CALIFORNIA INSTITUTE OF TECHNOLOGY

Engineering and Science

OCTOBER 1969

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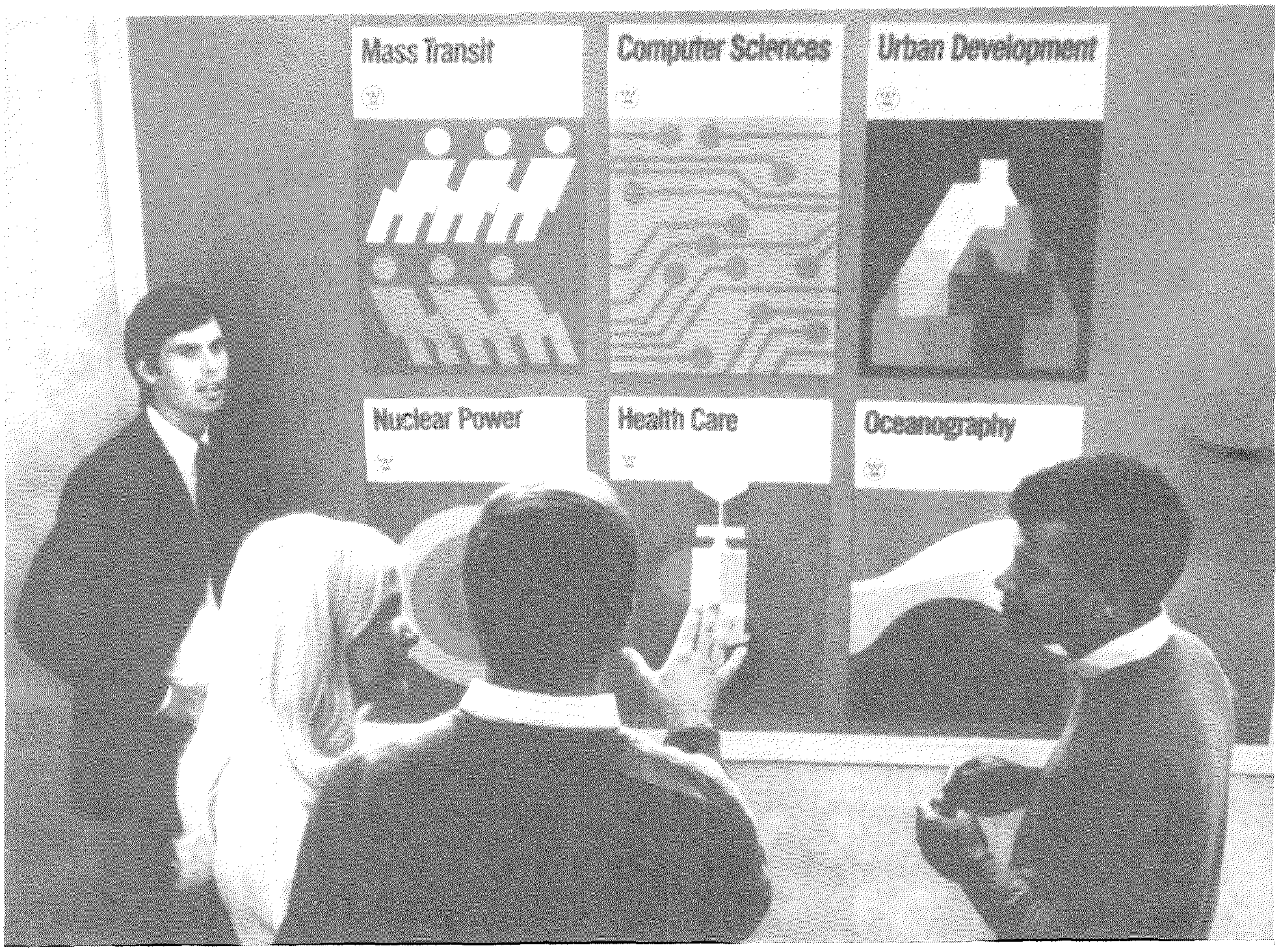

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RCA's Spectra 70/46, the Octoputer, takes a whole new approach based on time sharing.
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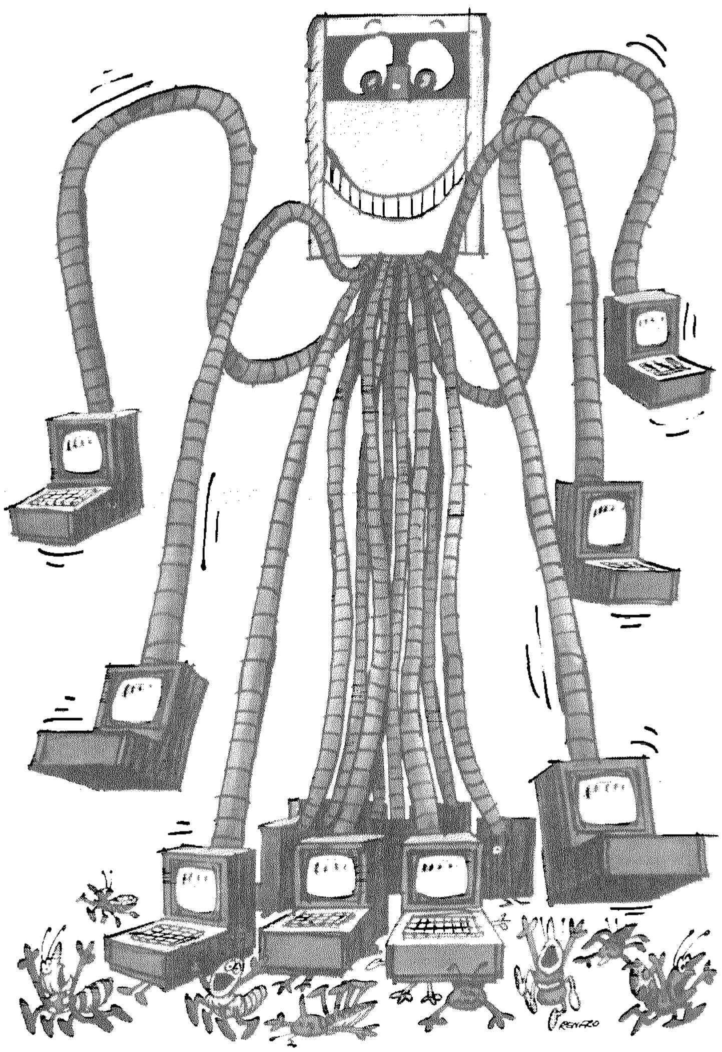

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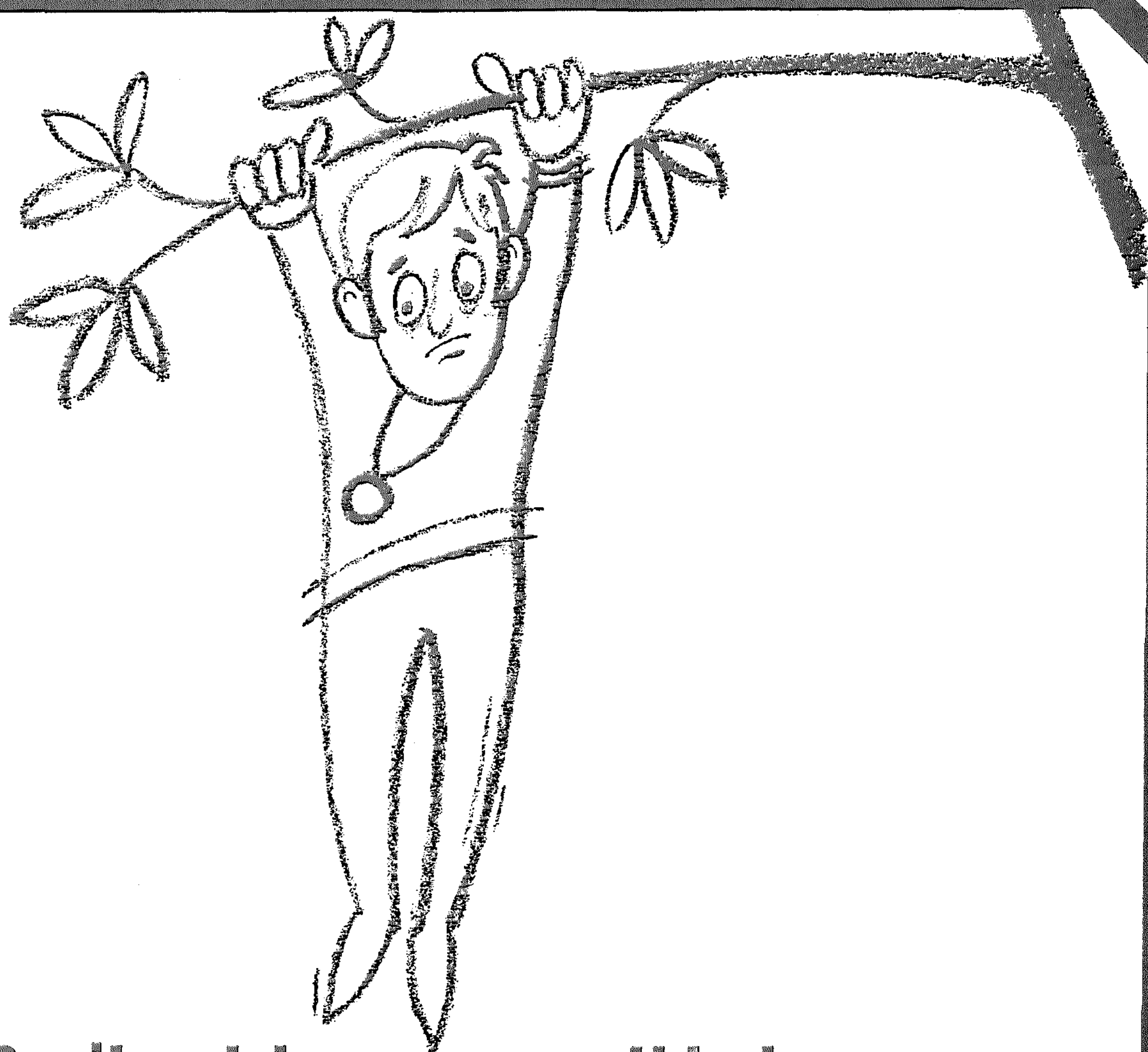

OCTOBER 1969 / VOLUME XXXIII / NUMBER 1

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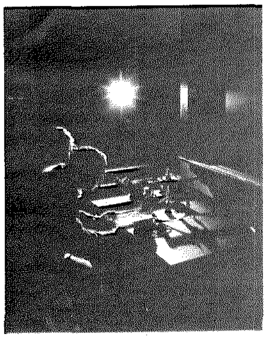

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On the cover geologist Gerald Wasserburg focuses a microscope on moon rocks shown to newsmen at a September 23 press conference held by the Caltech geologists who are principal investigators for the Apollo 11 flight. The studies that Wasserburg, Samuel Epstein, and Leon Silver will make of their samples are described on page 31.

The Caltech man most involved in the Apollo program is geology division chairman Eugene Shoemaker, who is principal investigator for the geological field investigations. Now that the first flight is over, he has raised some serious questions about what will be done on the other nine—as well as on proposed unmanned flights to Mars. His credentials for making this evaluation are substantial. Among them:

Organized the Branch of Astrogeology of the U.S. Geological Survey in 1961.

Organized the Manned Space Sciences Division of NASA in 1963.

Established the USGS Observatory for geological investigation of the moon and planets in 1963.

Established the USGS Center of Astrogeology in 1965.

Co-investigator of the Project Ranger (hard lunar landing) television experiment.

Principal investigator of the Project Surveyor (soft lunar landing) television experiment.

Shoemaker's comments on the Apollo program were made at a Caltech YMCA Luncheon Forum on October 8. An adaptation of these remarks begins on page 9.

Bill Becker is on the staff of Caltech's News Bureau. For the past several years he has written about science activities at the Jet Propulsion Laboratory; his summary of the Mariner VI and VII flights is on page 13.

Gregg Wright, a biologist who got his BS from Caltech in 1969, became interested in problems of teaching and found himself in a public elementary school trying to put theory into practice. His impressions of that attempt begin on page 18.

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PICTURE CREDITS: 13-17, Jet Propulsion Laboratory / 28, *Chemical and Engineering News* / All others, Floyd Clark.

Published seven times each year, in October, November, January, February, March, April, and May, at the California Institute of Technology, Pasadena, California 91109. Annual subscription $4.50 domestic, $5.50 foreign, single copies 65 cents. Second class postage paid at Pasadena, California, under the Act of August 24, 1912.

PUBLISHED BY THE CALIFORNIA INSTITUTE OF TECHNOLOGY AND THE ALUMNI ASSOCIATION


Sixteen years later,
sixty companies were
trying to hire this kid.

While still in kindergarten, science was already moving to make Dennis Twining a hot property.

"By the eleventh grade they launched Sputnik I. The science race was on and I was in it. I started cramming.

"After high school, I had a chance to go to the University of Michigan and work as a research assistant.

"Our project was in a cemetery in case of explosions. Great for dates.

"When I got my metallurgy degree there were sixty companies with jobs for six of us. I checked out the top ten and picked International Nickel. Why?

"Because they gave me the best chance to stay at the front edge of technology and also learn the other half of the equation—business.

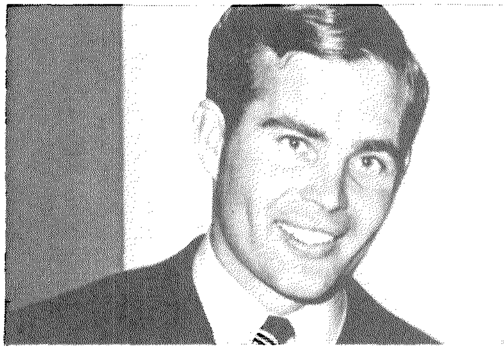
"It worked.

"I spent the first year in research. Then moved on to marketing—Chicago, Hartford, and now New York. Fantastic city.

"I'm responsible for development in mainstream markets—motor freight, containerization, construction equipment.

"Here I am on Wall Street, past halfway to my MBA at NYU with a thousand opportunities in front of me.

"Yes, Sputnik took me quite a way."



