh, also professor of physics, as current and long-term Kellogg co-workers. He also cited physics professors Ward Whaling and Thomas Tombrello as former colleagues and Steven Koonin, professor of theoretical physics, as one of his more recent collaborators. (The close-knit Kellogg group has also long been known for its parties, and Fowler, affectionately known around campus as "Willy," is a treasured collaborator in this respect as well.)

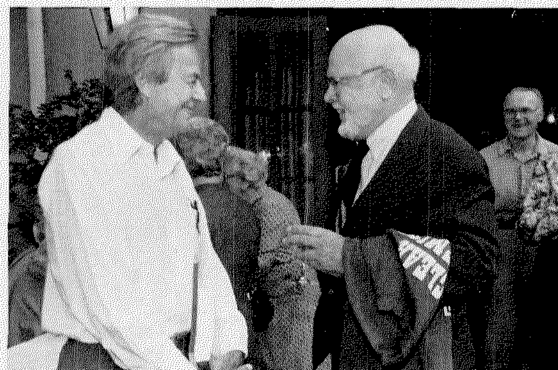
Lauritsen's discovery (in Kellogg) in the 1930s of the radiative capture of protons, as well as other work by Fowler with both Charles and Thomas Lauritsen, set the stage for later studies of nucleosynthesis. And by 1939 it was clear, at least to Fowler, after Hans Bethe and Carl von Weizsäcker's suggestion that hydrogen was converted to helium by the capture of protons (fusion) in stars, that "problems in the application of nuclear physics to astronomy could only be solved by detailed and accurate measurements of nuclear reaction rates."

All of this was put on hold during World War II, when the Kellogg Lab, and Fowler with it, was drawn into defense work, first on proximity fuses for anti-aircraft shells and later on the development of rocket ordnance. After the war Kellogg returned to the field of low-energy, light-element nuclear physics — particularly those reactions thought to take place in the hot interiors of stars. Although the first problem attempted was figuring out how hydrogen burns to form helium, by the mid-1950s the question was: How does helium burn? The arrival at Caltech of British astronomer Sir Fred Hoyle in 1953 and of Geoffrey and Margaret Burbidge in 1955 produced a collaboration with Fowler that resulted in 1957 in the



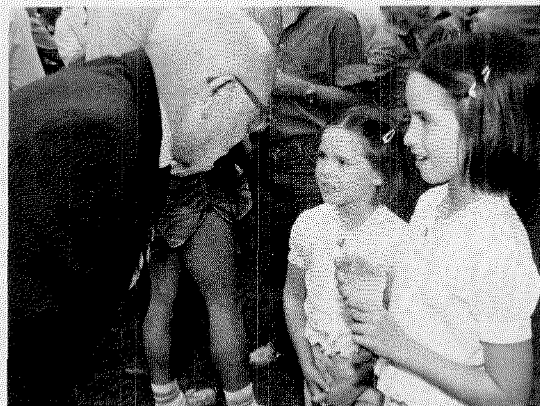
*Faculty-student collaboration led to the sign atop Millikan Library (far left), the faculty being physicists Robert Christy and his wife, Juliana Sackmann, and the students being members of Ruddock House, who managed the logistics of getting it into place.*



*Two long-time Nobel laureates welcome a new one — top, Murray Gell-Mann, bottom, Richard Feynman. With Gell-Mann and Fowler are President Emeritus and Mrs. DuBridge.*

*They worked together and were happy to toast the results together. On either side of Fowler are Ralph Kavanagh (left) and Charles Barnes, long-term Kellogg collaborators. Jerry Wasserburg's (right) work on meteorites is also strongly identified with the Kellogg group.*

*From left to right, two more sets of Fowler friends, Alexa and Ilia Christy; and Evaline Gibbs, who was on the staff at Kellogg for 26 years, and Marty Watson, who replaced her as administrative aide for the lab in 1979.*



classic summary paper in the *Review of Modern Physics,* "Synthesis of the Elements in Stars."

In the paper, which was based on the experimental measurements of Barnes, Kavanagh, Whaling, and physicists at other institutions, the four authors detailed the processes by which nuclei could combine to form the elements up to the iron group by successive burning of heavier and heavier nuclei through charged-particle (proton and alpha-particle) reactions. This is currently taking place in stars more evolved than the sun, which is still in the hydrogen-burning stage. Beyond the iron group, however, neutron capture processes have played the major role in the synthesis of the heavier elements and their isotopes. Not all of the elements were formed, therefore, by a single process in a single primordial event, such as the big bang; except for helium, they have mainly been synthesized by a succession of different processes during the evolution of stars. The neutron-capture reactions take place through a *slow* process in red giants (younger stars composed of light elements previously synthesized by other stars) and through a *rapid* process in supernovae. These elements are constantly being ejected into interstellar space, providing building materials for new stars. Some of the matter that has been through this long chain of nuclear processes has been incorporated into the meteorites that are the objects of study of Gerald Wasserburg, the John D. MacArthur Professor of Geology and Geophysics, and long-time collaborator of the Kellogg research group.

Trying to sort out the nuclear physics of what happens in supernovae — how the capture of electrons by protons and other nuclei to form neutrons contributes to the gravitational collapse of the interior of a star and its eventual explosion — still occupies Fowler, who has continued to be active in research in his new emeritus status. In fact, when the Nobel Prize was announced, he was attending a conference at Yerkes Observatory in Williams Bay, Wisconsin, on "Challenges and Opportunities in Nucleosynthesis in Stars," where he was invited to deliver the opening paper. (He was not actually *at* the conference when the phone call came, but in the shower — when the phone always rings.)

The Caltech physicist shares the 1983 Nobel Prize in Physics with Subrahmanyan Chandrasekhar of the University of Chicago, who has studied stellar structure and stellar evolution in theoretical research with important links to Fowler's work in nuclear astrophysics.

Fowler has always been insistent on the basic nature of his research work, which has also included nuclear cosmochronology, the origin of isotopic anomalies in meteorites, synthesis of helium in the big bang, the emission of neutrinos by the sun, and general relativistic effects in quasar and pulsar models. In 1946, in the laboratory's first proposal to the Office of Research and Innovations (which later became the Office of Naval Research) for Kellogg's postwar funding, it was specifically stated that, "It is also essential that it be clearly understood that these studies are primarily fundamental in nature and that the possibility of applications is of secondary importance."

And again, on receipt of the Nobel Prize, when queried repeatedly about the practical applications of his work, Fowler reiterated that practical applications had never been his principal motivation. "What we're doing is mainly a cultural and intellectual contribution to the sum total of human knowledge, and that's why we do it," he said. "If there happen to turn out to be practical applications, that's fine and dandy. But we think it's important that the human race understands where sunlight comes from." □ — *JD*

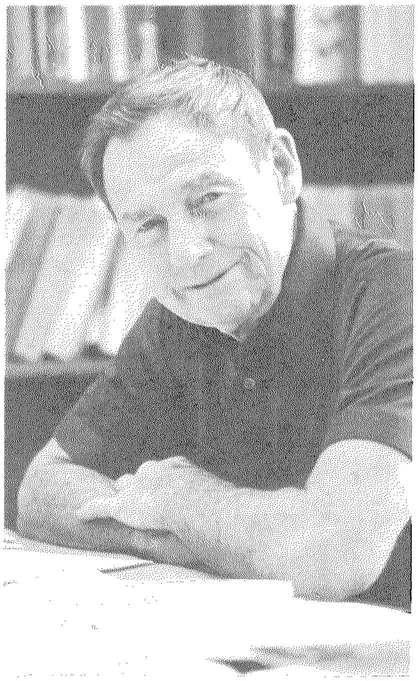

Indians. A computer-animated vector superimposed on a circle inscribed on the ground with a rope and stake leads into the mathematics — but not for long, as the amusement park makes its first entrance. Plato, represented by a rotating bust, and his uniform circular motion of the heavens soon appear, followed by another cut to the amusement park and a distorting mirror in the house of horrors. ("The Platonic ideal was imposed upon the nature of reality. If reality wasn't mirrored ideally, it was a reflection of incorrect perception.") For the rest of the 23 minutes, historical elements (Ptolemy, Copernicus, Newton) and the amusement park rides are intercut with computer animation of planetary orbits, rotating vectors, and dancing derivatives, until finally Newton solves the riddle of why, if the earth's gravity makes the moon accelerate, it moves at nearly constant speed (the answer lies in the directions of the vectors).