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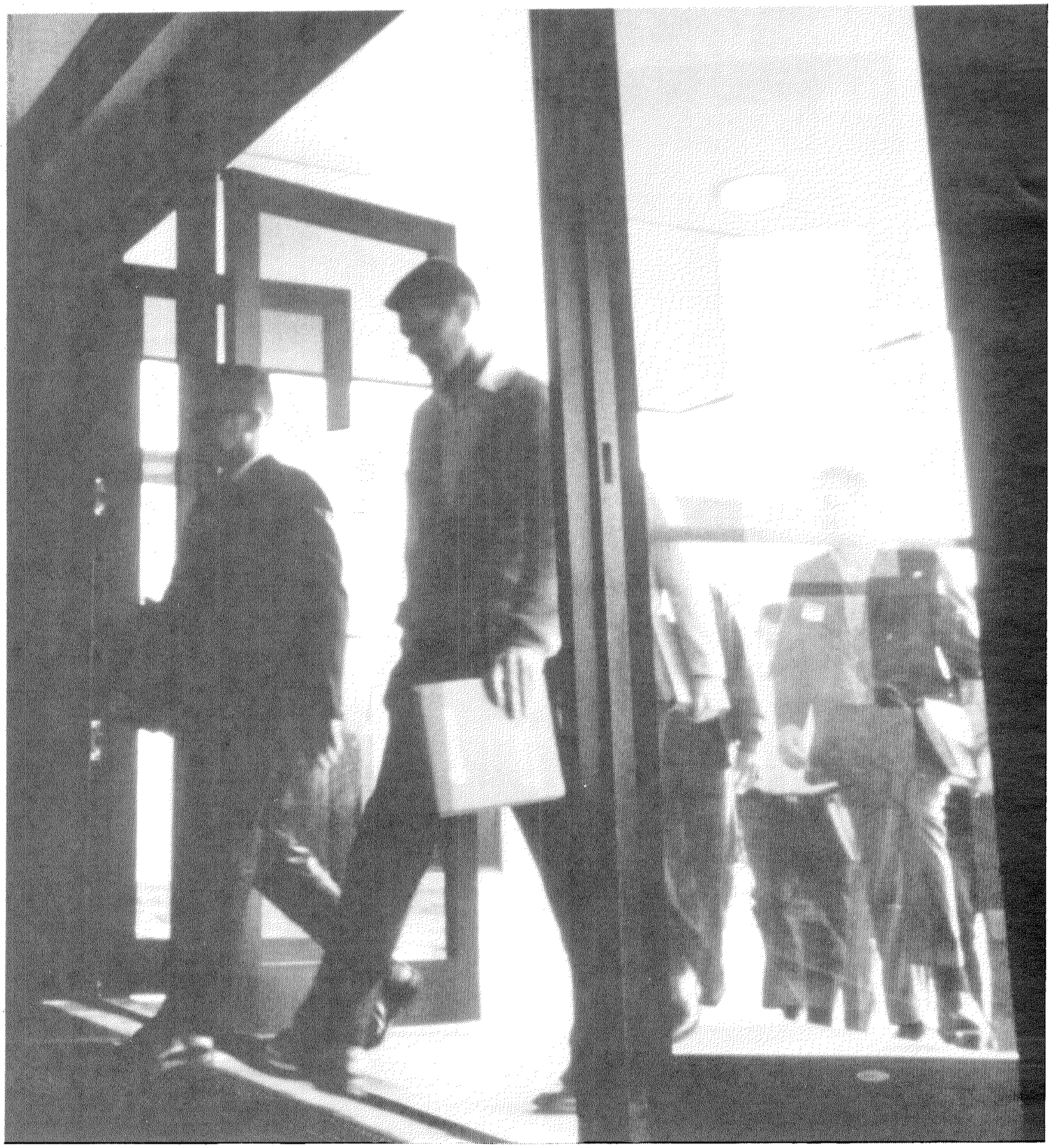

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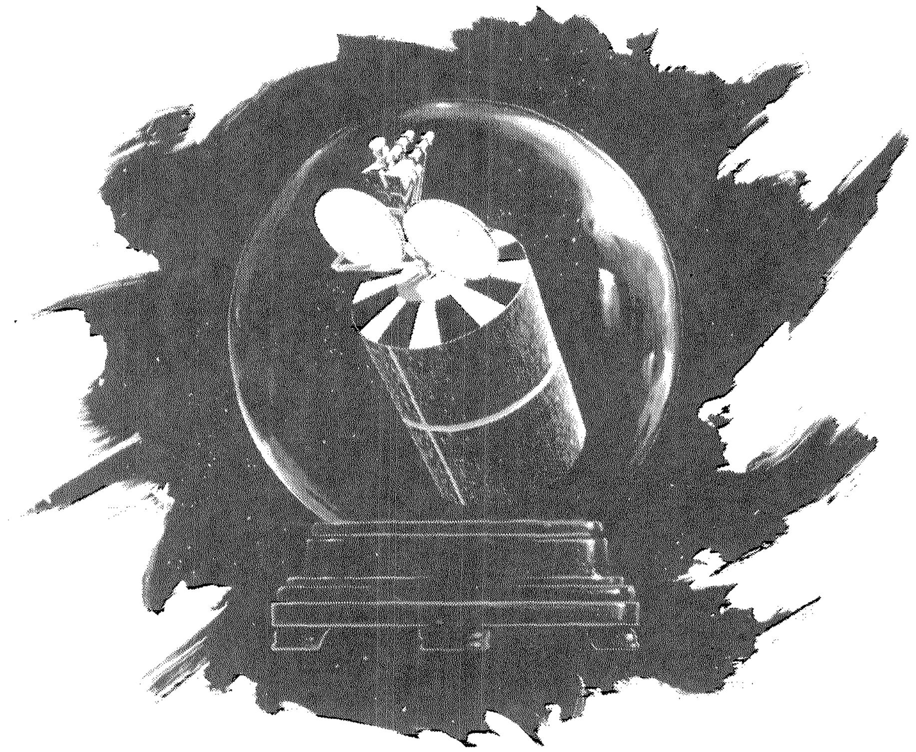


Space – Where Now, and Why?

by Eugene Shoemaker

A pioneer lunar geologist, long involved in the space program, says we haven't yet learned how to use man in space.

For the past ten years, I have been going around the country talking up the space program—explaining why it was a good thing and why we ought to send men into space. Now, for the first time, I'm speaking against it. More specifically, I'm against the series of plans that have been presented to President Nixon by his space task force. I am deeply concerned about these plans and about the way the manned space program of NASA is going right now. This concern is part of the reason I am getting out of the program after I have met my commitments for the next two Apollo flights.

The report of the Presidential task force presented three principal options for the future space program, all of them with the goal of landing a man on Mars. These options differ mainly in the time at which the U.S. should attempt to meet that goal. The fast option is to put man on Mars in 1983, with an estimated cost of about $134 billion; the intermediate option is to achieve the Mars landing in 1986, at a total cost of about $97 billion (present-day dollars). The third option, without a specified price tag, is to take it easy, still going for that goal, but sometime after 1990.

The guts of the report, the plan for the *near* future, is to develop what Dr. George Mueller, Associate Administrator of NASA for Manned Space Flight, calls a space transportation system. This system is to be developed to a certain point at which we can decide we're ready to send a man to Mars. The plan for space transportation includes a big earth-orbiting space station. Shuttles take men from the earth to the space station, and from there they can go to other, more distant places. One of the potential ancillary parts of this plan is to place an orbiting space station around the moon; travelers could be shuttled from the earth-orbiting space station to the lunar-orbiting space station, and then shuttled from there to a base on the moon. The principal justification for building this elaborate system is to put a man on Mars.

Of course, the real reason that this scheme has been proposed is that NASA wants to build big, new systems in space. NASA, after all, is primarily a big engineering organization, a good engineering organization, and good engineers like to build things. Putting a man on Mars is the next logical step for the engineers, a technological step to continue the kind of business that NASA has been in up to now.

Landing a man on the moon was considered analogous to Lindbergh's flight across the Atlantic. You wouldn't ask Lindbergh to do it a second time.

NASA has just gone through an eight-year program of building a big system, primarily for the sake of building a big system. This program is called Project Apollo. It is instructive to see how this program came out.

If we go back to the beginning of Project Apollo, to President Kennedy's decision in 1961 to put an American on the moon, the rationale behind it went something like this: The Soviet Union had the jump on us with a very considerable lead in large launch vehicles. To upstage the Soviets and pull ahead of them, we had to plan far enough ahead to allow a fair chance to overcome that lead. The best bet was to plan a large long-range effort, such as landing a man on the moon. The decision by Congress to establish NASA in 1958 was made somewhat on the same basis. It was a reaction by the nation to the sudden realization that the Soviet Union was a well-developed technological power. The creation of NASA was intended to help the U.S. catch up technologically. Project Apollo was a natural development under those circumstances.

If you talked to the NASA people directing the manned flight program, after the decision was made to begin Project Apollo, and asked them, "Why are we sending men to the moon?" you got a very direct and consistent answer. "Because the President said we were going to put a man on the moon before 1970." It was as simple as that. That was the reason around which the whole program was designed. This goal had a direct effect on the engineering. What was built was a successful system to transport man to the moon and get him back to the earth. The system worked the first time it was used for that purpose.

The Apollo spacecraft is poorly designed, however, for men to work out of, once they get on the moon. That was never a significant part of the goal, and we are now in the embarrassing position of having a system that is very good for getting to the moon and getting back, and difficult to use for anything else.

One of the early decisions, which insured that it would be difficult to explore the moon with the Apollo system, was to adopt the lunar orbital rendezvous mode—that is, to go to the moon by first putting a spacecraft into orbit around the moon and then taking a detachable module down to the moon that later comes back up to rendezvous with the main spacecraft.

The lunar orbital rendezvous mode was chosen, after detailed study, because it was a practical way to meet President Kennedy's goal in the available time and with a launch vehicle of realizable dimensions. The total weight of the spacecraft is significantly reduced by using this mode, in preference to direct descent onto the moon and direct return to earth. But the result was a spacecraft with room for only two pilots in the module that descended to the lunar surface. One pilot had to stay behind to tend the command module in orbit. There is no place in the spacecraft to take along a passenger—someone, for example, who might be a specialist in doing something after he got to the moon, rather than a specialist in flying spacecraft. That possibility was engineered out of the system right at the beginning.

Another difficulty with the Apollo spacecraft is that it is designed for only a very short stay on the moon. The Apollo 11 mission allowed time for one traverse on the lunar surface for both the astronauts. They had time to rest up; then they were off again, and they didn't have much leeway. Had they stayed longer on the lunar surface, they would have exhausted the electrical power and life-support capability of the lunar module. In the next few lunar landings the astronauts will have just two short periods of extravehicular activity.

Still another problem is that working on the lunar surface out of the lunar module is awkward, at best. Simply crawling through the hatch out onto the so-called front porch of the lunar module and climbing down the ladder is time-consuming and cumbersome. There must be better ways for a man to get out of a spacecraft that has landed on the moon. Equipment was transferred from the lunar module cabin to the lunar surface by a method that was primitive, to put it mildly. Armstrong and Aldrin used something like an old clothesline with pulleys. Other scientific equipment was stored inside in a bay that is nominally at shoulder height. With the limitations of the space suits, there was some doubt that it would be physically possible for the astronauts to remove equipment from this bay if the spacecraft landed tilted in the wrong direction or over a little crater on one side.

The lunar orbital rendezvous mode has placed major restrictions on the selection of landing sites on the moon. This limitation arises from the fact that the orbit of the command module tends to remain fixed in orientation;

because of weight constraints, the command module has only limited capability to change its orbital plane. Meanwhile, the moon is turning all the time. Unless the orbital plane of the command module coincides approximately with the equator of the moon, the lunar module soon drifts out of that plane so far that the fuel required to achieve rendezvous exceeds the capability of the spacecraft. This limitation can be overcome only if the weight of the spacecraft is greatly increased, or if the capability for staying on the lunar surface is increased to a period of a month.

These limitations of the Apollo spacecraft are a few of the consequences of the decision to send men to the moon primarily to develop space technology. They are the consequences of focusing on getting a man to the moon and getting him back, rather than focusing on why he was going to the moon and what he was going to do after he got there. The spacecraft design is not an accident. The men in charge of the manned lunar program genuinely thought that the moon was not a particularly worthwhile place on which to spend much time. They felt it was worth going to the moon once, to show that it could be done, but it was not something to make a practice of. Landing a man on the moon was considered analogous to Lindbergh's flight across the Atlantic. You wouldn't ask Lindbergh to do it a second time.

Not only is there a lack of design in the Apollo spacecraft to carry out lunar exploration, but there has been only minimal preparation for conducting scientific studies in the manned lunar program. Scientists were recruited vigorously at the Manned Spacecraft Center only very late in the game, too late to effectively build up a scientific staff of the size and competence needed. And it was too late to build equipment that would improve the effectiveness of the men on the lunar surface or to prepare the ground facilities adequately to process the samples brought back. The Lunar Sample Receiving Laboratory, for example, was not truly ready to receive samples from the moon. The staff of the Laboratory had been working very hard, but they started preparing five or six years after the Apollo program itself was started. Science was patched onto Apollo very late.

I submit that it is an open question whether it's really worth sending a man into space. We haven't begun to learn how to use men in space effectively. Mercury and Gemini were engineering development programs designed to learn how to get a man into space. Although a few scientific tasks were assigned to the astronauts, no serious effort was made to conduct research in space with the Mercury and Gemini spacecraft. Apollo was supposed to have some science in it, but the astronauts were given many tasks that take minimum advantage of having sent a man to the moon.

Lunar samples could have been collected, probably before Apollo 11, at far smaller cost.

The Apollo lunar scientific experiments package consists of a central station with cables that go out to different instruments which have to be set out and oriented by hand. This operation takes about 30 to 45 minutes. If the astronauts were being used effectively, they would set out a package that would deploy itself, or the package would be deployed by remote control or automatically from the lunar module. In fact, the instruments deployed in the Apollo 11 mission and the geophysical instruments planned for the succeeding Apollo flights could have been taken to the moon more readily by an unmanned spacecraft. Had the instruments been ready, every one of them could have been taken to the moon on a Surveyor spacecraft several years back.

Even the task of collecting samples could have been done without men. In the Surveyor program, samples were picked up from the lunar surface and manipulated with a mechanical claw, and a Surveyor-type of spacecraft could also have been built with a capsule to return samples to the earth. Lunar samples could have been collected, probably before Apollo 11, at far smaller cost.

I believe the only purpose for sending man into space that might stand close scrutiny is to explore. Exploration of the solar system is a more fundamental goal that can be set as a major objective for the nation's space program rather than the flexing of our technological muscles. There are some tasks on the surfaces of the moon and other objects in the solar system that man may be able to do better than remotely controlled instruments. Many of these tasks are analogous to the things a field geologist does on earth, although they should be done in a much more sophisticated way than they are usually done on earth. The astronauts' tasks should be planned to utilize his best attributes—his physical dexterity coupled with his visual acuity and his ability to make judgments, to make observations, to decide what to observe next, and to carry out complex tasks using his physical skills.

If we can't learn how to make advantageous use of men on the moon, then I see no point in sending men to Mars.

If our purpose is to explore the solar system, then we had better start learning how to use man in space. The most propitious place to start is on the moon. If we can't learn how to make advantageous use of men on the moon, then I see no point in sending men to Mars or any more distant place. In that case, there's no point in building an elaborate transportation system.

About ten Apollo spacecraft have been purchased by NASA. Most of them have been built; a few are still on the assembly line. The U.S. also has about ten launch vehicles to send these spacecraft to the moon, and all of the supporting facilities, such as the launch complex at Cape Kennedy, the tracking network, and the people trained to operate them. It seems clear that the prime task for NASA in this next decade is to use these national assets, which have been acquired at great cost, in a way that will provide a maximum return of information from the moon. This means that we need to make modifications to the spacecraft and to develop equipment and supporting techniques to enable the astronauts to carry out efficient scientific exploration.

First of all, the stay-time capability of the Apollo lunar module needs to be increased to many days or a week. Second, the astronauts need life-support systems that will enable them to stay out longer on the lunar surface during each extravehicular activity period. The present systems have limits of useful time of about three hours. That time ought to be improved by at least a factor of two.

Next, the space suits should be greatly improved. A much better suit design is already in hand. On the Apollo 11 mission, because the astronauts could barely bend their knees, they could not readily reach down and pick up something off the surface. They were provided with tongs with a squeezer handle on one end and claws that open and close on the other end with which to pick up rocks. Nearly everything to be done on the surface had to be done with extension handles. The astronauts did move around fairly well on the lunar surface, but it was tiring. The space suits, when pressurized, feel as stiff as a tin can. Considerable energy is expended in bending the suits at the joints. If Armstrong and Aldrin hadn't been in top physical condition, they would not have loped around as they did. It looked easy on television, but they were working hard.

If the astronauts are going to discover the origins of larger features on the moon or investigate and sample a variety of geologic terrain at key localities, they will need some kind of vehicle—a lunar jeep, if you will—to get around. At present they are limited to the relatively short traverses they can accomplish by walking.

If the stay time on the moon is increased and that time is used to visit many different places, automatic systems will be needed to keep track of the astronauts; they shouldn't have to use precious time to locate themselves. Other systems are needed that will return large quantities of field data back to the earth. Portable television systems are good for this; instead of describing what they see, the astronauts can point the camera at it. They can then be supported by an earth-based team of field assistants who compile data as the astronauts go along to help them decide where to go next. The tactics of field geology are essentially going to the right places to make critical observations, then deciding where to go to make the next critical observation.

With the right systems and with earth-based support, experiments conducted by my colleagues in the U.S. Geological Survey indicate that astronauts could obtain the information needed for detailed geological investigation on the moon and do it in a much shorter period of time than is normally taken on earth. It is possible to compress some of the scientific tasks that typically take two or three months into a few days. What we're buying when we put a man on the moon is time for him to do the scientific tasks, so it is essential to do them efficiently.

In short, the first order of business in NASA's manned spaceflight effort should be to reorient the Apollo program to carry out an experiment in scientific exploration. The first returned samples have already shown that the lunar surface is rich in information about the early history of the solar system. In ten missions we should be able to find out whether a man can be used effectively to explore a planetary surface, or whether it would be better to send only unmanned instruments. If, at the end of these missions, the answer is clearly "Yes, it was worth sending the men," then, perhaps, we should start thinking about sending men to Mars. But let's be sure the program is planned to meet the purpose of exploration. I guarantee that it won't be worth sending a man to Mars just to demonstrate the technical feasibility of building a hundred-billion-dollar transportation system.

Mariners VI and VII showed the planet to be cold, dry, and rugged. But does anything live there?

Mars—A New Mystery

by Bill Becker

Mars south polar cap—believed to be a layer of frozen carbon dioxide a few feet thick.

Just the day before yesterday, as time is measured by astronomers, Mars seemed to be a friendly place to go. If any of the neighboring planets was like Earth, it had to be Mars.

Then came the space era. Mariner IV flew by the red planet in 1965, sent back the first non-Earth-based photographs of Mars—and most scientists revised their opinions: Mars was like the moon. Now, in the eventful summer of 1969, Mariners VI and VII have forced a further reevaluation. The cameras and sampling instruments aboard the Caltech Jet Propulsion Laboratory's latest Mariners indicate that Mars may prove to be unlike any other planet in our solar system.

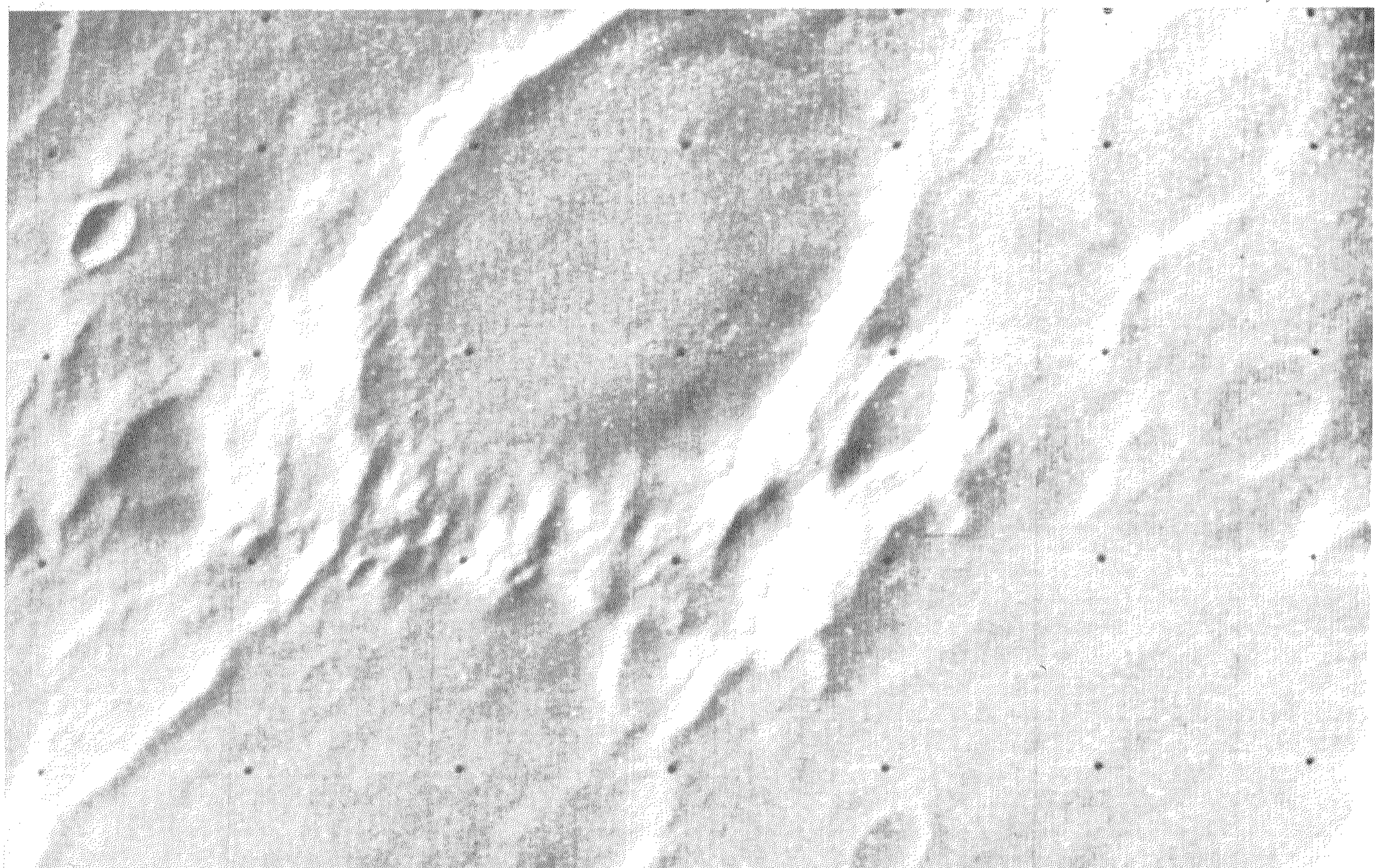
Mariner VI swept by the Martian equatorial zone on July 30 at an altitude of 2,131 miles, following a 241-million-mile flight in 156 days. Mariner VII made a south polar pass 2,130 miles out on August 4, after a shorter flight of 197 million miles in 130 days.

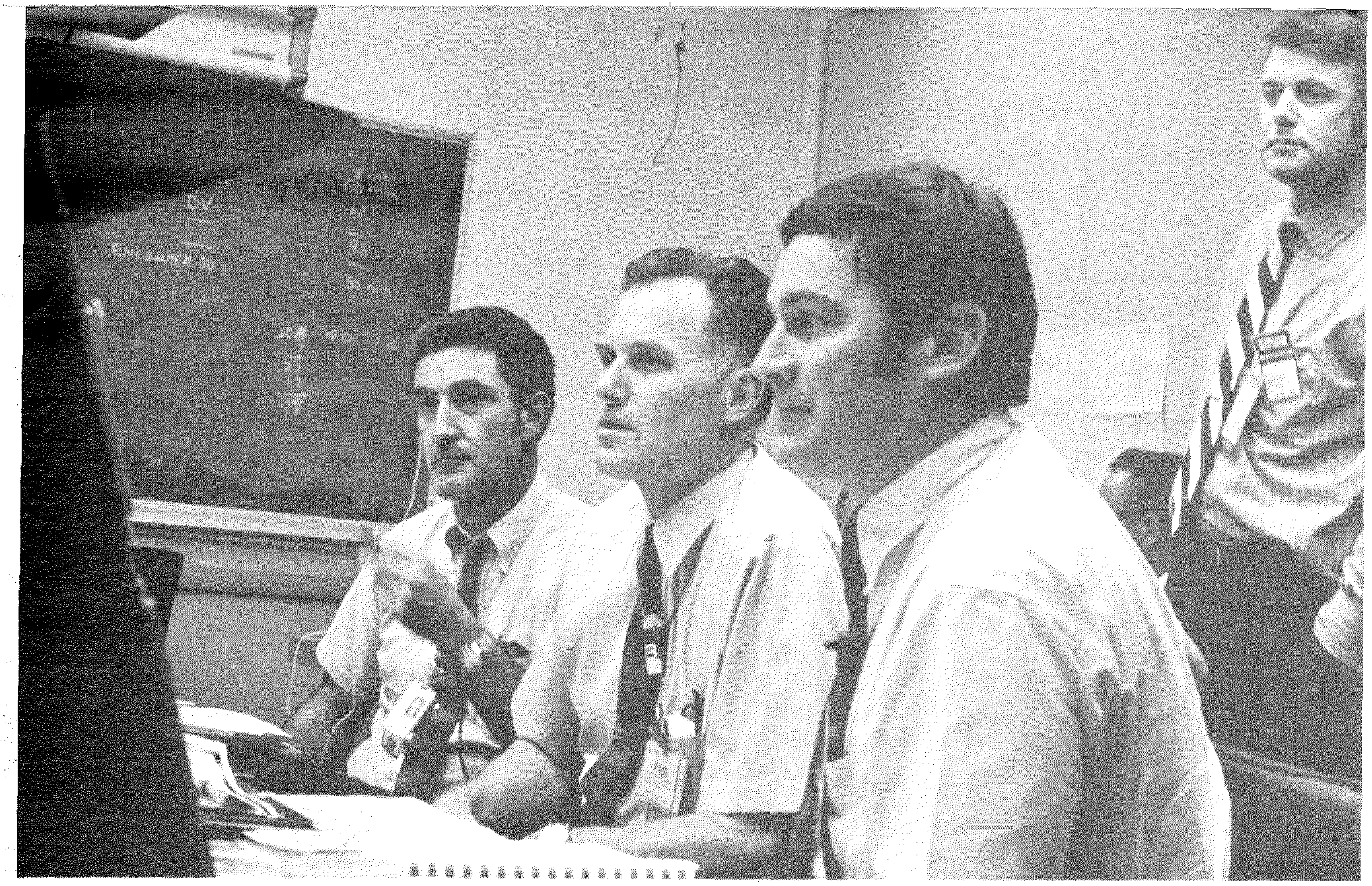
Yet, in spite of the resulting advances in our knowledge of Mars, the planet remains a tantalizing mystery that is seemingly, although not conclusively, inimical to life. "There is nothing in the new data that encourages us in the hope that Mars is the abode of life," says Caltech biologist Norman Horowitz, a member of the television experiment team. "However, there is nothing that excludes that possibility, either."

If there is some form of life on Mars, it would have to be a unique species able to exist on vapor or ice, Horowitz adds. Mars may have some warm spots, but basically it is "a very cold desert," with a scarcity of water an inhibiting factor to growth.

The dual camera systems aboard the Mariners transmitted 200 pictures, including 57 high- and medium-resolution views. The photographs reveal a heavily cratered, ice-covered south polar cap; a remarkably uncratered desert in the Hellas region; a jumbled, chaotic terrain near the Margaritifer Sinus area; and, alas, for die-hard romantics, no canals.

The giant's footprint—two adjacent craters foreshortened by oblique viewing of the south polar cap of Mars. The sun is eight degrees above the local horizon off to the upper left; the area shown is approximately 85 by 200 miles.





As they receive pictures from Mars, JPL's Al Hibbs and three members of the television experiment team (leader Robert Leighton, Caltech professor of physics; Bradford Smith, New Mexico State University astronomer; and Bruce Murray, Caltech professor of planetary science) evaluate them for thousands of home TV viewers.

The anomaly that seemingly puts Mars in a class by itself is an area of wild hills and valleys, covering several hundred square miles, in an area that appears bright to Earth telescopes. Caltech geologist Robert Sharp, also a member of the television experiment team, says this area resembles features caused on Earth by landslide slumping, but on a much greater scale. The jumbled terrain also registered two degrees warmer than nearby areas, but Sharp finds no evidence that surface volcanoes are active or that they produced this wild region.

In other areas, most of the surface is heavily cratered, and some of the craters are more than 300 miles wide. Sharp says Mars, like the moon, was impacted and "roughed up" early in the history of the solar system.

One notably different area studied in detail is the circular desert, Hellas, near the equator. This bright region, 1,200 miles wide, is devoid of craters even in the closeup pictures. Sharp suggests that the surface material of Hellas may be like pumice or tiny bits of popcorn. Such fine-grained matter would be easily distributed by wind, and any craters that might exist could be filled by it.

Pictures taken of the planet's limb (or rim) indicate that a layer of haze hugs the surface and goes up to 10 to 30 miles above it. This might be an aerosol of fine particles, according to meteorologist Conway Leovy of the University of Washington, another television experimenter.

Aside from the jumbled terrain and the blandness of Hellas, topographical highlights of the photographs are few and disillusioning, in the main, to exobiologists. For example, the historic wave of darkening which, from Earth, seasonally seems to pass over the face of Mars does not appear in the pictures. Many scientists once hoped that such darkening might be linked to vegetation.

Nor did the "blue haze" long seen by Earth's astronomers materialize in the Mariner photographs. As for the canali, first named by G. V. Schiaparelli in 1877, the best photographic evidence is in—and canals are out. Three suspected canals proved to be strings of craters giving the impression of a linear indentation.

Caltech physicist Robert Leighton headed the TV experiment team, which also included geologist Bruce Murray of Caltech.

While the pictures were being received and evaluated, other experimenters were getting different kinds of data back. The infrared and ultraviolet sensors revealed that the Martian atmosphere consists almost entirely of carbon dioxide and substances (oxygen and carbon monoxide) formed by the breakup of carbon dioxide molecules in sunlight.

Although small amounts of water vapor were detected, *We are obliged to continue the search for life. We have to get to Mars to make a direct test.*

no nitrogen was found in the air of Mars. Moreover, the polar cap appears to be frozen carbon dioxide—dry ice, not water ice. The infrared radiometer experiment directed by physicist Gerry Neugebauer and astronomer Guido Munch, both of Caltech, showed temperatures as low as −193 degrees Fahrenheit. If polar temperatures had exceeded −170 degrees, there would be stronger hope for water ice. Temperatures at the equator ran as high as 60 degrees in the daytime, with minima dropping to under −100 degrees on the night-side of the planet.

George Pimentel of the University of California, head of the infrared spectrometer experiment, reports possible fog or hoarfrost, and evidence of dry ice particles over warmer areas. However, he now withdraws a preliminary report that the instrument had detected methane and ammonia gas in the atmosphere over the south polar cap. The presence of those gases could have increased the possibility that life might exist at the fringes of the south polar ice.

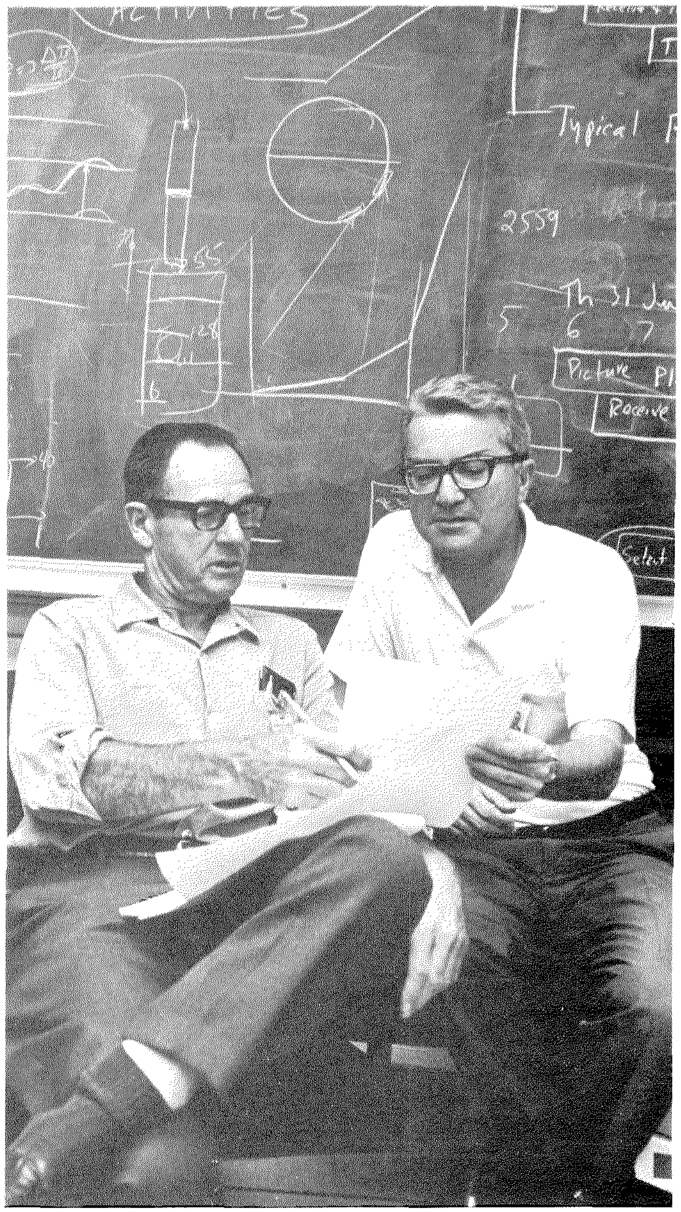
While the infrared spectrometer concentrated on the atmosphere from the Martian surface to a height of about 75 miles, an ultraviolet spectrometer analyzed the upper atmosphere, out to 600 miles. This experiment, headed by C. A. Barth of the University of Colorado, revealed no nitrogen at that altitude, but atomic hydrogen and atomic oxygen were found, along with the expected carbon dioxide and carbon monoxide.