Newton's study dissolves to the amusement park again, which dissolves into animation of traveling in space, and suddenly the viewer will be back in the lecture hall, where Goodstein is changing the subject. A rather puzzling discussion of medieval torture methods (burning at the stake, drawing and quartering) closes the program, including the impact of the mere threat of torture, which did in Galileo. Goodstein ends:

"You might be wondering why I'm lecturing on such a bizarre subject. It has to do with introducing our next topic, which is the use of force."

The scenes in Bridge were videotaped in August (before real classes began), and location shooting took place this fall, mostly at Knott's Berry Farm. Program 9 will be completed by next spring, and the entire series of "The Mechanical Universe" is scheduled for broadcast in 1985.□ — *JD*

Oral History



# Robert P. Sharp — How It Was

*Robert P. Sharp has the distinction of being the first holder of a named professorship in geology at Caltech and — even more unusual — of having that chair named for himself. He is now Robert P. Sharp Professor of Geology, Emeritus, and he was interviewed for the Oral History program of the Caltech Archives by Graham Berry, former director of the Institute's News Bureau. We present here a shortened version of the original transcript of that interview.*

*Robert Sharp:* I'm a second-generation native Californian. My father was born in Santa Rosa and my mother in Saticoy. My father ran a lumber company in Oxnard when I was a little boy, and later he ran one of the citrus ranches that belonged to my grandfather. Neither of my parents got beyond the freshman year of high school, so I didn't come from a family that was intellectually oriented.

My grandfather loved kids, and he and my father and my uncles were always going off somewhere on fishing and hunting trips. I think largely through my grandfather's influence I got to go on a lot of these. I went to work at age ten, though I had nothing but a paper route to begin with. Later I worked in a jewelry store and then in a service station, which was a very good thing for me. I was a shy, withdrawn kid, and while working in the service station, you had to deal with people from all walks of life, from the town drunk to Buron Fitz, who was running for lieutenant governor of California — and to Gary Cooper, who used to come through on Sunday with Lupe Velez in his big yellow Duesenberg.

Between the time I graduated from Oxnard high school in 1929 and when I came to Caltech in the fall of 1930, I worked in a service station 60 hours a week and went to school part time. I'd hardly ever heard of Caltech when I was a youngster, but in my high school class there was one of these boy-wonder scientists. Caltech dominated his thoughts and talk. Eventually, three of us from Oxnard came to Caltech as freshmen in the fall of 1930. To the best of my knowledge, the only person from our high school to come to Caltech prior to that was none other than Vito Vanoni [now professor of hydraulics, emeritus].

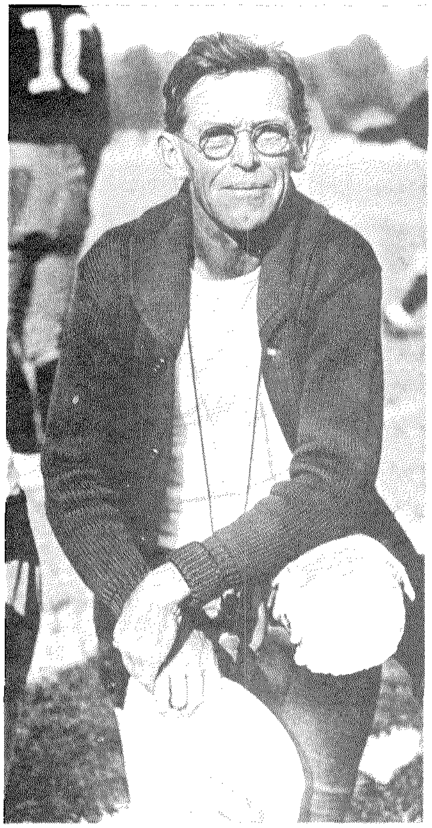
I guess the roughest three months I can remember as a young person was the first quarter at Caltech that fall. It was rough for a lot of reasons. First, I didn't come from a really good high school. Then I went out for freshman football, and I was so sore and stiff for the first month I could hardly walk. And the student houses were not yet opened, so I had to live in the town.

*Graham Berry:* Had you decided on your major?

*RS:* No. I came down here thinking I was going to be a civil engineer. The first year you didn't have a chance to think about such things, and truthfully you were too busy to give a damn. We had to make a decision at the end of the freshman year as to whether we wanted to go into engineering or science. At that time I shifted from engineering to science, focusing on chemistry, but I think Ernest Swift [now professor of analytical chemistry, emeritus], who was a soft-spoken tyrant, a perfectionist, convinced me I wasn't going to be much of a chemist.

In the first term of my sophomore year I had to take a course in geology. I had hardly ever heard the word geology before that time, but this course hit me just right. Bingo! John Buwalda gave the lectures, and he was very good. It was a revelation to me. All of the things I had seen as a little kid, had made a note of, and didn't understand suddenly began to fall in place. I had done a lot of fishing up in the Mono Basin. I can remember walking over ridge after ridge after ridge to get to Walker Creek. Buwalda was lecturing about mountain glaciation one day, and it suddenly hit me, "My gosh, those ridges are lateral moraines!" So came the third quarter of my sophomore year, and I had to make a choice. I elected to give geology a try. Discovering it was one of the great good fortunes of my life.

One of the great opportunities offered by Caltech, if you had the will, was participation in varsity sports. I went out for football as a freshman and



*Above, William L. "Fox" Stanton, physical director at Caltech for more than 20 years. Below, Robert Sharp in 1934. He had just been awarded the Wheaton Trophy for "ability, leadership, and scholarship," and was vice president of ASCIT and chairman of the Board of Control, which then, as now, administered the Honor System.*

as an upperclassman did both football and track.

*GB:* Were you a quarterback?

*RS:* I came to Caltech having played a little quarterback in high school, but I told the freshman football coach, who was Layton Stanton, the son of Fox Stanton [physical director at Caltech at that time], that I was a halfback. He took me at my word, and I worked out at halfback, ending up on the second team of the freshman squad. We had enough freshmen out for football to have a couple of teams in those days. Later, I was a quarterback, and this put me on the first team. We probably had about 30 freshmen out for football.

As long as we're talking about football, let me talk about Fox Stanton, who was the ideal coach for Caltech. He was a fiery little guy, who had been trained originally as a clergyman, a preacher. Some of the finest sermons I ever heard in my life were in the Rose Bowl locker room. Stanton recognized that he didn't have a lot of talent to work with in terms of physical ability, so he had to rely on a bunch of kids who were relatively intelligent. He had worked up a beautiful, very complex offense. People who were scouting would come down to him during the game and say, "My gosh, Fox, I can't tell what's going on out here." And Fox would reply, "Well, I can't either, but sit down alongside of me, and if I see anything I recognize, I'll tell you what it is."

*GB:* Stanton acted more like a preacher than a coach?

*RS:* Well, no question, he built character. He could be a very caustic old guy, a very stern disciplinarian, given to those little phrases that just cut you right to the quick. He'd give us a new play, and then he'd turn around to me and say, "Sharp, don't you ever run this play; you're too slow." One time during practice I got ready to unload a little shovel pass when I suddenly realized I had the wrong player in my sight. The ball just rolled out from my hand. Stanton came storming out on the field and said, "What are you doing, feeding the chickens?" So ever after I was "Feed the Chickens" Sharp.

In those days, every Monday at eleven o'clock the entire student body had to assemble in Culbertson Hall, which was where South Mudd is now. Attendance was required, and I think we got one unit of credit for being there. You signed a little slip — we had the honor system then, just as we have now — indicating how many assemblies you had missed during the term. Your grade depended on how many you had missed, up to the point where you could flunk. Then you had to do something special to make it up. The point is that once a week the entire student body got together, and there was communication on student body things. I think it was a unifying influence, which unfortunately is lacking now.