The surface pressure of Mars was measured at about 6.5 millibars in the Mariner VI radio occultation experiment conducted by JPL's Arvydas J. Kliore and his colleagues. However, Mariner VII gave figures of 3.5 and 7 millibars, indicating that one region near the south polar cap may be four miles higher than the average. The 6.5 millibar figure is equivalent to the pressure at 100,000 feet in Earth's atmosphere. An ionosphere about 82 miles above the planet was also detected by each experiment.

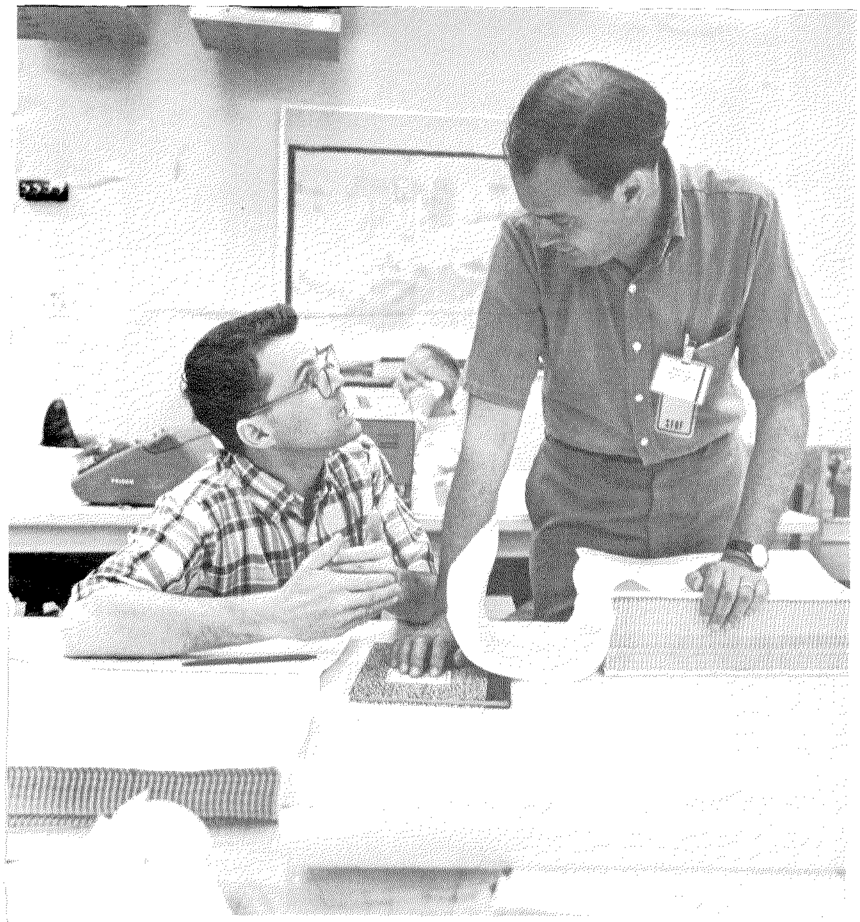
Even as 1969 Mariner studies continue, NASA is pushing ahead with plans for two Mariner-like craft to orbit and photograph Mars for three months in 1971. One of these orbiters will approach to within 1,500 miles of the planet—600 miles closer than the 1969 Mariner flybys. Then in NASA's Project Viking in 1973-4, two capsules are to land on Mars to sample the planet's surface and air.

Norman Horowitz expresses the consensus of Mariner scientists when he says that "We are obliged to continue the search for life. We have to test our current notions about how life started in the solar system. We have to get to Mars to make a direct test."

And Robert Leighton adds: "It is a remarkable fact that each of the three Mariners revealed a new and interesting kind of terrain not seen by its predecessors. Could it be that Mars has even more tantalizing secrets in store for us in 1971 and 1973?"



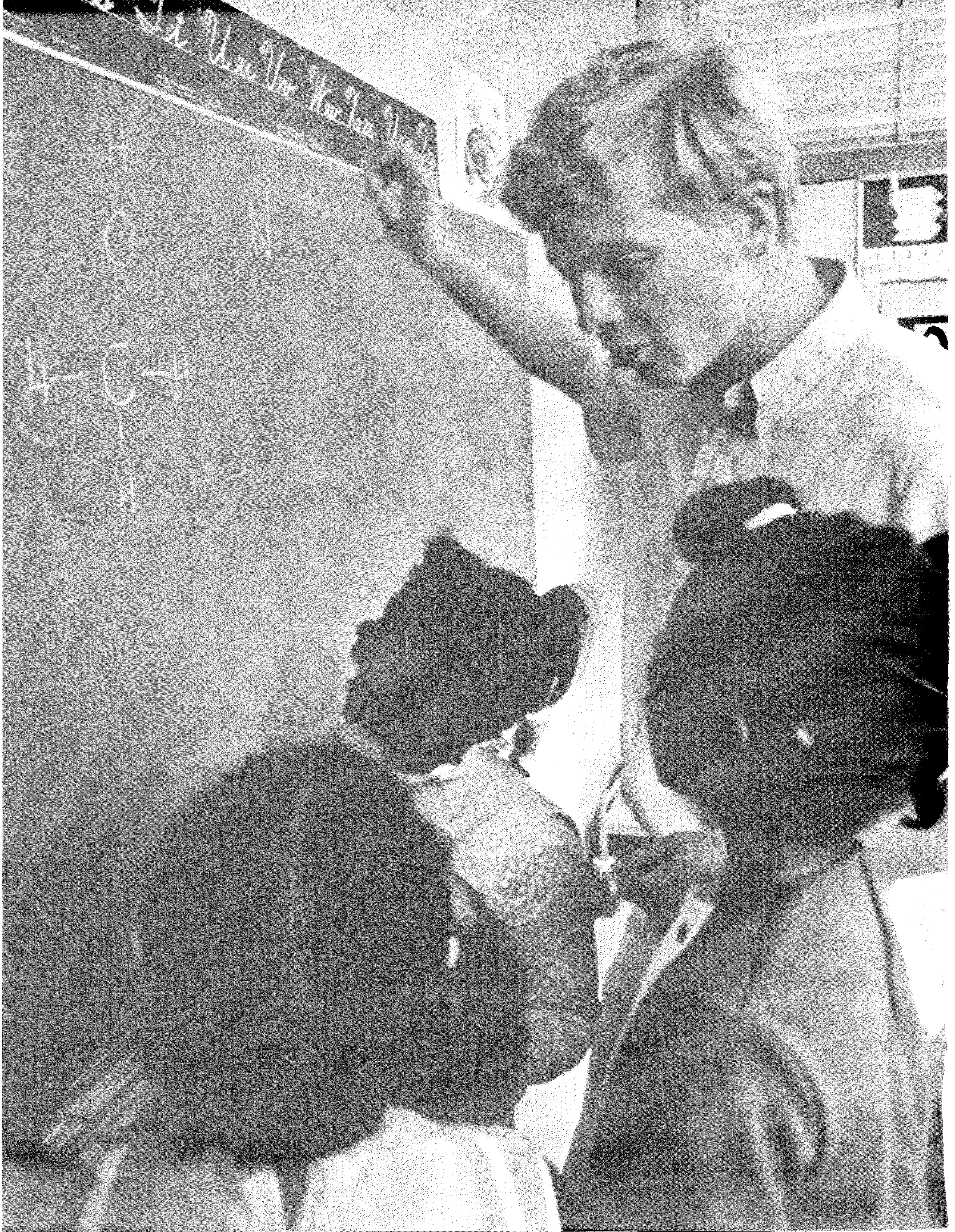
Television experimenters Robert Sharp, professor of geology, and Norman Horowitz, professor of biology.



Infrared radiometer experiment team—Gerry Neugebauer, associate professor of physics, and Guido Munch, professor of astronomy.

Caltech President Harold Brown watches incoming pictures at JPL with Robert Sharp.

Caltech's Mariner Men



OK, Teacher, What Does Living Mean?

by Gregg Wright

The third grade is a good place to see how much you learned at Caltech; it's also a good place to pick up some of the things you missed.

It's one thing to decide that elementary education is in sad shape and that *you* can do a better job than *they* are doing now. It's another thing to stand in front of 30 kids in a classroom and try to *do* it. But I tried it—and I think Caltech students can, and should, teach science in elementary schools.

At Berkeley, math graduate students are paid to teach abstract algebra in elementary schools with the "discovery method," devised by William Johntz, a high school math teacher in Berkeley. To find out about his techniques, a group of us (Caltech students and students from other colleges working at the ASCIT Research Center) invited Johntz to give a demonstration seminar on campus in October 1968. He impressed most of us with his skill at exciting fifth graders about mathematics, and excited us with the prospect of what we could do.

From this meeting a small group formed to discuss elementary education, and Caltech's role in it. By January, aided by a $500 grant from the ASCIT Research Center, we were ready to try to teach.

The principles and techniques of the discovery method, as I understand it, are these:

Avoid making more than two statements in a row. Rely heavily on questions.

Move around the class; don't spend all the time up front. Support individual students with a word or a hand on their shoulders.

Write all answers on the board, right or wrong. This validates the answers and encourages participation.

Avoid a pat, "No, that's not right." Each answer is valid to the students. They shouldn't have to feel 100 percent sure of the response the teacher wants before they feel free to respond.

Have students indicate disagreement by waving two hands vigorously in the air. This is an active but non-disruptive way to disagree with a fellow student or the teacher, and the class enjoys it.

Gregg Wright, playing the "molecule game" with third graders at Pasadena's Cleveland School, is a 1969 Caltech graduate now in his first year at Case-Western Reserve Medical School.

Armed with these techniques, we planned to excite kids with the abstract concepts of science. We started by recruiting 60 fifth- and sixth-grade students from Cleveland Elementary School in Pasadena for an after-school class. Shortly after that class started, a third-grade teacher invited us to teach a session of her class twice a week. A few of us accepted her offer. In comparing notes with those who remained with the fifth grade, we found that they had similar teaching experiences.

In our third-grade class we experienced three distinct phases, corresponding to the three teachers we worked with. We began with a teacher on a two-month exchange from her regular school. Because she did not particularly enjoy science, she was content to turn the class over to us and observe. This was the best relationship, because it was clear to the kids that we were in charge when we were teaching. Phase One lasted only three weeks.

February 4, 1969

My plan for the first day was to encourage the kids to ask questions. It seems to me that half of science is being able to ask good questions. Many of these kids are very non-verbal. I hoped to encourage them to notice things around them and then to formulate their vague curiosity into solid questions. After telling them that we were going to study science and introducing the hand-waving convention, I began asking them questions.

"What kinds of questions do you think a scientist might ask?" (No response.)

"Well, how about this one?" and on the board I wrote: HOW DO FROGS GROW? (A few shook their heads, and many looked skeptical.)

"I think some scientists at Caltech are asking questions like that," I said, and I had them take out their science books, open to any page, and see if they got any ideas. The ice was broken, and the questions came in as fast as I could write them on the board. Many of their questions were quite original. I could not trace them either to their books or to anything I had said. They included:

How do babies get in mothers' stummicks?
Why can't we see ourselves grow?
Why do we have brains?
How do brains work? (That's a tough one.)
What makes us laugh and cry?
Why do dogs bark?
How can a space man see in the dark?
Before there were numbers, how did people know how many people in a family?
Is gravity like a magnet?
Why do people have veins?
Why do we send people to the moon?
What is a pencil made of?

What makes boats float?
What is a rock made of?
Who was the first person on earth?
How do people grow teeth?
For real, didn't the Indians discover America?

In retrospect, I am discouraged that, given this material on the first day, we could not do more with it. However, it seemed like a good start.

While we were discussing the questions, one girl asked, "How did the first person to learn about electricity find out about *it?*"

It seemed to be a very important question, and I asked it back to the class.

"He discovered it."

"But what does that mean?"

"Well—he thought about how he thought it might work, and then he tried it to see if he was right."

I was floored. As many times as the scientific method has been drilled into me, I'm not sure that I could have put it that well. I wrote TRY IT on the board, and that became the way we would answer some of the questions that we had asked. They were frustrated at not having the answers. I let that frustration go for now.

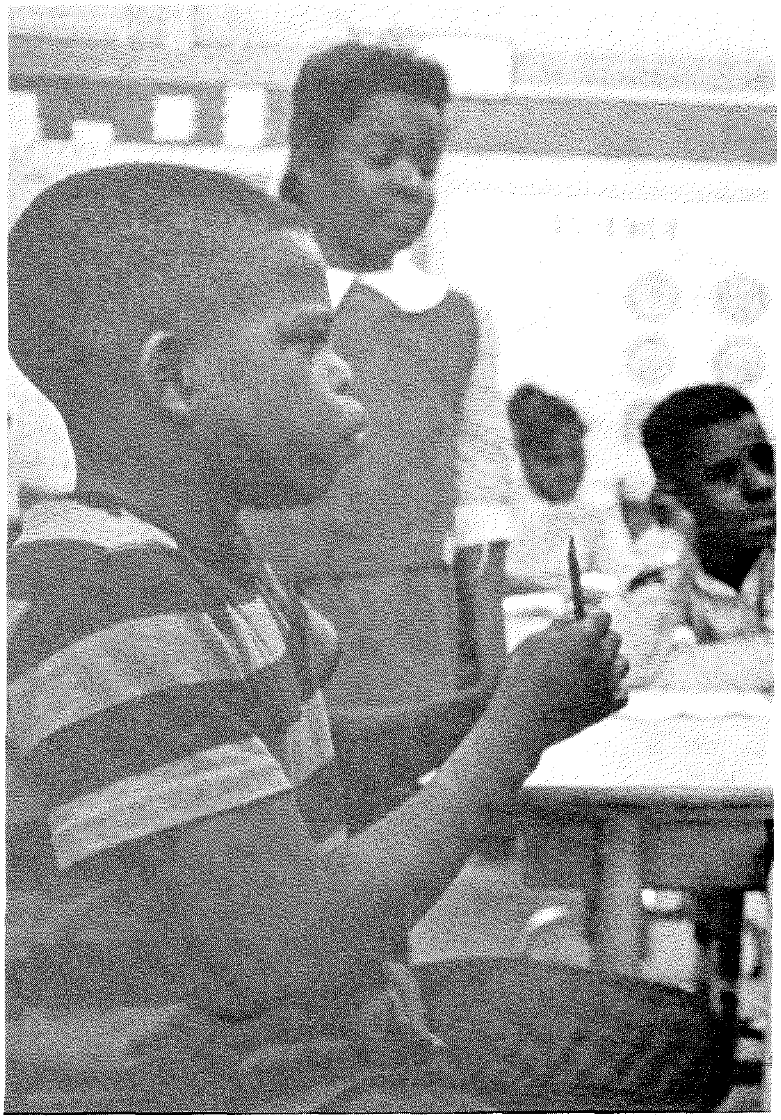
February 6, 1969

The second day was physically exhausting. The level of excitement was high, and perhaps I was working hard at being excited to keep it there.

I wrote some questions from last time on the board, and the students added some new ones. All the biology questions happened to be together on the board, as were the questions about space, and those about weather. I enclosed each group in a circle and named it. Questions about living things were called biology, space questions were astronomy. We also had a weather circle and a physics circle. The kids caught on, and they added questions to each circle.

We began to discuss what qualified a question for the biology circle. What is a living thing? That would keep us busy for a while.