*GB:* Were you a Caltech graduate student at all?

*RS:* I did spend one year at Caltech as a graduate student. The year wasn't a complete loss, but it would have been better if I had left sooner.

*GB:* Why would you say that?

*RS:* The change of intellectual environments is stimulating. My world was centered in Caltech, southern California, the West Coast. When I got away, I realized I was a very provincial person.

I went about as far away as I could get, to Harvard, which I found very stimulating, good in geology, and a complete change. Caltech gave me an educational discipline that made study at Harvard relatively easy, so I had ample time to capitalize on the rich intellectual menu available there. Socially, Harvard was a blank. It was possible to feel you were a non-person to the third power.

*GB:* Did you specialize in any particular field of geology?

*RS:* I had not before I got to Harvard, but within my first year I had to decide on a PhD thesis. I wanted to do a field geology problem, and I was inclined toward one in structural geology. I had gone to the map room and discovered a brand new topographic map in northeastern Nevada. I could just look at it and tell that it was nice country. So that's what I finally did. It was basically a structurally oriented problem, but I also mapped the glaciation of the range and a lot of geomorphological features.

I spent the summer of 1937 in northeastern Nevada in the Ruby-East Humboldt Range, doing my second year of field work on my PhD thesis. Late in the summer I got a letter from Ian Campbell [at that time, associate professor of petrology at Caltech] asking if I might be available to go on a Caltech-Carnegie Grand Canyon boat expedition that he was organizing. We would go down the Colorado River from Lee's Ferry to

Pierce's Ferry in the fall, completing a study of the old Archean rocks in the inner gorges of the canyon. He and John Maxson [an instructor in the Caltech geology division] had been conducting this study for a number of years under support from the Carnegie Institution.

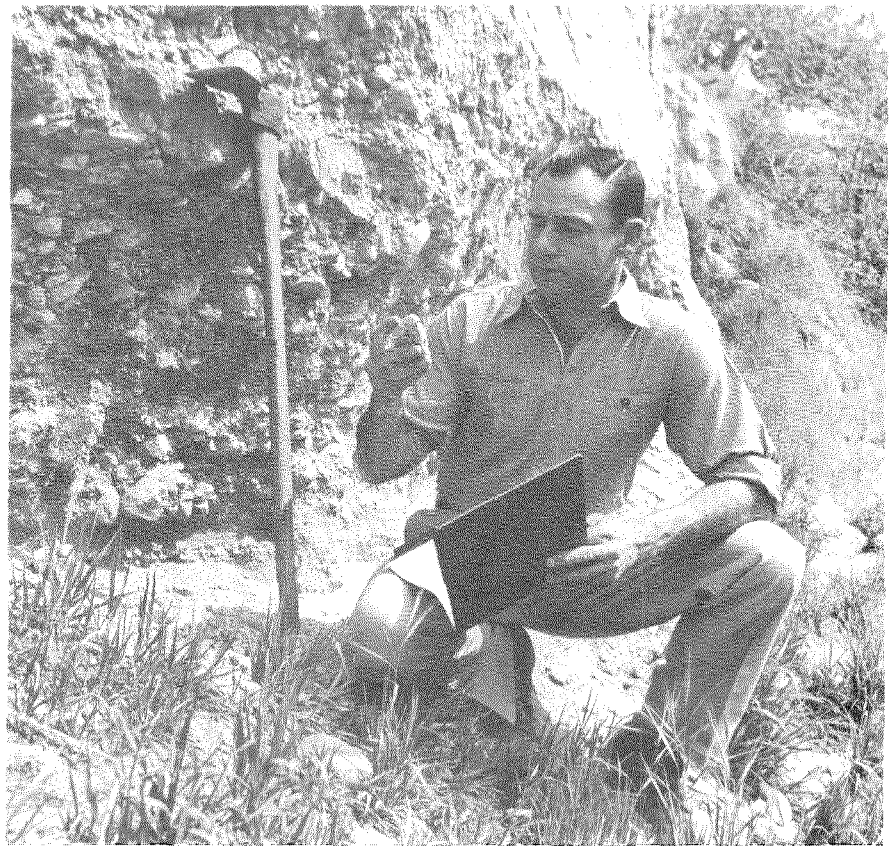
It was the opportunity of a lifetime, so I wrote to Harvard and asked, first, if they would grant me a leave of absence for the first semester and, second, if I could have my Woodworth Fellowship for the second semester. Harvard not only said yes, but they made my fellowship a traveling fellowship for the first semester. It amounted to something like $400, but I thought that was just terrific.

On the Grand Canyon trip there were seven of us all told, three boatmen and four geologists. I was the kid of the outfit, the gun bearer so to speak. That was the greatest trip I ever had. We got out of the canyon just a little before Christmas, and I spent Christmas at home and then took off back to Harvard where I had to write my thesis and defend it within the short period between January and May. I did it.

*GB:* You met your wife at Harvard?

*RS:* She was a graduate student at Radcliffe in 1937-38, and I knew about her through Dick and Frances Jahns. Dick Jahns was a Caltech graduate who was on the Caltech geology faculty. They told me, "When you get back to Harvard, you must look up this wonderful girl, Jean Todd, and get acquainted with her." After I got back from the Grand Canyon trip, I got somebody to point Jean out to me, and I invited her to supper. We were married in the late summer of 1938. By then I had a job at the University of Illinois, and we settled into a little apartment in Champaign. I worked at Illinois for five years — 1938 to 1943 — and I never worked harder in my life.

What finally got me out was World War II. I went into the Army Air Force in 1943 and spent three years in the Arctic-Desert-Tropic Information Center, part of the time in Alaska and out in the Aleutians. In 1946, I took a job at the University of Minnesota as an associate professor. In my second year there I received offers from Caltech and Stanford, and the University of Illinois asked me to come back and head up their geology department. I finally chose Caltech even though I had some serious reservations about coming back to my own alma mater.



*Teaching and administrative duties as chairman of the division didn't keep Sharp from getting out into the field, as shown by this 1956 photograph.*

*GB:* How was it to be back?

*RS:* I arrived at Caltech early in the fall of 1947. John Buwalda, who had been for over 20 years the chairman of the geology division, had just stepped down, and Chester Stock occupied the head spot. Stock was just the opposite of Buwalda, who ran a tight ship. Chester operated with a very light touch. He died, however, within three years. Then Ian Campbell became acting chairman for a couple of years, and finally I succeeded Campbell in 1952.

I hadn't been here but about two days in 1947 when John Buwalda walked into my office and said, "I have been teaching the elementary physical geology course in this department for over 20 years, and I'm tired of it. Here are my notes; you do it." So I immediately inherited a big elementary physical geology course, which at that time was required of all students at Caltech. I taught that course for about 25 years, and I was glad to do it because I think that's probably the most important course taught in the whole division.

In 1952 I was made division chairman, more or less over my own dead body, and I stayed in that spot for about 15 years. The first thing I did when I was appointed was to call up George Beadle of biology and Robert Bacher of physics and ask them to have lunch with me so I could ask them how to be a chairman. So we had lunch together at the Athenaeum, and I kept putting questions to them, and they'd look at each other and say, "Well, how do *you* do it?" Then they'd discuss it and often say, "Gee, *I* don't do it that way." At the end of the luncheon I think it was Beadle who said, "You know, we ought to get all of the division chairmen together and talk about some of these things." That was the beginning of what used to be called the Division Chairmen's Meeting, which has now become the Institute Administrative Council, the IAC.

*GB:* You didn't do much teaching while you were a division chairman, did you?

*RS:* Oh, yes, I did! I did both teaching and research. I feel very strongly about that. It's very important that administration figures keep contact with the front-line activities of the Institute. My research suffered, but I continued to do some, and I think that's highly desirable. The Institute encourages you to do this, and it's a sound policy.

We were building our division all through those years, and I can remember in 1955 when we had an opportunity to hire two young assistant professors. We looked all over for people and finally had a line on three that we'd like to hire, but we could only place two of them. Those three people were Leon Silver, Clarence Allen, and Jerry Wasserburg [now all senior professors in the division]. We had already gotten Frank Press [who has since been a professor at MIT, science adviser to President Carter, and is now president of the National Academy of Sciences] and Harrison Brown [who left Caltech in 1977 to become director of the Resource Systems Institute, East-West Center, in Honolulu], and they were both highly entrepreneurial and good operators. Thanks largely to their imagination — and using some money I had managed to raise independently — we ended up hiring all three of those young men in one year. They have all subsequently been elected to the National Academy of Sciences.

I want to talk a little bit about the geology division in historical perspective. John Buwalda built a very sound operation based on discipline, toughness, and a devotion to field work. He established a classical geology base into which he then integrated seismological work, and eventually Caltech wound up with a whole seismological laboratory in its pocket.

This made us different, and I think established a fortunate frame of mind. Our seismological laboratory is world famous. When Stock died in 1950, we had an extended introspection within the division, and we elected to go into geochemistry. At that time, this was quite an innovation, but our geochemical operation has proved to be a huge success.

As geochemistry developed, a curious thing happened, and I hope that it will happen again. We had on our staff here perhaps three people who would have been called geochemists anywhere. Slowly, other staff members became involved in the geochemistry program, and although we never called them geochemists, other people would have because of the nature of the work they were doing. I'm a classical geologist — a geomorphologist — but eventually I did a lot of work with Sam Epstein [professor of geochemistry]. We wrote a good many papers on isotopic techniques in the study of snow, ice, and glaciers. At that time, this was pioneering work.

Once our geochemistry operation was matured, we began looking around for what to do next. Press, who was still with us at the time, wanted us to go into ocean-floor geophysics, which is a great field. The trouble with it is that you have to have ships. Owning a ship is like marrying a harem: You've got problems.

We debated this for a long time and finally said, "No, let's not go that way. Let's go into space science because the bus, in a sense, is right at our back door. Through the Jet Propulsion Laboratory we have an opportunity to participate." Now, either decision would have been good, but we had a greater chance for uniqueness by allying with the space program, and it worked out well.

We have been one of the top geology-geoscience operations in the country, but you have to work doubly hard to maintain that status. And you have to get good young people and develop a sense of mission, a focus. Barclay Kamb [chairman of the division from 1972 to 1983], I think with good judgment and astuteness, had identified the field of natural resources as the next area in which we could become an outstanding contributor. Over the next 10 to 20 years in this country, natural resources are going to be a major concern, and basic research having to do with the discovery and use of them is going to be required.

*GB:* Can you tell me about your research?

*RS:* As I progressed through my career, I came to have a greater and greater interest in what I call "today's geology" — things that are going on currently on the earth's surface in the way of geological processes, events, and their products. I particularly like to work with things you can measure. That's how come, in part, I got into research on glaciers. They're dynamic bodies, and you can measure how fast they move, what the velocity distribution is, what their growth and shrinkage is, and so on. To some degree, the work I did with wind is related to the same thing. We have the desert in our backyard, and since I had always been interested in deserts, the opportunity to work directly with arid-region features was welcome.

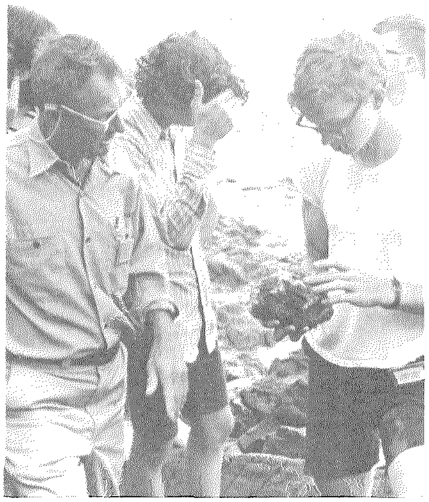
*GB:* How about your experience on the Harold Brown Presidential Search Committee?

*RS:* This was a faculty committee appointed in 1967 at the wish of the trustees, who have the final word as to who the president of the Institute will be. Arnold Beckman, who was then chairman of the board of trustees, requested Jesse Greenstein, who was chairman of the faculty, to appoint a committee. Jesse came and talked to me about it, and we drew up a list of possible members, being sure we got campus-wide representation. I don't quite know how I ended up as chairman, but I did. We worked very closely with the trustees. As a matter of fact, they used us as their search and evaluation arm.

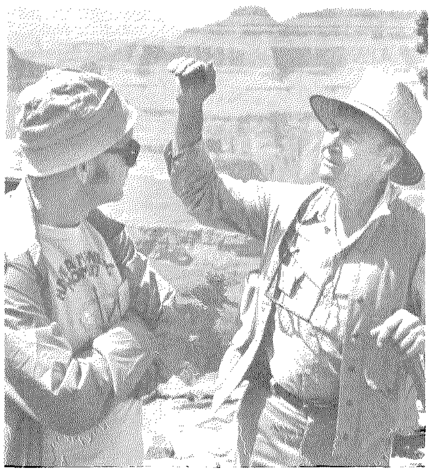
*GB:* Did you compile a series of biographies?

*RS:* Goodness, yes. We made large files on many candidates. They have all been destroyed now, except for one or two crucial files which rest in the archives in Millikan Library under a sealed setup. It is interesting to note that finding a new director for JPL in 1976 required more work over a longer time and was harder than finding a president for Caltech. I was chairman of the JPL committee too, and we used to deliver dossiers about the candidates to Harold Brown [Caltech's president from 1969 to 1977]. I remember the first one we ever delivered to Harold. He looked at it and said, "Boy, I'd like to see what you guys have on me." And I said, "Well, Harold, that's one thing you *can't* see."

One of the most unusual aspects of the whole presidential search procedure was bringing Harold to campus before he was annointed as an acceptable candidate. Brown was Secretary of the Air Force at that time. That was the era of student disruptions, and you couldn't have brought the Secretary of the Air Force onto the campus of most institutions then without having a confrontation. You could do it here, but even so it was a sensitive issue. We simply said to the trustees that Brown could not be a viable candidate unless he came and exposed himself to the community so we could see what kind of person he was. So Harold came out and spent the better part of three days meeting with small groups of the faculty and a fair-sized group of students in head-to-head sessions, going from one to another of them without a break. He's a very durable guy. When he left, I was completely worn out, but he never lost his cool once during the whole time.



*Wherever he goes, Sharp gets a chance to "do" geology. Above, at Freshman Camp on Catalina Island; below, on an Alumni Association trip to the Grand Canyon.*



*GB:* You haven't talked about your space research.

*RS:* The planetary exploration operation has been important for our whole division. We only got 12 or 14 pictures of Mars from Mariner 4, and they came in very slowly. Furthermore, they didn't look like anything to begin with because JPL had not yet developed its processing and enhancement techniques to any degree.

Mariner 6 and 7, still as flybys but with a much expanded program, came next and eventually Mariner 9 gave us a continuing orbit. With the flybys, in effect you just lean out the window and take a bunch of pictures as you go by. But when you start orbiting, that's a different ball game. By the time Mariner 9 was finished, I'd had about all I wanted. These space missions are very demanding; the pressure on experimenters is heavy.

*GB:* Let's discuss your field trips for the geology staff people.

*RS:* It's long been my feeling that the non-academic people at Caltech don't get the recognition they deserve. In our own division I always felt that the lab technicians and secretaries must have felt left out when they saw our faculty and students going on field trips. So we started a non-academic staff field trip.

Initially I ran very simple one-day trips, such as over the San Gabriel Mountains and back by way of Mint Canyon. The first two-day trip was up to the Owens Valley and back by way of Panamint Valley. We stayed overnight at and near Lone Pine. After we had eaten supper in town, we dropped all the people who were staying at the motel off, and then I climbed back on the bus with the people who were going to camp out in the hills. What was left on the bus besides me? Seven girls, and nobody else. So I had seven girls camping with me in the Alabama foothills that night. I had brought some firewood and some popcorn, and we really enjoyed a great evening. [Sharp has also conducted a number of field trips for alumni — on the island of Hawaii, for example, and through the Grand Canyon and Yellowstone Park.]