Now—later—I am struck by a contrast. While I was in my home town for a vacation, I visited my own elementary school. In a third-grade class, they were studying science by taking turns reading aloud from their science book. They were studying green plants. When they came to the word chlorophyll, the teacher stopped them to explain, "You know what chlorophyll is, don't you? It is the green stuff that they put into some chewing gum that makes



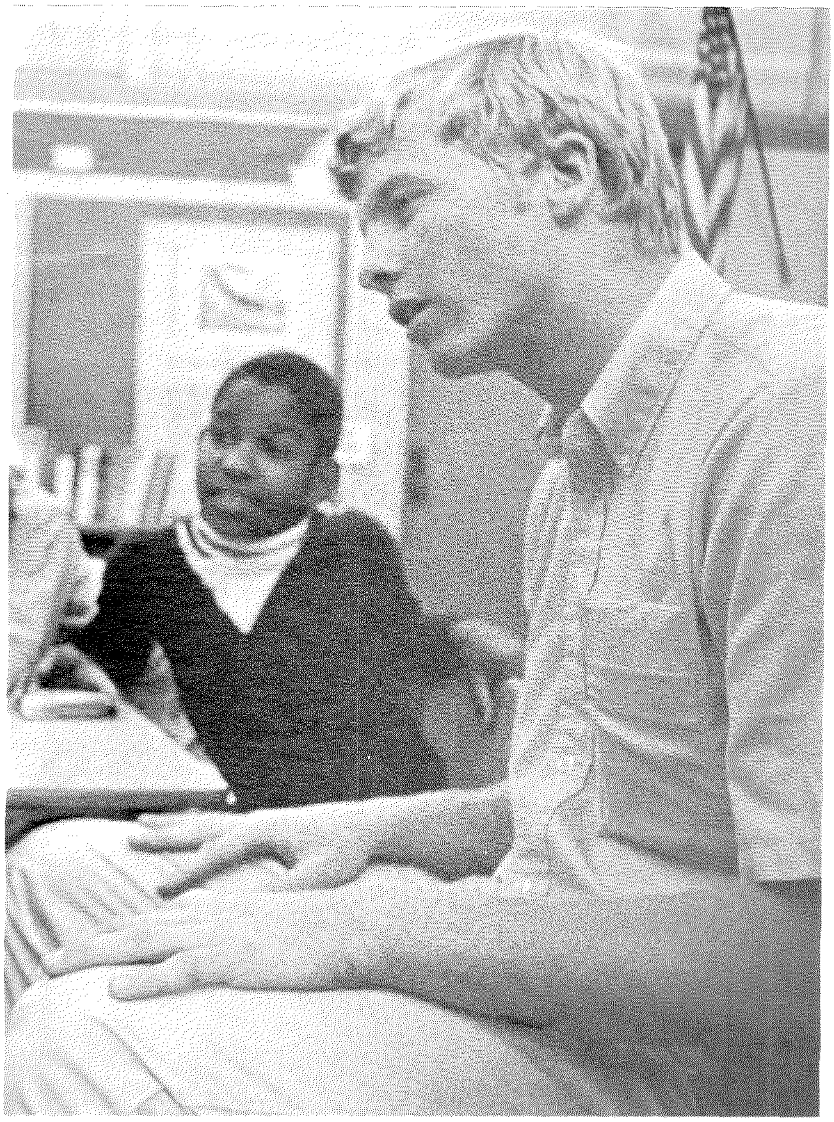
your breath sweet." The class nodded in agreement. The striking thing is not the teacher's explanation of chlorophyll. She has a hard job, many areas to teach, and science was just not her best subject. What was amazing, and upsetting, was that not one of the kids thought to ask, "But what does that have to do with green plants?" There was no response, and they continued their reading.

February 11, 1969

We spent today in confusion. How can we tell what is a living thing? Last time a boy suggested that living things grow, and most of the class was satisfied with this answer. Without thoroughly comprehending the consequences, I had come prepared to completely confuse them.

I brought a balloon and a package of "magic rocks," which are small seed crystals. When they are dropped in a super-saturated solution, the crystals "grow." First I asked, "How do we know what is living?"

"Living things grow."



"Oh? Watch—" and I blew up the balloon.

"Well, living things move."

I let the balloon go, and it flew around the room.

"Well, living things grow by themselves."

But a classmate objected. "No, we don't grow by ourselves; we need food and water."

Then I showed them the magic rocks, which most agreed were not living. In the solution, they grew. Now we were all confused. I had these doubts instinctively, and I hadn't thought about what I would do with the confusion that I produced.

We tried to isolate some things we knew were living and look at their properties. But the class was too confused. About ten voted that trees were not alive. They don't move much. I asked them to tell me on their papers why a balloon was not alive but a tree was. Some described some properties of balloons. Some asked me new questions. The best answer was probably from a boy who said that it doesn't matter. Another said, "I can think of something, but I don't want to." To finish things off, a boy insisted that in Arkansas there are rocks that grow; then they split in half and grow some more.

OK, teacher, what does *living* mean? I knew that at their age I had a three- or four-point definition of living things. I could not recall it, and I think that in good conscience I could not teach it. It isn't that simple.

We tabled the question until next time, and I went home wondering what I would do.

February 13, 1969

I wanted to work on the idea of TRY IT. The method is to dream up a statement about living things that might be true, and then try it somehow and see if it *is* true.

As the first statement the class suggested, "All living things breathe." They quickly changed this to, "Some living things breathe," and we were ready for our first experiment.

"What living things should we use?"

"The tadpoles!"

"Well, is there a better living thing around?"

They were stumped, but only for a minute.

"Oh . . . Oh! . . . US!"

They were happy and excited. One girl volunteered to come up in front and breathe for the class. We were all satisfied. Some living things breathe, sure enough. Then some of them wanted to try, "All living things breathe." But this caused a dispute. There seemed to be two factions in the class. Two spokesmen from each side debated in the front of the room.

"All living things breathe, because they would die if they didn't."

"No, some living things are so small that you can't tell if they are breathing."

"But, they would die if they didn't."

"OK. How about an ant? How do you know an ant breathes? You can't see him breathe."

We decided to make "Ants breathe" the next statement, and the time was up.

Now, I wondered—how in the hell are we going to show that an ant breathes?

February 18, 1969

I was surprised by the class. They had asked their teacher what "alive" meant, and together they had looked in their science books for the answer. Living things grow. Living things change. Living things reproduce. So now they knew. I was glad that they had taken the initiative

to follow up in their regular class. I'm still not sure of the value of a three-point description of life, but I'm sure it is better that they learned it on their own initiative. They were proud and happy.

Over the weekend, and with their new decision about living things, the group lost interest in ants. That was the end of our TRY IT technique. I think it could have been very successful.

I passed out some *Scientific Americans,* and it was one of the most rewarding days for me. The class was very disorganized, but the interest was high. Each one had a different issue of the magazine, and they kept running around to show someone else a picture. I walked around and answered their questions. It was a challenge to explain a three-dimensional model of a protein, or a chart of the elementary particles and their properties, but they asked. When I used big or new words, I wrote them in the margins next to the pictures. They especially liked the pictures of lab equipment, spaceships, and strange animals.

Because it was so successful, I brought the magazines in the next time also. This time I let the kids keep them. The high interest of a few turned out to be a desire to accumulate something—an I-have-more-than-you reflex.

This was the last day of Phase One. We had started orderly and moved toward disorder, but I feel that there was learning in the disorder. In the disorder of Phase Two, we who were teaching did most of the learning. We came to refer to Phase Two as our biweekly third-grade riot.

February 25, 1969

I had a series of slides about the Mariner Mars shot that included some comparative pictures of Earth and Mars. They were beautiful, and the comparison was quite striking. I wondered whether the kids would ask questions about them. Showing them that day was a mistake.

It was the third day of a substitute teacher, and she was having trouble keeping the kids quiet. It was also a rainy day, and she had cancelled their recess. They were overflowing with energy. As soon as the lights were out, kids were all over the room—chasing pencils, under tables, over desks. The substitute teacher was no help; those who were running around were questioning her authority as well as ours.

I moved the projector close to the screen so that the six or seven who were interested could watch with the lights on. In the face of this, thoughts of discovering science were far away. I tried to stop everything and institute one rule: DON'T BOTHER OTHERS. If they would follow this, things might be chaotic, but learning could take place.

For four more weeks there was no recess, hyperactive kids, and no control. For many reasons, I feel that this was a valuable aspect of the program. We saw a part of the kids that is blocked out and covered up by our traditional discipline.

Schools are governed by two guidelines. Children must sit and look interested, even if they are not; and children must not worry about the relevance or importance of a subject, because they will realize its value later. I think this is wrong. I think that the time we were able to spend outside these guidelines became a valuable learning experience.

We were forced to face the question of discipline. How much should we impose? Why do we impose it? Why is it necessary? Is education really so foreign to human beings that they must be made to endure it for their own good?

February 27, 1969

The day just started out wrong. When we came in, there were kids doing cartwheels in the aisle. Again they had had no recess. Jan Streiff, a Grinnell College student affiliated with the Research Center, tried to teach today. She had good success getting them to sit down, and the first 20 minutes were spent peacefully playing a 20-questions game about living things. Then they put on a play that a few of them had made up to celebrate a birthday. It had a rambling plot involving an accident, a fight, a hospital, doctors and nurses, and an operation. I couldn't follow it, but they were completely involved.

With this start, Jan tried to direct a play about living things. Kids were to play the parts of seeds, wind, rain, dirt—everything needed to make the seeds grow. They enjoyed it at first. There was not enough room, however, and the seeds started pushing with the dirt, and fighting with each other. The class ended in confusion.

March 4, 1969

When we came in today, the class was really wild. The teacher had taken a troublemaker to the office and had left the class alone for 15 minutes. As soon as we came in, there was a muffled, "Oh! Oh!" A group quickly formed around us.

"Billy dumped my plant on the floor."

"She put dirt in my book."

"They aren't supposed to be playing the record player."

"Hey, come on and dance."

"Are you going to get the teacher?"

The rest of the hour was general chaos. That day I think we witnessed the pressures that made the schools what they are today. It is easier to say, "Sit down. Learn this. Repeat this back." But I still can't believe that it is right.

This was Phase Two. I've called it a riot and general chaos. I don't want to give the wrong impression. Hyperactive is a good term. My goal was to solve the discipline problem by bringing in something that was more interesting than running around in class.

During this phase, I introduced several new activities. I brought in a set of space-filling molecular models. These are plastic oxygen, carbon, nitrogen, and hydrogen atoms that snap together. When a group began playing with these, I told them the correct name for each piece, and if I could, I named the completed molecules. Their first reaction to the models was to build them into molecules with an axis of symmetry. They would then spin like a top. I could hardly object to this. I remember a biochemistry seminar at Caltech where we spent half an hour building bigger and better tops. This activity could probably pass as a study in spatial relationships and symmetry, and it is probably worthwhile.

Others played another game, at the board or on paper at their desks. The game consists of alternately adding carbon, nitrogen, oxygen, or hydrogen atoms to a basic structure. The winner is the one who completes a molecule. Of course, it is possible to continue the game forever by adding carbon atoms, so I occasionally sprinkled hydrogens in the structure to cut down the possibilities. A few students made the connection between the game and the models, and could draw the structure of a molecule that they had built.

Another activity that we periodically tried was to talk about the state of the class. They voted 25-2 that DON'T BOTHER OTHERS was a good rule. However, I don't trust that vote much. One day that wasn't particularly bad (for Phase Two anyway), I asked how many thought that it was too noisy. Many raised their hands. When I asked how many thought it was OK, I raised my hand. I thought that that much noise was all right. This caused an interesting reaction. Five or six of those voting for more quiet became very uncertain, and some changed their vote. Perhaps it had not been too noisy after all. I wonder how many answers in school are calculated to agree with the teacher.

March 13, 1969

Today something happened that reinforced my feelings about relevance and discipline. Tony Searcy, a black student at Caltech working with the Research Center, taught the class, and I observed. As he walked in, he had an immediate rapport with the kids, troublemakers and all. The boys were excited that he had a natural comb like theirs, and he was relevant to them. He spoke their language.

They spent the time talking about what soul is. I was relieved and encouraged that they accepted me without question, and several wanted me to help them with the meaning of soul. Their answers were good. "Soul is holding hands and dancing. Soul is I'm black and I'm proud. Soul is together. Soul father, soul mother, soul grandmother." I was convinced that the students aren't intrinsically troublemakers. They aren't uninterested; the material in school is uninteresting. Something is wrong with our presentation.

"Now I wondered—how in hell are we going to show that an ant breathes?"

That was the end of Phase Two. Tony taught one more day, and I left for spring vacation. While I was away, the regular teacher returned and kept a firm control on the class.

April 10, 1969

By the time I returned, the third graders were interested in the microscopes that our fifth-grade class had been using. I promised that we could use them today, and then found out that they had all been taken back to Caltech. One small dissecting microscope was left, and we spent the day looking at hands, paper, pencils, and so on. They continued to play the games with molecules, build the models, draw, and look at *Scientific American.* Arguing and running around have shown a remarkable decrease.

April 16, 1969

With enough microscopes now available, I introduced the concept of cells to the class. Then we looked at onion skins, cork, hair, and pieces of chipped paint from the wall. Except for the paint, the class did not suggest new things to look at, but they seemed to enjoy this activity.

April 17, 1969

Today I learned that I was at a dead end. I had assumed that the concept of a cell was both important and interesting. I am not sure of either.

The exposure to the microscopes was probably good, especially since they had asked for it, but I definitely think that I shouldn't have said anything about cells before they had seen them. They could have asked about them if they noticed. As it was, where was there to go? I told them that they would see cells in some things, and they did. Big deal.

April 23, 1969

I introduced two new activities today. I left about 20 batteries, light bulbs, wires, and switches on a side table, without saying anything about them except that they were available, and I wired one simple circuit. From then on the electricity table kept many kids interested for hours.

Following an idea developed in our fifth-grade class, I brought in a tape recorder. The teacher helped operate it, and the kids were encouraged to tape stories about science so that we could write a science book.

April 30, 1969

Many are interested in the batteries and wires. One boy just likes to short a battery out and hold it while it heats up. Perhaps he will ask why. Another boy was fascinated by a switch he had made. He could turn the light off by connecting up a new wire. This shorted it out, and he ran to me to show me.

A few like to look at the *Scientific Americans* that I bring in, and a group of girls consistently plays with the models. Once I showed them a ring structure, and they built several others with different atoms. It is hard to pinpoint what they are learning. Sharing is still a big problem. If I haven't brought enough of something, it usually disrupts things a bit.

Today I brought in a five-ball pendulum, of the kind that is popular now. They liked it but didn't ask a lot of questions. I showed them my favorite modes, and they invented a few new ones themselves.

My function has become to walk around between the various activities, ask questions, answer questions, and join in the activities. I often make deals with students who haven't found an activity. I tell them that they can ask me any question that they like, or I will ask them a question. With one group of three, I described respiration using models of O_2 and CO_2. Then one of them explained it to a fourth person.

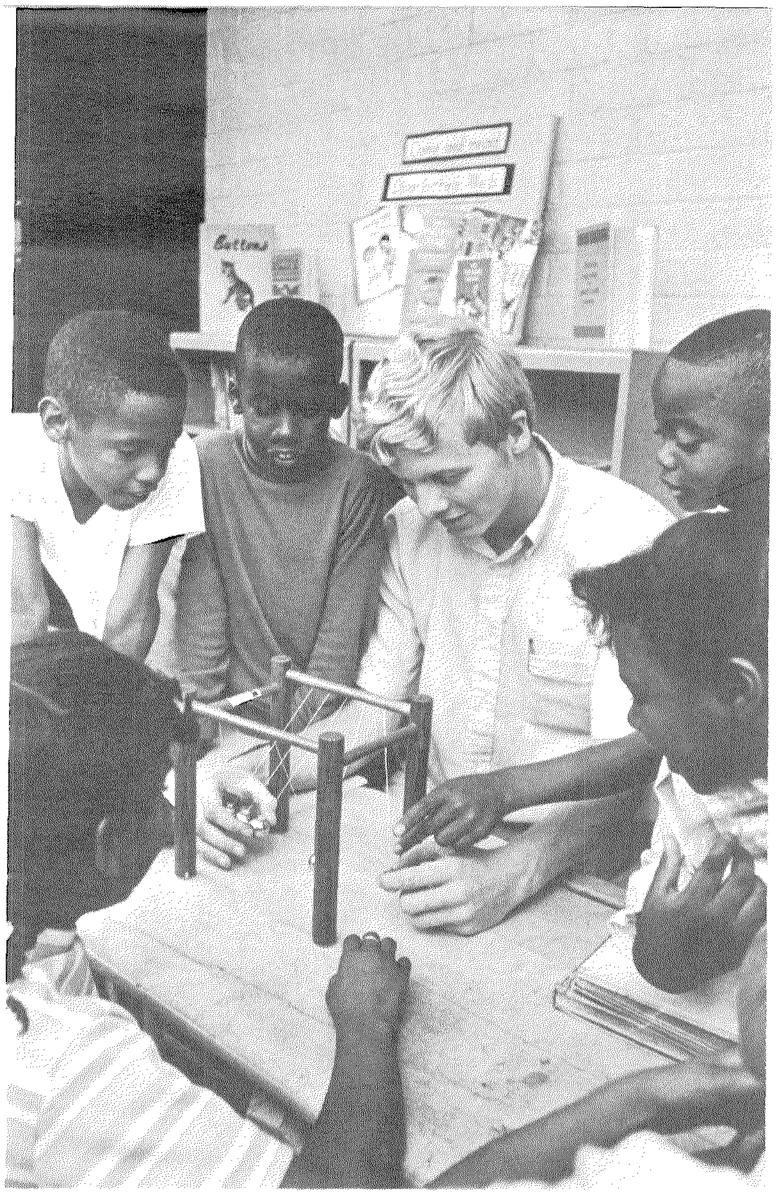
May 1, 1969

Today one of the very shy, quiet girls asked me to help her record a story. To find some topics we looked at the current *Scientific Americans.* She became interested in the pictures and asked some questions. The teacher told me later that she had shown very little interest in anything before and that the tape recorder was a help. A group of three boys hammed it up with a trio version of "Grapevine" at the tape recorder also.