*GB:* You've written two geology field guides?

*RS:* Yes, there are two. The first difference between my field guides and those done by other people is that mine are written expressly for the layman. Second, I tried hard to make them focus on what you see while traveling. I tried to give a continuous running account of what you'll see between Victorville and Barstow, for instance. The last book, on the south coastal region, was a difficult chore. I found it very hard to do a guidebook for freeways, and it's also hard to use on freeways. But I felt if we were going to try to reach the lay public, we had to stick to freeways. People are not going to turn off and follow some back road just because you've written a geological guide about it.

*GB:* What about some of the awards you've gotten?

*RS:* Well, let's run down through some of them just to get them in perspective. For example, the business of the *Life* magazine award as one of the ten best teachers in the United States. That's a very capricious selection — to pick out only ten guys in the whole country and say these are the ten best teachers. You have to have certain basic qualifications, perhaps, but after that other things control the selection. *Life* wanted somebody from a small technical school because they already had people from Harvard and other big liberal arts places. Still, they wanted a prestigious school, and Caltech qualified.

One of the most meaningful honors, from my standpoint, was the naming of the endowed professorship for me here at Caltech. I had worked very hard on that project, which was taking people on a geologically oriented boat trip through the Grand Canyon for enormous sums of money to endow the professorship. I was more than a little embarrassed that it ended up bearing my name. The other honor, which is a highly specialized thing, is the Penrose Medal of the Geological Society of America. That's a very humbling sort of award because the former Penrose medalists have been the great names in geology in this country as well as abroad. You have to wonder if you belong on that list.

*GB:* What about the National Academy election?

*RS:* I'm going to give it to you straight. My humble opinion is that I was elected to the National Academy of Sciences, not because I did any unusual geological research, which is supposed to be the basis, but because Caltech's geology department was recognized as a real gung-ho operation. People gave me, probably incorrectly, more credit than I deserved for that fact.

I'd like to end this with a sort of summation, which is very personal in some ways. I think luck plays a very large role in what happens to us. I was lucky in simply being at the right places in many instances, at the right time. I was fortunate in having a grandfather who made it possible for me to get a really good education. I don't know anything that has made more difference to me than that. If I hadn't come to Caltech, if I had just quit at the end of high school, I could be like hundreds or thousands of other guys who are in some little town working in a store or a service station. Which is not to say that's bad, but my life has certainly been, to me, a lot more exciting and interesting and satisfying because I had wider opportunities afforded by a good education. □

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*Understanding how the in-cylinder flow of the fuel-air mixture is influenced by chamber geometry provides a key to improving engine performance. By applying a laser measurement technique, a researcher at the General Motors Research Laboratories has gained new insight into the behavior of the flow.*

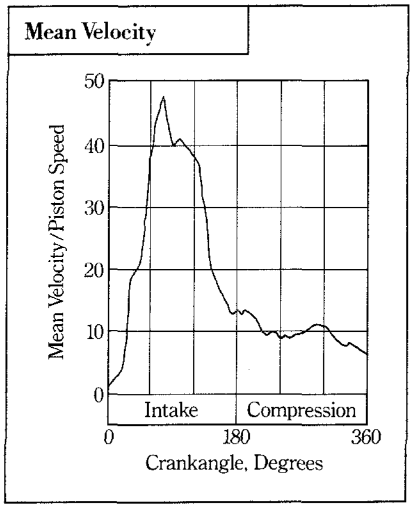
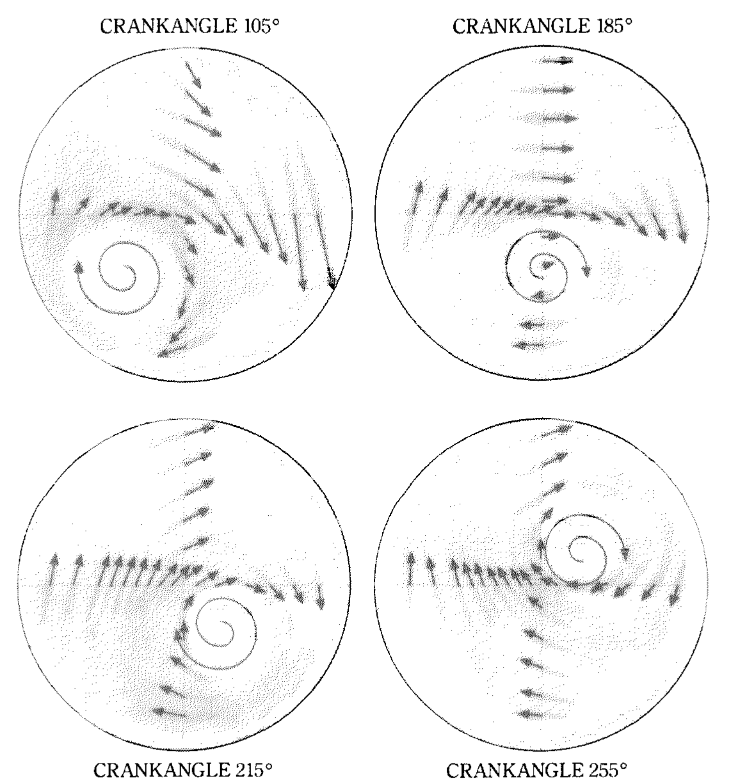



*Figure 1: History of mean velocity at a single engine location.*

*Figure 2: Panoramic view of engine flow patterns. With changing crankangle, the center of rotation precesses from the cylinder's lower left quadrant to its upper right quadrant.*




THE FLUID motions inside engine cylinders have considerable influence over the progress of combustion. Mixing of air and fuel, combustion rate, and heat losses from the cylinder are all important transport processes strongly dependent on fluid motions. The motion inside the cylinder has two components. Mean velocity influences the transport of momentum, energy, and species on a cylinder-wide scale, while the turbulence component influences the same phenomena on a local basis. The in-cylinder flow field depends primarily on the geometry of the cylinder and inlet port. Hence, decisions made in the engine design stage exert a controlling influence over the flow. But before questions about how different geometrical features affect the flow field can be answered, the problem of how to measure the flow must be solved. By applying Laser Doppler Anemometry (LDA), Dr. Rodney Rask, a researcher at the General Motors Research Laboratories, has obtained detailed measurements of the flow field.

LDA is a technique in which two focused laser beams pass into the cylinder through a quartz window. In the minute measuring region where the laser beams cross, a regular pattern of interference fringes is created. As the 1-micron particles, which have been added to the engine inlet flow, cross the measurement region, they scatter light in the bright fringes. In Dr. Rask's LDA system, the scattered light is collected by the same lenses used to focus the laser beam, and measured by a photomultiplier tube. The resulting signal is processed electronically to determine the time it takes a particle to traverse a fixed number of fringes. Since the fringe spacing is a known function of the laser beam crossing angle, this transit time provides a direct measure of velocity.

During operation of the LDA, measurements of velocity as a function of engine rotation (crankangle) are made at a number of locations within the cylinder. The instantaneous velocity at each point must then be separated into mean and turbulence components. The simplest technique is to declare that the mean velocities for all cycles are identical and ensemble average the data. However, this approach ignores the cyclic variation in the mean velocity. Another technique looks at individual cycles and uses a variety of methods, including sophisticated filtering, to split the instantaneous velocity into its components. This approach is consistent with the LDA measurements, which clearly show that the mean velocity does not repeat exactly from one engine cycle to the next.

Differences in the flow field from one cycle to the next can seriously compromise engine efficiency. Near the end of the compression stroke, it is important to maintain a consistent velocity at key cylinder locations (e.g., at a spark plug). Dr. Rask's LDA measurements have identified design features that control cyclic variability.

FIGURE 1 shows mean velocity measured at a single location during an engine cycle. High velocity exists during the intake stroke when the inlet flow is rushing through the narrow valve opening. This jet-like flow into the cylinder causes large velocity differences between adjacent cylinder locations and produces strong turbulence. As the end of the intake stroke is approached (180 degrees in Figure 1), the levels of both mean velocity and turbulence drop rapidly. This decrease is a result of the changing boundary conditions for the cylinder—from strong inflow to no inflow. During the compression stroke the flow field evolves, but it undergoes no drastic changes. However, in a high-squish chamber, where the flow is forced into a small bowl in the piston or cylinder head, considerable turbulence is generated near the end of the compression stroke.

Measurements from many cylinder locations are necessary to make the flow field understandable. Figure 2 shows four flow patterns covering a period from near the end of intake into the compression stroke. Note the strong vortical flow, with the center of the vortex away from the cylinder center and precessing with changing crankangle.

By experimenting with geometrical variables, Dr. Rask has gained new understanding of phenomena observed in operating engines. The resulting knowledge has guided the design and development of new engines with a minimum of trial-and-error testing. The LDA findings are also being used to validate and calibrate engine flow computer models under development.

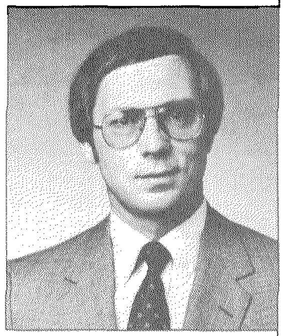
"From our measurements," Dr. Rask states, "we have been able to deduce how changes in the geometry of the port and combustion chamber modify the velocity field. These flow field effects are now being used to help designers tailor engine combustion for optimum performance."

General Motors

GM

MARK OF EXCELLENCE

## THE MAN BEHIND THE WORK



Dr. Rodney Rask is a Senior Staff Research Engineer in the Fluid Mechanics Department at the General Motors Research Laboratories.

Dr. Rask received his undergraduate and graduate degrees in mechanical engineering from the University of Minnesota. His Ph.D. thesis concerned the Coanda effect.

Prior to joining General Motors in 1973, Dr. Rask worked on the design of nuclear reactors at the Knoll's Atomic Power Laboratories. In addition to further refinements in LDA measurement techniques, his current research interests include computer simulation of engine systems, with special emphasis on the intake manifold.

# Research in Progress

## Amorphous Alloys

Amorphous metals are alloys whose atoms do not line up neatly in the regular periodic array of a crystal but rather in the more disordered arrangement of a liquid or glass ("New Materials: Atomic-Scale Architecture of Metallic Solids," *E&S* May-June 1980). This structure makes amorphous, or glassy, metals stronger and more wear- and corrosion-resistant than their crystalline counterparts and also confers on them superior electrical properties useful, for example, in cross-country power transformers.

The only trouble with these promising new materials is that it's not so easy to alter atomic structure and make it stay that way at normal temperatures. Manufacturing methods still depend on a basic process developed in the 1960s by Caltech's Pol Duwez, now professor of applied physics and materials science, emeritus. This involves cooling a liquid metal so rapidly (at a rate of a million degrees per second) that it doesn't have time to crystallize and retains instead its liquid atomic structure. Current fabrication techniques can turn out amorphous metals only as ribbons, necessarily thin in order to remove the heat quickly. No one has, until now, figured out a way to directly make metallic glasses in bulk.

William Johnson, associate professor of materials science, thinks he has found a way. With Ricardo Schwarz, a visiting associate last year and now at Argonne National Laboratories, he has developed a method of growing thin layers of amorphous metals at relatively low temperatures. Thin layers aren't much of an improvement over ribbons; but since there is no necessity of a rapid cooling process, Johnson sees no fundamental reason why the process won't work in bulk as well as in layers.

An accidental discovery by graduate student X. L. Yeh and research fellow Konrad Samwer that hydrogen would diffuse into a crystal of zirconium and rhodium, making it amorphous, led to the new process. By itself the discovery wasn't particularly interesting. But to Johnson and Schwarz it signaled the possibility that the same thing might happen with known pairs of metals that exhibit "anomalous fast diffusion"; that is, one metal can move rapidly through the other at low temperatures. At low temperatures where the atoms have little freedom to move around, the easiest structure for the resulting alloy to form is a glass.

The two scientists experimented with a number of these pairs including gold-lanthanum, gold-yttrium, nickel-hafnium, and nickel-zirconium. Johnson believes there are many other good candidates for the process, including nickel-titanium and iron-titanium, alloys that are used for high-temperature applications, and carbon-iron, better known as steel.

By evaporating submicron-size metal layers, Johnson and Schwarz built up alternating layers of thin films of, for example, gold and lanthanum. When heated to 100°C, high enough to produce a reaction but low enough to prevent growth of crystalline compounds, anomalous fast diffusion occurred at the layer interfaces, and an amorphous alloy was formed. The process has to be thermodynamically allowable, so the two metals must react exothermically; that is, the reaction must produce energy and move toward equilibrium, so that the glass is more stable than the original crystalline state. Actually what occurs in the process, says Johnson, is a matter of "tricking nature into a constrained equilibrium."

Although they don't yet have any experimental evidence, Johnson expects the process to work in three as well as in two dimensions — just mix the metal powders together, compact the mixture so there are no holes, heat it up a bit, and it should become a chunk of metallic glass. But first he wants to understand the science of what's going on by "getting the theory of the reaction sorted out." He's collaborating in this work, which has been supported by the Department of Energy, with a group at JPL under Satish Khanna. They want to know, for example, how far the amorphous alloy layer will grow through a layer structure before it crystallizes. Such experiments will tell the scientists what size grains of metal powders can be used; it may be possible to use grains of micron size or tens of microns, more standard sizes that would be of considerable advantage in commercial applications. They also need to determine and control the times and temperatures necessary for the process and figure out how to eliminate such problems as surface oxides on the metal powders. Solutions to these problems may well lead to a process capable of producing large structures of amorphous metals cheaply and easily. □ — *JD*

# Fading Fast

*When exposed to ozone, the yellow of the hut roofs and the mat at left, as well as the blue-green of the foreground, faded noticeably in this Japanese woodblock print, an early 20th-century half plate reproduction of Minakuchi from the Hoeido Tokaido series by Hiroshige.*

ART IS LONG, though life is short, time fleeting, and so on, according to centuries of poets. But some works of art may not last long enough. Research at the Environmental Quality Laboratory has established that ozone, a prime ingredient of modern air pollution, is a threat to certain artists' pigments.

Ozone, formed by photochemical reactions between hydrocarbons and oxides of nitrogen, attacks organic materials, particularly at unsaturated double bonds. Besides being the culprit in the respiratory irritation familiar to inhabitants of smoggy areas, ozone has been implicated in cracking rubber, fading textile dyes, and erosion of the binder in painted exterior surfaces. But while art works are known to fade in the presence of light and oxygen, ozone, a more powerful oxidant than oxygen, can apparently cause the deterioration of some pigments even in the dark.

Glen Cass, assistant professor of environmental engineering, and Cynthia Shaver Atherton, BS '83 (working together with James Druzik of the Los Angeles County Museum of Art), prepared two sets of common artists' watercolor samples applied on watercolor paper. One set was kept in a dark place as a control and the other placed in a light- and air-tight chamber, where it was kept for 95 days with no light, at constant temperature and humidity, and exposed to 0.40 ppm ozone. They also included two Japanese woodblock prints (by Hiroshige) in the experiment, neither one an original, but printed by traditional techniques.

Before and after being exposed to the ozone, all the samples were characterized according to a standard system by hue (gradation of color in reference to a color wheel), value (lightness or darkness in relation to a neutral gray scale), and chroma (departure from a neutral gray of the same value). Reflectance of the samples was measured at red, blue, and green wavelengths by a microdensitometer, and at continuous wavelengths by a spectrophotometer, and high-quality photographs were taken of all the samples. The latter was especially important for the woodblock prints, since there were no controls.

During the three-month exposure, several of the pigments faded dramatically. One of them, alizarin crimson, is a widely used red pigment consisting of an organic anthraquinone colorant in an aluminum complex (a combination known as a lake). Two other close relatives of alizarin crimson also faded significantly — crimson lake and purple lake, which consist of anthraquinone bound to different metal compounds. The scientists suspect that the chemical process at fault is ozone's cleavage of the anthraquinone molecular ring structure.