May 5, 1969

I tried to get a group to play a game illustrating how the batteries and lights work. They were to role-play the electric circuit. There were batteries, lights, wires, and electrons. While in theory the game was good, it needed some refinement. First of all, wires should be lines on the floor, and not be played by kids. To be a wire requires standing still, holding hands in a line, while batteries are pushing electrons around. This required a little more restraint than our wires had.

After this class, the pressures of setting up our Summer Institute [page 38] took me out of the classroom. That ended my experiences teaching in the third grade.



One conclusion I came to as a consequence of trying to be a creative teacher is that exposure to the problems of education is a valuable experience for Caltech undergraduates, relevant and important to their professional training.

Many Caltech undergraduates eventually become teachers. Most become teaching assistants as graduate students, and many continue to teach in universities and research institutes. As it is now, they are not confronted with the idea of teaching a group until, as teaching assistants, they are suddenly faced with a section of 20 undergraduates. In this situation, many of them begin teaching in the same manner that they were taught. A TA may do this even if it was completely inadequate for him as a student, because it is familiar, and perhaps easier.

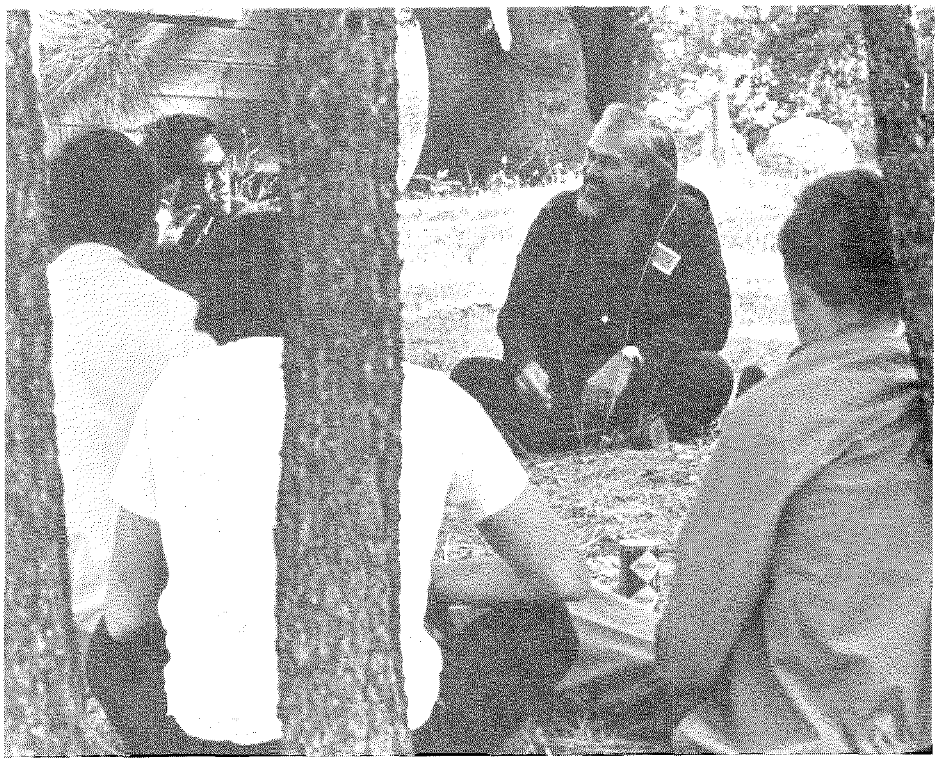
While there may be better ways for him to teach, the pressure of an undergraduate section keeps him from trying other ways. If he is given an opportunity to confront the problems of education before this time, he may become a more dynamic, self-assured teacher, open to change. This is an important part of a Caltech education that has been overlooked.

The questions I was forced to ask about third graders are in many cases the same as those being asked in setting up the experimental biology curriculum at Caltech and in the committee that is reviewing it. In addition, several techniques that I used in the third grade were later used with some success at Caltech. In some ways, an elementary school is an ideal place to develop techniques. Third graders are honest. They do not hesitate to ask, "Are you nervous?" or "Why do you talk so much?" This kind of honest feedback is valuable, and often lacking in a college classroom.

Many of the problems in our schools seem to stem from a manpower problem. Teachers teach unimportant facts to uninterested students as a way of coping. To let the students lead, and switch from facts to creative thinking and learning to learn, a teacher must be confident enough to follow and experienced in both creative thinking and self-education. He, then, can set up the conditions for the students to experience problem solving, experiment with new approaches, and learn to learn.

Universities represent a great untapped potential for public schools. Business and industry are also untapped resources. If the education and experience within these resources were available to the schoolteacher, he could teach the things that he enjoys and act as a coordinator for the other community resources.

The Summer at Caltech



New master of student houses David Smith with some of his charges at New Student Camp.

At Last -- Women

Some traditions die hard, but as Caltech's oldest enters its last year, there is little distress on campus. Beginning next spring the faculty committee on freshman admissions will be interviewing bright young ladies along with the men, and in the fall about 25 women—freshmen and transfers—are expected to enter the Institute. They will be followed in 1971 by another 25, and by 1973 there should be about 70 women undergraduates.

Caltech's trustees approved the admission of women "in principle" a year ago, but wanted to see a definitive plan before giving final approval. On October 6, 1969, they saw the plan and gave their unanimous consent. Surprisingly, women undergraduates can be integrated into the all-male community with little difficulty—at least on paper.

They will not live in a separate dormitory as was contemplated originally, but are taking over adjoining sections of Dabney and Blacker Houses. Each of the women will be a member of one of the two houses. Their quarters are going to be refurbished next summer as the first step in the eventual rehabilitation of all four old student houses.

The coeds will be counseled by the usual advisers and deans, and a woman adviser will probably be hired part-time for personal and career counseling. In the athletic department the women will displace the visiting teams in their locker rooms; Caltech's opponents will have to share the main locker room.

Meanwhile, the admissions office is busy advising high schools all over the world that the last barrier is down; Caltech is out to get its best freshman class ever in 1970.

Growing Up with Smith

The Olive Walk office of the master of student houses has a new occupant this fall—David R. Smith, an associate professor of English who joined the Caltech faculty in 1958.

The master is responsible for "the

quality of the non-academic life" in the seven undergraduate residence halls, and Smith wants to work with students on a long-range program to make the houses more civilized places in which to live. "Not," he emphasizes, "that I expect to outlaw fun or to institute fingernail inspections, but the raunchiness that turns up now and then reminds me painfully of situations in *The Lord of the Flies.*"

Smith hopes improvements can take place by "self-directed change, possibly through the formation of a kind of free university within the houses where students would have the chance to try out some of the changes they seek in the Institute."

The existence of a Master's Fund makes it possible for Smith to underwrite some special projects. For instance, on November 5 Blacker House will begin a series of seminars in "role-playing" led by actress Nina Foch and by Ian Hunter, the new Institute psychologist.

For those houses with particular interests in music, Smith plans to invite some of southern California's small but good groups to give house concerts.

He would also like to provide art seminars for the houses—aimed not only at aesthetic appreciation but also at a knowledge of technique.

A really long-term plan for the houses is to mix men and women undergraduates and graduates into all of them. Perhaps some day there may even be research fellows and an apartment or two with married students in residence. This kind of change presupposes a decision to make all 11 student houses—seven undergraduate and four graduate—into amalgams of age and gender groups. Though each might still keep a particular balance and individuality, they all would become less fraternally oriented and more creative centers of residence.

Smith's appointment climaxed several months of shifting names, titles, and personnel in official Caltech faculty-student relations. Several months ago Lyman Bonner, associate in chemistry, was appointed to the newly created position of director of student relations; Robert Huttenback, professor of history and for 11 years master of student houses, became dean of students; and David Wood, professor of materials science, was made associate dean of students.

New Duties

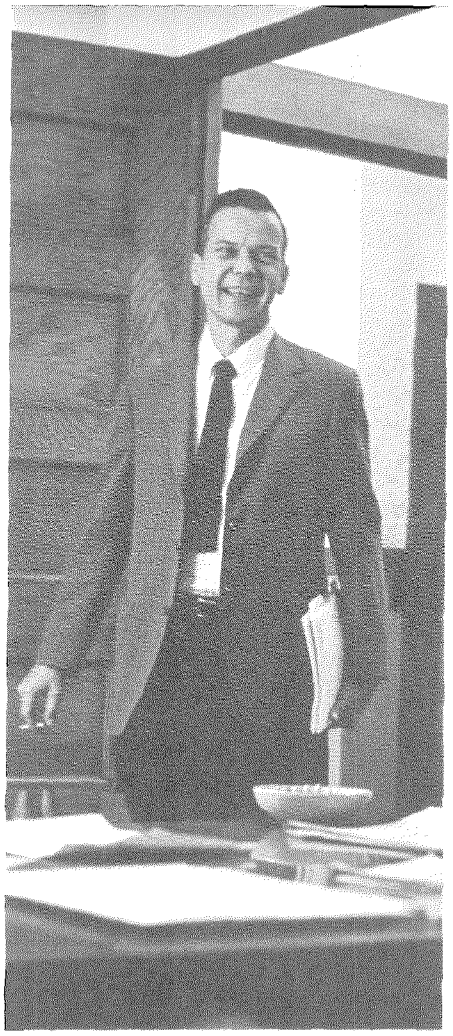
Cornelius J. Pings, professor of chemical engineering, is the new executive officer for chemical engineering. He will assist division chairman George Hammond with faculty appointments, student counseling, and department budgets. Pings is the Institute's seventh executive officer. The others: Robert Christy, physics; Norman Davidson, chemistry; David Elliot, humanities and social sciences; Jesse Greenstein, astronomy; Marshall Hall, mathematics; and Ernest Sechler, aeronautical engineering.

"My job is to help Dr. Brown make more efficient use of his time." Since Brown is already spending more hours at his desk than just about anyone, that responsibility should keep his new executive assistant, Hardy Martel, hopping. Martel, associate professor of electrical engineering and also secretary of the faculty for the past eight years, will spend about three-fourths of his time at his new job and will continue to teach an undergraduate course in electronics.

The extent of his new duties is still nebulous, and Martel is the first to admit that a clear description of his job is impossible. He does anticipate much "fact-finding," and he'll handle the follow-up on many of Brown's meetings.

Brown wants an open door policy with students, faculty, and administrators, and, having invited all that activity, he wants the extra eyes, ears, and mind of an executive assistant.

Martel, son of the late Romeo Martel, a Caltech professor of structural engineering for 42 years, received his BS from Caltech in 1949 and his PhD in 1956. He has been on the faculty since 1953.



Hardy Martel

Alexander Kosloff

Alexander Kosloff, 67, part-time lecturer in Russian at Caltech since 1955, died in Mexico City early in September. Kosloff was also an associate professor and head of the Slavic studies department at the University of Southern California.

Trustee

Stanton G. Hale, president and chief executive officer of Pacific Mutual Life Insurance Company, was elected to Caltech's board of trustees in June. Hale entered the insurance business as a salesman for Mutual of New York where he later became vice president in charge of sales and finally senior vice president. In 1963 he joined Pacific Mutual in Los Angeles and was named chief executive in 1967.

Honors and Awards

Harry B. Gray, Caltech professor of chemistry, has won the $2,000 Award in Pure Chemistry for 1970 from the American Chemical Society. The award, given annually to chemists no older than 35, for fundamental research, recognizes Gray's contributions to the understanding of complex and unusual compounds containing transition elements such as rhodium, palladium, and platinum.

He is also known for his studies of iron- and oxygen-containing proteins and polymers, and for his description of the electronic and structural configuration of the transition elements and their reactions. Gray, who in 1961 was the youngest full professor ever to teach at Columbia University, is the chairman of the freshman committee on the Advisory Council of College Chemistry of the ACS, and is the associate editor of *Inorganica Chimica Acta.*

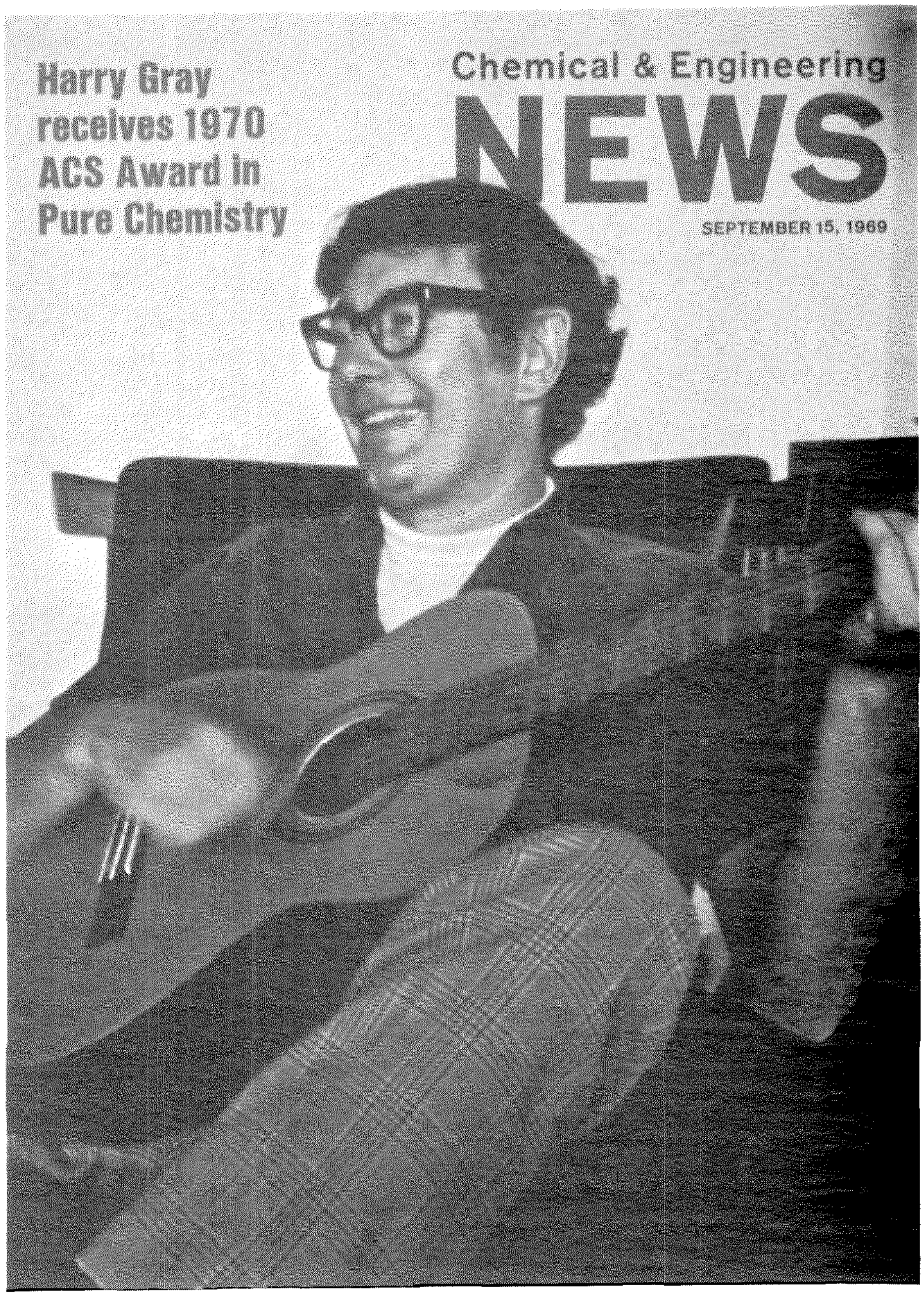
Previous Caltech winners of the award are Nobelist Linus Pauling and John Roberts, both former chairmen of the division of chemistry and chemical engineering.