The researchers also observed a change in hue, from purple to more bluish, in the mauve pigment, which is a blend of copper phthalocyanine and triphenylmethane lake. Apparently the latter faded (it has also been shown to oxidize rapidly in light), leaving the blue phthalocyanine behind. The yellow pigments in the Japanese prints also faded noticeably. Although the scientists could not determine precisely the composition of these pigments, chemical tests suggested that they were either gamboge or turmeric, both of which contain exposed carbon-carbon double bonds and aromatic rings that could be attacked by ozone.

The ozone concentration of 0.40 ppm used in the experiments is typical of Los Angeles under heavy smog conditions (although the annual mean concentration is lower by a factor of 10). The research team also measured ozone concentration inside several local art museums. In the Huntington Gallery and the Los Angeles County Museum of Art, which are equipped with activated carbon filters on the air conditioning system, ozone concentrations stayed very low — below 0.01 ppm. In Caltech's Baxter Art Gallery, however, which doesn't have a chemically protected air conditioning system, they determined that the ozone concentration was quite high — about half of that outdoors, which is consistent with others' findings. The three researchers estimate it would take three years outdoors or six years in an unprotected building to equal the ozone exposure undergone in their experiments. Six years for a work of art is hardly long. □
— *JD*

# Books — by, about, or of interest to Caltech people

MACROECONOMICS AND MICROPOLITICS: The Electoral Effects of Economic Issues

*by D. Roderick Kiewiet*

The University of Chicago Press $15.00

Focusing primarily on the issues of inflation and unemployment, Rod Kiewiet, associate professor of political science at Caltech, investigates in this book whether voters are influenced more by direct personal experience with economic problems or by economic problems they perceive to be troublesome to the nation as a whole. He tests four hypotheses designed to answer this question and establishes that national problems, rather than those personally experienced, are the predominant influence on voters' decisions. Personal economic hardships affect voting only among a small minority (the very recently unemployed). Objective economic circumstances, he concludes, combine in complex but regular ways with perceptions of government responsibility and party competence and differences to determine who will win or lose at the polls.

GUGGENHEIM AERONAUTICAL LABORATORY AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY — THE FIRST FIFTY YEARS

*edited by F. E. C. Culick*

San Francisco Press, Inc., Box 6800, San Francisco, California 94101-6800

Cloth ........................ $12.50
Paper ........................ $ 7.50

On December 15, 1978, more than 400 alumni and friends of GALCIT (now called the Graduate Aeronautical Laboratories at the California Institute of Technology) gathered at Caltech to celebrate the 75th anniversary of the Wright brothers' first powered flights and the 50th anniversary of GALCIT. A symposium was held during the day, followed by a banquet in the evening. This book contains the 12 talks given on that occasion.

Each of the speakers whose remarks are reproduced in this book had had some relation to GALCIT and/or to aeronautics more broadly, and the articles are full of affection for those two institutions. They are also full of information about the history of flight — from the Wright brothers at Kitty Hawk through early rocketry and supersonics to the Gossamer Condor. The book is illustrated with a series of historical photographs. The editor, Fred Culick, is professor of applied physics and jet propulsion at Caltech.

THINKING ABOUT NATIONAL SECURITY

Defense and Foreign Policy in a Dangerous World

*by Harold Brown*

Westview Press ............... $17.95

Harold Brown, Secretary of Defense during the Carter administration, outlines here the agenda of national security issues from the vantage point of one who has had firsthand experience with these complex problems. Now distinguished visiting professor at the Johns Hopkins University School of Advanced International Studies, Brown discusses his views more broadly and candidly than he could while in office. As a framework for thinking about defense in the 1980s, he places the issues in historical perspective, ties together the political, economic, and military aspects of national security, and suggests some rational and practical approaches to forming U.S. policies. He discusses specifically U.S. interests and alliances in various regions of the world and confronts "the stark facts of the nuclear age."

Brown has also served as Secretary of the Air Force and member of the U.S. SALT delegation — as well as being president of Caltech from 1969 to 1977.

THE ROMANTIC IDEOLOGY
A CRITICAL INVESTIGATION

*by Jerome J. McGann*

The University of Chicago Press... $15.00

Claiming that the scholarship and criticism of Romanticism and its works have for too long been dominated by a Romantic ideology, Jerome McGann presents a new view of the subject in this book. He analyzes both the predominant theories of Romanticism (those of Coleridge, Hegel, and Heine) and the products of its major English practitioners — Wordsworth, Coleridge, Shelley, and Byron. He argues that poetry is produced and reproduced within concrete historical contexts and that criticism must take these contexts into account, and he shows how the ideologies embodied in Romantic poetry have shaped and distorted contemporary critical activities.

McGann is the Doris and Henry Dreyfuss Professor of Humanities at Caltech.

A CRITIQUE OF MODERN TEXTUAL CRITICISM

*by Jerome J. McGann*

The University of Chicago Press... $12.50

In this volume, McGann undertakes a critical examination of the central questions of modern editorial theory and textual criticism. He first traces how attempts to reconstruct lost texts evolved into a search for "most authoritative" editions and finally into a theory of the author's "final" intentions. He then argues that current methods of studying and interpreting texts are inappropriate to what he calls "modern national scriptures" and pleads for a more flexible theory that will accommodate the realities of the writing, editing, and publishing of modern literature.

THE SCIENCE OF MUSICAL SOUND

*by John Pierce*

Scientific American Library ..........

*The Science of Musical Sound* is a guided tour of scientific research into music, from the classic investigations of Pythagoras to the current fieldwork and experiments by acousticians, psychologists, and composers. But, says John Pierce, professor of engineering emeritus at Caltech, "in the field of sound and music, complicated equipment and ingenious experiments are not ends in themselves. They are the means by which we can evaluate the acuity, the discrimination, the powers and limitations of hearing, a sense that we use continually, a sense through which the whole of music came into being." He is confident that rational enquiry into this intensely subjective aesthetic experience will open up new realms for enjoyment of that experience.

Pierce is particularly well qualified to discuss contemporary electronic and computer-generated music, because he was a principal member of the team at Bell Laboratories that, more than 20 years ago, invented the basic techniques by which computers generate the musical sounds now so familiar from the sound tracks of *Star Wars* and other movies. Pierce looks on electronically produced sounds not as a part of electronics but "as a part of the evolution of musical sound, from drum, lyre, and Stradivarius to some of today's entirely new sounds."

The book is profusely illustrated and also has two 33-rpm records that demonstrate something of what the psychology of acoustics has learned about the perception, the illusion, and the effect of sound. Currently, the book is available only to members of the Scientific American Library. Those who wish to enroll should write to Scientific American Library, P.O. Box 646, Holmes, PA 19043.

VLSI: SILICON COMPILATION AND THE ART OF AUTOMATIC MICROCHIP DESIGN

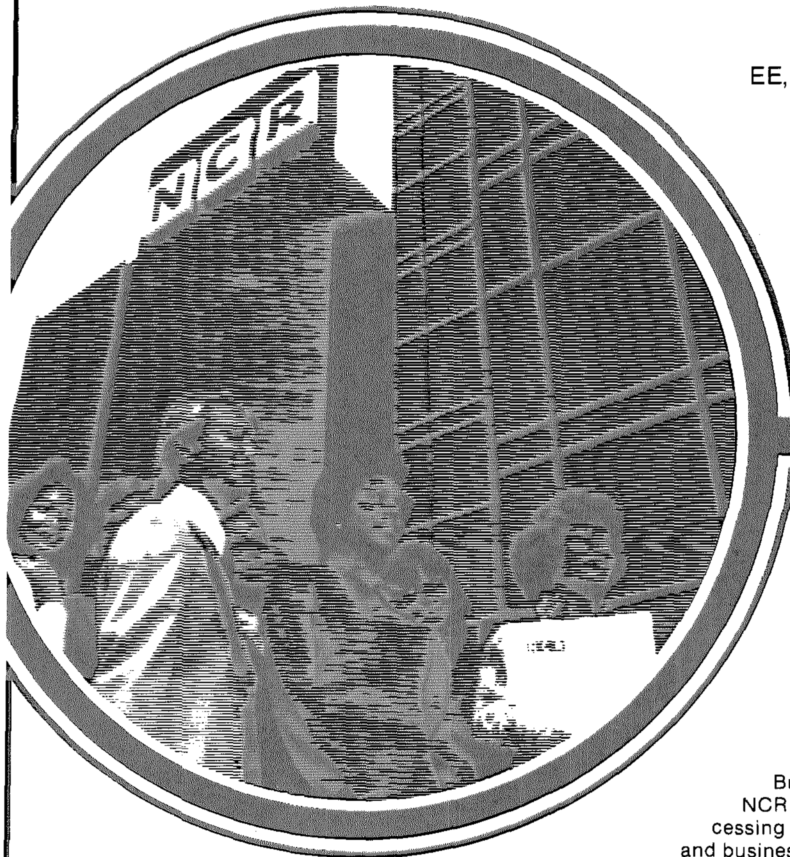
*by Ronald F. Ayres*

Prentice-Hall, Inc. ............ $39.95

One of the most serious problems of the ongoing microelectronic revolution is that of the increasing complexity of the design process for integrated circuits and the resulting bottleneck in actual fabrication of the chips. Conventional chip design can, for example, take a year and cost several million dollars. The fabrication of the then somewhat out-of-date result can take less than a month and cost well under $10,000. This book by Ronald Ayres, lecturer in computer science, discusses Caltech's pioneering research in silicon compilation as a technique for automatic microchip design for VLSI (very large scale integration) and suggests that its time- and money-saving possibilities may offer a substantial solution to the hardware crisis.

There are two focal points of concern in a silicon compiler, says Ayres — the *target language* (the capabilities of silicon) and the *source language* (the language in which the user specifies the function to be performed by the new chip). The first part of this three-part book deals with the target language — the integrated circuits themselves; the second, with the source language — the integrated circuit behavior. The final part of the book — silicon compilation — presents a variety of translations from the source behavior to the target layout.

EE, CS, Information Systems Graduates

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*UNIX is a trademark of Bell Laboratories.

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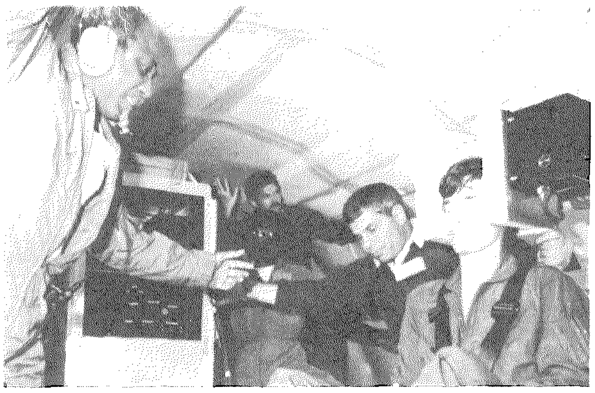
# Random Walk

## Space Orbiter

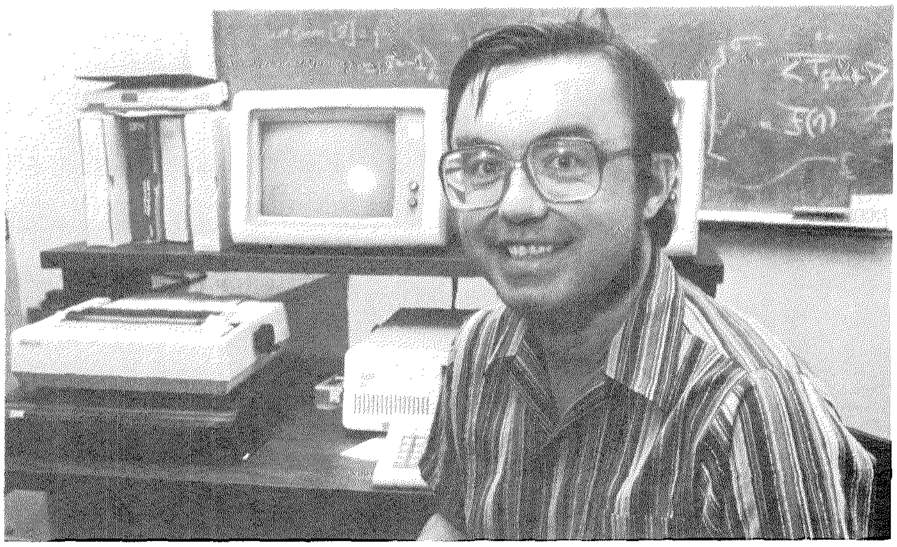


IF THESE men look a little spaced out, it's all in a good cause. In preparation for actually working in space, they were participating in a simulation of an experiment that included periods of weightlessness. The second man from the right is Caltech alumnus Robert Parker (PhD '62 in astronomy), a scientist-astronaut who was named one of two mission specialists for the Spacelab 1 flight slated to be launched into earth orbit aboard STS-9. That trip will involve nine days of working without the comforting pull of earth's gravity.

At the time he was selected as one of our scientist-astronauts in 1967, Parker was an associate professor of astronomy at the University of Wisconsin, who had a strong interest in space exploration. Working for NASA, he has been a member of the astronaut support crews for the Apollo 15 and 17 missions and served as program scientist for the Skylab Program Director's Office during the three manned Skylab flights. He was awarded the NASA Exceptional Scientific Achievement Medal in 1973 and the NASA Outstanding Leadership Medal in 1974. Among his other accomplishments are over 2,500 hours flying time in jet aircraft.

Parker is the one of a distinguished group of Caltech alumni to travel in space. They include Frank Borman (MS '57), who was an astronaut aboard Gemini 7 and Apollo 8. Harrison Schmitt (BS '57) landed on the moon from Apollo 17. Edward Gibson (MS '60, PhD '64) was one of the crew of Skylab 3. And Gordon Fullerton (BS '57, MS '58) has piloted the space shuttle Columbia.

## Fox Tale



GEOFFREY Fox, professor of theoretical physics, has been named Caltech's first dean for educational computing — a post in which he will oversee the Institute's investment in computing facilities and development of creative ways to use those facilities in education.

Making plans for "educational computing" — and implementing them — is still in an early stage, but Fox has some interesting and innovative ideas. For one thing, students will govern the major student computing facility. For another, there will be a wide array of hardware and software, to avoid graduating students who know about only one type of computer or one operating system. The Institute has recently upgraded or purchased a number of computers from several corporations in pursuit of this goal, and is currently adding 100 computers for undergraduate use. The hope is that in five years there will be about one station per student.

Important as hardware is, the real challenge will be to develop the use of computers for educational aims, not just in engineering, but in physics, chemistry, biology, geology, and the humanities as well. As a beginning, new courses in computer science and in computational physics and engineering have been added this year. But, says Fox, "we don't plan to lose our students to a CRT screen. We will continue to maintain balance with rigorous and excellent teaching."

In addition to his work in physics, Fox has served as executive officer for physics and is a leader in a major project at Caltech to develop a new kind of supercomputer, based on concurrent processor architecture. He received his PhD from Cambridge University, and has done research at the Institute for Advanced Study in Princeton, and for the Brookhaven and Argonne National Laboratories.

## Watson Lectures

PAUL JENNINGS, professor of civil engineering and applied mechanics, led off the fall Watson Lecture Series on October 26 with a discussion of the Coalinga earthquake. For our readers who couldn't attend, we offer some of the same information in "Lessons from the Coalinga Earthquake," an interview with Jennings that begins on page 6 of this issue of *E&S*.

The next four Watson Lectures include "Is the Population Bomb Still Ticking?" by Alan Sweezy, professor of economics, emeritus (November 16); "New Approaches to Cancer Diagnosis and Treatment," by John Baldeschwieler, professor of chemistry (December 7); "Innocence and Experience in the Immune System," by Ellen Rothenberg, assistant professor of biology (January 11); and "Big Brother in Orbit — What Has He Learned?" by Alexander Goetz, senior research scientist at the Jet Propulsion Laboratory (January 25).