The American Chemical Society's annual $2,000 Award in Colloid Chemistry will be presented next May to Jerome Vinograd, Caltech professor of chemistry and biology. Vinograd's studies in submicroscopic particles have verified the existence of "circular" molecules, combined in chain-link structures. In isolating these molecules he also contributed significantly to the study of nucleic acids, viruses, and proteins.

The $25,000 Louisa Gross Horwitz Award was presented on October 8 to two microbiologists, Caltech professor of biology Max Delbrück and Salvador E. Luria of MIT. Given annually since 1966 by Columbia University, the prize was split between the two men in recognition of outstanding research in biology.

Both are credited with work leading to the birth of the Phage Group of scientists whose prime interest is the study of bacteria and viruses. Delbrück was the first to discover genetic recombination in a phage, a cell that destroys other cells; Luria discovered mutations in viruses.

Delbrück donated his $12,500 share of the prize to Amnesty-International, an organization devoted to helping obtain freedom for political and religious prisoners throughout the world. He said that "If society expresses its debt to scientists by happenings like the present [award], it seems to me that the scientist might as well express his debt



Harry Gray

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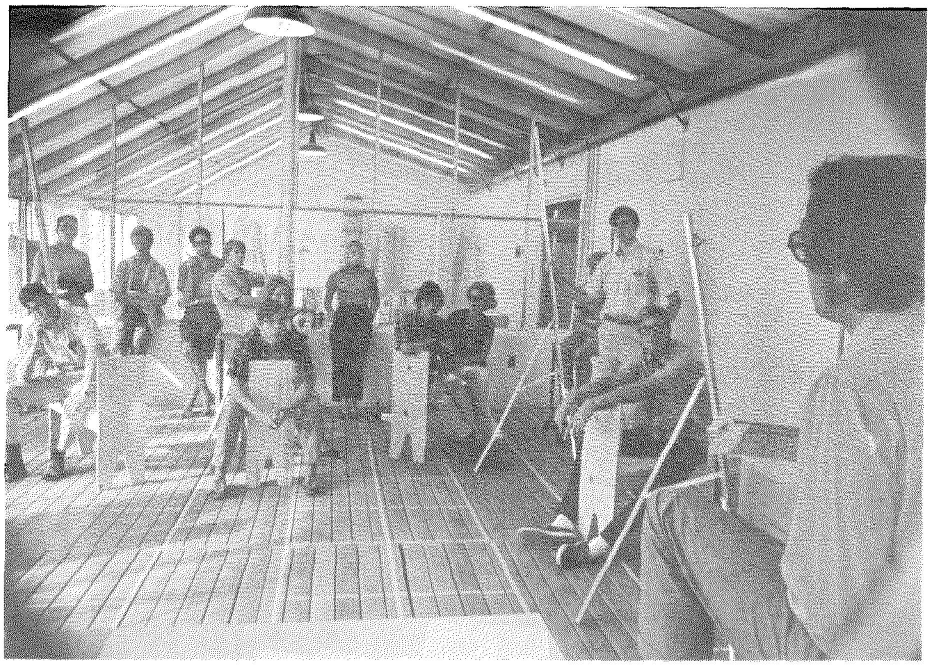
to society, which permits him the pursuit of truth in a life exceptionally free of the constraints put upon most of its members. In my case I feel I owe my life as a scientist to the fact that I did not remain in Germany during the Nazi days to participate in one form or another of the German resistance. Many did and paid with their lives. It is in memory of these prisoners of conscience, and as a debt to all prisoners of conscience that I wish to support Amnesty-International. The pursuit of truth is a many-sided thing. Science is one of them."

Provost Robert F. Bacher has been elected president of the International Union of Pure and Applied Physics.

Ian Campbell, research associate in geology, is recipient of the 1969 American Federation of Mineralogical Societies Foundation Award.

Hans W. Liepmann, professor of aeronautics, will receive the 1969 Worcester Reed Warner Medal of the American Society of Mechanical Engineers for his contributions in gas dynamics and turbulence.

Wallace L. W. Sargent, associate professor of astronomy and staff member of the Mt. Wilson and Palomar Observatories, will receive the Helen B. Warner Prize of the American Astronomical Society for significant contributions to astronomy before the age of 35.



Lukas van Vuuren meets with an art class in the converted Earhart Plant Laboratory.

Greenhouse Art

Art joined technology at Caltech this fall as artist-in-residence Lukas van Vuuren opened an art workshop in the vacant Earhart Plant Research Laboratory. Van Vuuren, who comes to Caltech from Scripps College, has begun a three-year stay as head of a broad art program for interested students and staff.

Van Vuuren is enlisting other southern California artists to help him teach both traditional and experimental forms of the visual arts. Classes are being given in the methods and materials of drawing, painting, and sculpture.

In addition, he is encouraging students and faculty to generate new art forms through the application of technology. As examples, he suggests such works as laser-holograms for organic sculpture, photo-cell-activated light shows, computer-generated films, or flying sculptures. Van Vuuren, a member of Experiments in Art-Technology, an organization of artists and engineers, is currently working on "environments" in which the art forms can be heard and touched as well as seen.

The opening of the art workshop is the first objective of a larger art program supervised by Van Vuuren and the faculty committee on art, headed by J. Kent Clark, professor of English. In addition to the studio classes, seminars will be given in art history. Van Vuuren also hopes to establish a lending library of prints and open a campus art gallery where a Caltech art collection would be housed. He has already commissioned artist David Elder to begin a sculpture for the Millikan Library pond, and he intends to hold three exhibits of contemporary art work during the year.

The existence of technical facilities on campus and the adaptability of the Earhart greenhouses for art classes help defray the initial costs of the program, all of which are being met by funds from sources outside the Institute.

Plugging In

Caltech will soon be sharing its computers with faculty and students at ten other colleges in southern California. Using leased telephone lines and typewriter consoles like the 25 already in use at Caltech, the other schools will have direct access to the computing center almost 24 hours a day. The colleges are University of Redlands, the six Associated Colleges of Claremont, LaVerne College, California Lutheran, and Occidental.

Users will have a choice of the mathematical languages, like Citran and Fortran, and also Caltech's English-speaking Rapidly Extensible Language (REL). REL enables the computer to understand most English grammar—and even enables most English grammarians to understand the computer.

Help Wanted

Faculty committees have begun the search for successors to three Institute administrators. Robert Bacher, 64, provost since 1962; Carl Anderson, 64, chairman of the division of physics, mathematics and astronomy since 1962; and Hallett Smith, 62, chairman of the division of humanities and social sciences since 1949, are all looking toward retirement.

This year will probably be Bacher's last as provost. Anderson, due to retire from the faculty in 1971, will give up his administrative duties as soon as his successor can take over. Smith, whose formal retirement from the faculty is still three years away, will also step down as division chairman when the new person is available.

Moving Day

The scientific method has rarely been better demonstrated than in the following research report from Fred Anson, professor of analytical chemistry. The story also seems to have a distinct moral —but perhaps it would be best not to look for this.

One day last summer my students and I decided to move our "small" half-ton computer from a room on the first floor of the Gates chemistry laboratory to one directly below it in the basement. We agreed it would be foolhardy to submit the ancient Gates elevator to a burden this much above its posted weight limit. So our plan was to push the computer to the elevator on the first floor of the adjoining Crellin laboratory, take it down two flights to the sub-basement, and then push it across the ramp connecting Crellin's subbasement with the basement of Gates.

We took the door off our lab, pushed the computer out into the hall, and carefully guided it into the Crellin elevator. The computer, the students, and I then descended to the subbasement of Crellin on the elevator. Unfortunately, the elevator door in the subbasement of Crellin is four or five inches lower than the one on the first floor of Crellin. Our computer wouldn't come out.

Disheartened, but not undone, we decided to take the computer up to the *second* floor of Crellin—there being no connection between Crellin and Church on the first floor—and push it across the bridge to the large elevator in Church laboratory. We would then descend to the subbasement of Church, push the computer into the subbasement of Crellin and across Crellin sub-basement to the ramp connecting with the Gates subbasement, where the room we were headed for remained.

We arrived safely at the second floor of Crellin, found that this elevator door was just large enough to get the computer off, and began our trek to the Church elevator. When we were half-way there, I had a phone call and had to retreat to my office. I told my students I would meet them in the sub-basement of Church.

As I walked back to Church a few minutes later, a fire alarm was sounding, and as I descended deeper into the building, frantic activity became more and more evident.

In the subbasement, people were running around with mops, sand, and foam. At the end of the basement near the elevator, the computer stood underneath a 1½-inch water pipe out of which was pouring about 50,000 gallons an hour of thick, black sludge. This was going directly into the central processing unit of the computer.

My three students, covered with sludge from head to toe, had obviously encountered some difficulty. Professor Vinograd, whose ultracentrifuge apparatus was beginning to be threatened by the rising water, was unhappy. And six Caltech plumbers who had been called to try and stem the tide were also unhappy—but not unamused—as they went about their work.

As it turned out, my students, earnestly pushing the computer down the Church hall, failed to notice that the ceiling suddenly dropped a few inches, permitting the computer to clip off an automatic fire extinguisher valve at the pipe—thus unloading ten years' collected sludge from the building's fire extinguisher system onto our computer.

The plumbers eventually found the hidden valve by which it is possible to turn off the automatic fire extinguishing system in Church. After doing what we could to clean up the mess, we continued our journey to the Gates basement, only to discover to our now considerable dismay that the doorway between Church and Crellin sub-basements was too low for the computer to pass.

Thoroughly stymied, we pushed the computer back into the elevator of the Church subbasement (there now being no fire extinguisher valve in the way), went back to the second floor of Church, pushed it back to the elevator on the second floor of Crellin, took it back to the first floor of Crellin, pushed it back into the room we had left only five hours earlier, and began a two-day period of cleaning the sludge from the computer.

The muck inside the main power supply was aspirated by hand with great care. And to remove the last traces of sludge, individual circuit elements were taken out and washed by hand with distilled water—the theory being that this would leave the least residue. Hot air was then blown over the computer, and we finally got it dried. But, since its auxiliary equipment had already been moved down to the basement of Gates, we couldn't try the computer out until we managed *somehow* to get them together down there.

At this point we decided to call for more expert help, which arrived in the form of the Buildings and Grounds moving crew. These six jolly men arrived at 1:00 one afternoon. We told them we wanted to move the computer down to the room in Gates basement but had tried it once before without much luck. We thought they would bring in a forklift truck, carry the computer out on the porch of Crellin, then around on San Pasqual St., and back into Gates through the lower doors.

But the B&G men were not nearly as concerned as we were about the weight limits posted on the Gates elevator—or about the fact that the computer wouldn't fit. They simply removed a couple of safety devices temporarily, shot the computer onto the elevator, rode it down—overweight and all—to the basement of Gates, pushed it out, and within 20 minutes had it installed in the room we had spent 5 hours trying to reach two days before. We were impressed.

After hooking things up, we plugged in the computer, stood back, and turned it on. One relay whose coils had been thoroughly soaked blew up, and a few water stains remained on the power supply. We replaced the relay, and since then, the computer has never worked better. We are seriously considering washing the contacts with distilled water on a regular basis, but we have no future plans for moving the computer to any other room.

Research Notes

Rocks from the Moon

Caltech geologists now have 100 grams of the moon to study. Among the questions they hope to answer: When were the pieces formed? Do they represent an early time of the solar system? Do the earth and moon come from a common chemical pot, or are they genetic strangers? What effect do cosmic rays and the solar wind have on the moon's surface? What were the temperatures of formation of the moon rocks? What kinds and sequences of geological processes have taken place on the lunar surface?

The deadline for completion of these preliminary studies is January 1970, when the Caltech men will join about 140 other investigator teams in Houston to compare and correlate results.

Geology division chairman Eugene Shoemaker is the principal investigator of the Apollo 11 field geology program, and Caltech has three principal investigators in the lunar sample program. Gerald Wasserburg, professor of geology and geophysics, and Leon Silver, professor of geology, are determining the ages of their samples by studying the decay products of radioactive isotopes in them. Their work will provide dates for several geological events at Tranquillity Base and will give the first absolute age for the formation of mare material on the moon. Samuel Epstein, professor of geochemistry, is studying relative abundances of stable isotopes—particularly oxygen and hydrogen—to see in what way they differ from the abundances in rocks on earth. Collaborating with the three principal investigators are Arden Albee, professor of geology; Donald Burnett, associate professor of nuclear geochemistry; Clair Patterson, senior research fellow in geochemistry; and Hugh Taylor Jr., professor of geology.

Both Shoemaker and Wasserburg were

At a campus press conference where Caltech's three principal investigators explain how they will study their moon samples, three particles of lunar soil are shown briefly to photographers.

advisers at the Manned Spaceflight Center in Houston during most of the preliminary studies of the lunar material. Wasserburg helped design some of the hand tools (built at Caltech early this summer) that were used to handle the rock samples behind the biological barriers.

Out of the preliminary work in Houston came three significant results. First, abundant glass is present in the fine-grained parts of the lunar soil. The observed glass is formed both by rapid cooling of molten material and by strong shock in crystalline material. Some glass, produced by meteorite impact, was expected, but the large amount surprised most scientists.

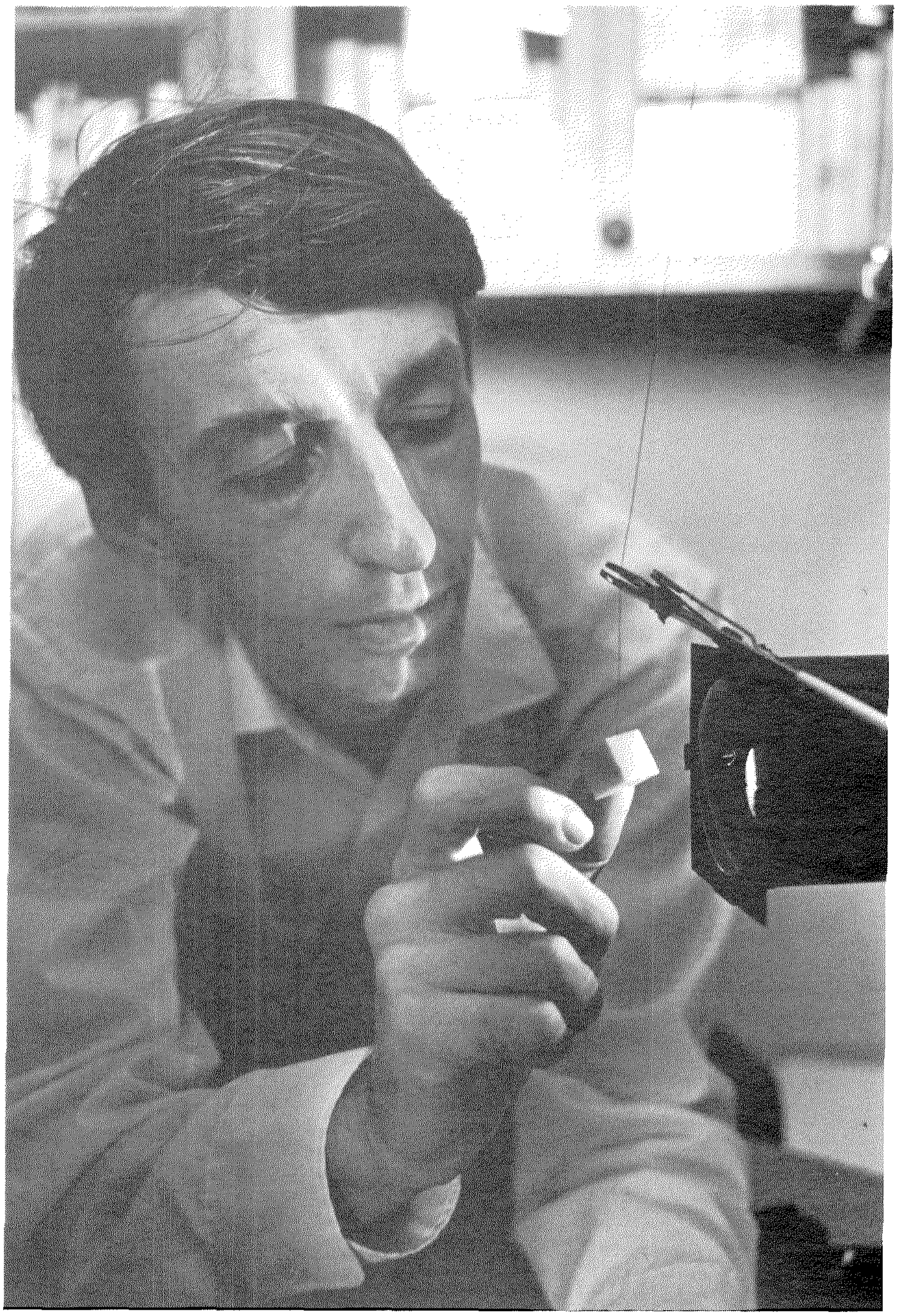
Second, many of the lunar rocks are very old—billions of years. Rocks of that age are rarely found on earth. This implies that the lunar surface at the landing site is old and has been relatively undisturbed over great spans of time.

Third, the fine material on the lunar surface is heavily impregnated with particles from the solar wind—a stream of hydrogen and heavier ions given off by the sun. Extraction of the particles from the lunar material will provide a direct determination of the isotopic composition of several elements of the sun's atmosphere.

Double Vision

Human vision apparently consists of two separate seeing mechanisms. A second process, one that transmits an elemental kind of vision from the eyes to the subconscious mind, has now been identified in man. This system, which probably works through the brain stem rather than the cortex, functions mainly for background and peripheral vision and for perception of peripheral movement. It helps a person make general spatial and orientational adjustments to his surroundings. These may occur at a subconscious level while at the same time the classical system for central vision is attending to focal identification and discriminatory functions.

Colwyn Trevarthen, a senior research fellow in biology, who works with Roger Sperry, Hixon professor of psychobiology, suggests that the primitive optic system allows a person to respond automatically to what's going on in the space around him. If something unexpected moves outside the central field of attention, it registers first through this second, more primitive system before the classical visual system becomes aware of it.



Biologist Colwyn Trevarthen uses a point source of light to project a cube silhouette on a screen used in testing peripheral vision, part of a second visual system.

Trevarthen says that this second visual system in man very likely is evolved from brain stem structures that comprise the main sight center for birds, reptiles, and lower animal forms.

The discovery has led him to propose a modified theory of the cerebral mechanisms for visual perception in which the two kinds of visual data arrive in the cortex through different nerve channels and interact to produce the completed perception at the conscious level. As with most other parts of the brain, these optic systems come in right-left pairs. Thus the brain has two pairs of seeing systems, one of each kind being located in each half of the brain. The better known "primary" visual system transmits only one half of the visual space to each half of the brain; apparently the more primitive system transmits both halves of space to each side of the brain.

The different functions of the two visual systems are difficult or impossible to distinguish under most conditions, but they become exposable as a result of a rare type of brain surgery used to treat certain types of epileptic seizures. Trevarthen and Sperry studied six people in whom the nerve cross-connections that link the two cerebral hemispheres had been severed. The process cuts off all mental communication between the right and left hemispheres, but does not significantly affect behavior of the subject under ordinary conditions.

Pieces of Smog

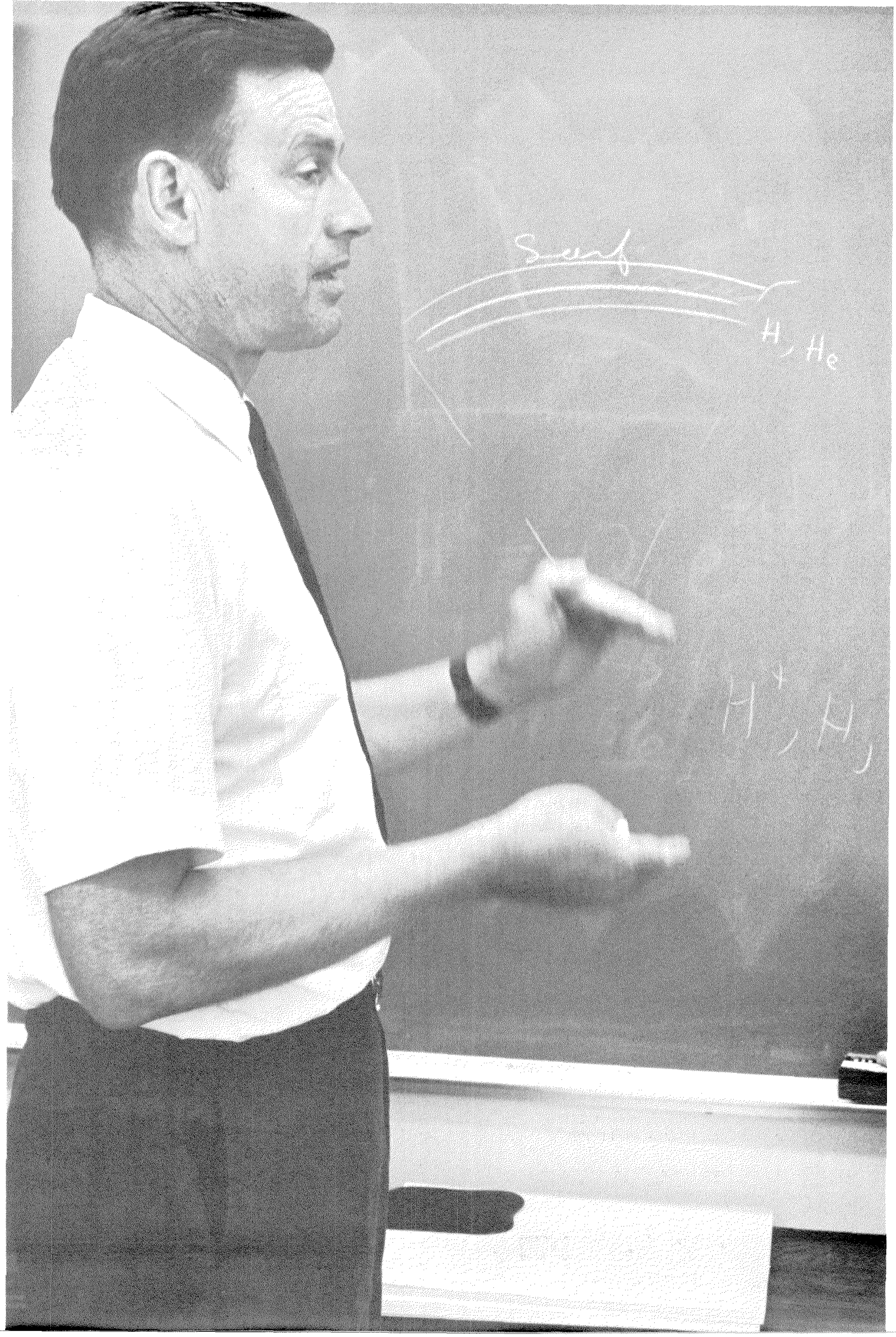
A great deal is already known about the gaseous components of smog, but comparatively little is known about the kinds and numbers of very small particles in it. These particles, or aerosols, are believed to have three negative effects: they reduce visibility; they carry toxic chemicals, such as lead, into the lungs; and they *may* modify weather. (Particles can serve as the nuclei on which water droplets can form, resulting in cloudiness. Some scientists blame air pollution, in part, for what they consider a gradual cooling of the earth.)

A group of engineers at Caltech, under the direction of Sheldon Friedlander, professor of chemical engineering and environmental health engineering, has begun the first combined analysis of gases and particles in the air. They are studying the relation of gases and particles to each other and the chemical changes that occur in them under the effects of sunlight and from contact with each other over a period of time.

The particles are being studied with instruments located in Caltech's W. M. Keck Engineering Laboratories. Air is collected through a plastic pipe that rises 22 feet above the roof of the three-story building. The instruments sort the particles in the air and count them by size, giving results every ten minutes.

With this technique, the atmosphere of the Los Angeles Basin is being analyzed on typically smoggy days as well as on some clear days. Sampling is occasionally done continuously for 24 hours to get a picture of how the chemical composition of smog changes with time and between daylight and night.

At the same time, Friedlander and John Seinfeld, assistant professor of chemical engineering, are developing a comprehensive mathematical model of Los Angeles Basin air. This, in combination with the results of the particle studies at Caltech and similar investigations being made in other parts of the country, will help experts make recommendations for improvement of the air in major industrial areas.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One of the Best

When a scientist like Robert Christy clenches his jaw and announces, "I can do it, dammit!" you generally see some fruitful results.

Robert Christy has always been a questioner of authority. Now that he has been elected chairman of the Caltech faculty for the next two years—a position of considerable authority—no one expects him to change his ways.

"If I'm involved in something," Christy says, "I like to understand the whys of it. So, in various Caltech matters, from time to time I have questioned authority simply because it wasn't clear to me why we were taking a certain course. From a faculty point of view, we should question the administration if we feel it isn't making something clear. It's up to the people running things to be able to explain. If no one can, possibly it's wrong."

The faculty—and the administration—should be in for an interesting two years.

Christy, a 53-year-old physicist, is not a man who invites familiarity. A general air of reticence, accentuated by an Olympian height and bearing, manage to keep most people a good arm's length away. But, though few feel an intimacy with him, no man is more respected.

"Bob is very much his own man," says a faculty friend. "But if I had a problem, there's nobody I'd sooner go to."

Christy came to Caltech in 1946 when Tom Lauritsen and Willie Fowler, continuing their prewar work in experimental nuclear physics, needed a theoretical physicist who was interested in their field. They asked Tom's father, Charles, who would be good for the spot, and he referred the question to J. Robert Oppenheimer, who promptly recommended Robert Christy as "one of the best in the world."

Christy's student and professional life has been characterized by the phrase "one of the best." He graduated first in his class from the University of British Columbia in 1935. After taking a master's degree in physics with a mathematics minor, he was accepted into Oppenheimer's group of graduate students at Berkeley.

At that time Oppenheimer was one of the few physicists in the world with a school in what is now called modern particle theory or quantum mechanics. It was a rare campus that was untouched in some way by the excite-

"Bob likes to get on with matters at hand, and he can be impatient with people who let problems float around."

ment generated by Oppenheimer and his students.

Christy was one of 20 in this talented group. The new concepts were intoxicating enough, but, in addition, Oppenheimer himself magnetized his students and even imprinted them to the point where they unconsciously absorbed his mannerisms—the way of walking, talking, gesturing, holding a cigarette.

Christy describes that master-student relationship as "an unequal friendship." The research students thought of Oppenheimer as larger than life, a superbeing. "Under such circumstances," says Christy, "students find it hard to acquire any real feeling of intimacy."

In the late 1930's, when Oppenheimer held a joint appointment at Berkeley and Caltech, Christy was one of the students who accompanied him to Caltech on two occasions to continue working in Pasadena during the summer months. This yearly migration prompted a Caltech mathematician to describe the group as "the mother hen and all the little chickens." During one of those summers the Oppenheimers occupied the Richard Tolman house at the corner of Michigan and Lura (now the residence of Provost and Mrs. Robert F. Bacher). Christy and another "little chicken" lived in the guest house, rent free except for occasional duty as rug beaters for Mrs. Oppenheimer.

Christy got his PhD in 1941 at the end of the depression, when even an Oppenheimer PhD found work scarce. He was elated to get an Illinois Tech job as an instructor at $2,400 a year.

At the end of that year an offer came to join the University of Chicago's Metallurgical Laboratory, the forerunner of the Manhattan Project. For a young scientist, this move meant progress toward the company of the great, which included not only physicists in this country but brilliant refugees from Europe as well.

It was obvious to everyone in the Laboratory that one of the ultimate results of their work could be a super bomb. But Christy, as a fledgling scientist—and he suspects this was true of the other young physicists—focused all his attention on the immediate objective of accomplishing a self-sustaining nuclear reaction.

"The ultimate goal of a bomb was far in the background so far as we were concerned," he recalls, "although of course this was not the case with the project leaders."

The work in Chicago culminated in the world's first self-sustaining nuclear reaction on December 2, 1942. A few months later Oppenheimer invited Christy to Los Alamos to work on the atomic bomb project, and in March 1943 he and his wife, Dagmar, were among the first to arrive.

"We got to Santa Fe before there were any places for us up on the Mesa, and for a few weeks we lived in a former school building filled with double-deck bunks for incoming scientists and their families. You just crawled over bodies at night until you found some vacant bunks."

During this period he met Richard Feynman, a fellow bunk-crawler. Later, when Christy was responsible for analyzing implosion calculations, Feynman organized and expedited them on the extremely crude computing machines that followed the effect of a spherical explosion on the material within.

Christy stayed at Los Alamos until 1946, then joined the University of Chicago faculty. During their short stay there, the Christys and the Edward Tellers shared an old rented mansion, which became an impromptu hostel for a whole string of physicists and their families coming through Chicago from Los Alamos.

At Caltech, as Fowler, Tom Lauritsen, and their group became acquainted with Christy, they marveled at his ability to do experimental work and to work with his hands. In fact, they sometimes referred to him as the "housekeeper."

"I wouldn't give most theoretical physicists a paper clip," says one of the old group, "because they'd hurt themselves. But Christy's amazing. He's even built a swimming pool. And he can do all kinds of complicated work around his house—not as a hobby, mind you, but as a challenge. If something breaks down, he'd rather fix it than have to say he can't."

Jesse Greenstein observes that when a scientist like

Christy clenches his jaw and announces, "I can do it, dammit!" you generally see some fruitful results. That, he adds, is in the best Caltech tradition.

In 1961 Oppenheimer, who was now director of the Institute for Advanced Studies in Princeton, asked Christy to spend a year there. Towards the end of his stay, he was asked to give a seminar on the work of Fowler's nuclear astrophysics group at Caltech. Having been away from the Kellogg lab for almost a year, Christy thought he'd better read up for the seminar. In doing so he came on a well-known astronomical puzzle that had been kicking around for almost 50 years. It had to do with how some types of stars vibrate.

"I found a solution I thought might work," he says, "and the nature of the computation was related to those I'd been familiar with at Los Alamos. It was a calculation never applied to a star before. What struck me was that this kind of calculation would enable one to follow, in great detail, what went on in a spherically vibrating star. If I could follow it in enough detail, I might be able to see whether the particular mechanism I was interested in would actually make the star vibrate."

If he hadn't been at Los Alamos, Christy wouldn't have known that the problem could be worked out by computer. The only hitch was that he had never confronted a computer.

He started with an hour's lesson on the basics from a computer man at Princeton, got the hang of doing simple problems, then started a growing and sometimes frustrating relationship with computers on his return to Caltech. He became increasingly immersed in astrophysics, and five years later he had solved much of the mystery of the variable stars. In 1965 he was elected to the National Academy of Sciences, and in 1967 he was awarded the prestigious Eddington Medal of the Royal Astronomical Society of London for his calculations.

"It's characteristic of Bob that he has developed such beautiful computer programming," Fowler says. "He's helped all the rest of us, teaching us about the efficient and economical use of computers. He has raised the general level of their use at Caltech tremendously."

The bundles of computations stacked in Christy's top floor lair in the new Downs physics building today are a symbol of only one part of his contribution to Caltech. He has been on the faculty board, the academic policies and the academic freedom and tenure committees, and more recently was a member of the presidential selection and the aims and goals committees.

He is considered by his peers to have, as one division chairman describes it, "a marvelously independent, incisive, and adventurous mind."

Last year he became executive officer for physics, and since then he has been conferring with other physicists, trying to get some idea of what the future of research and teaching in Caltech physics might be.

As a teacher Christy is as demanding as any, but he has some doubts about Caltech's—and particularly the physics department's—rigorous required courses.

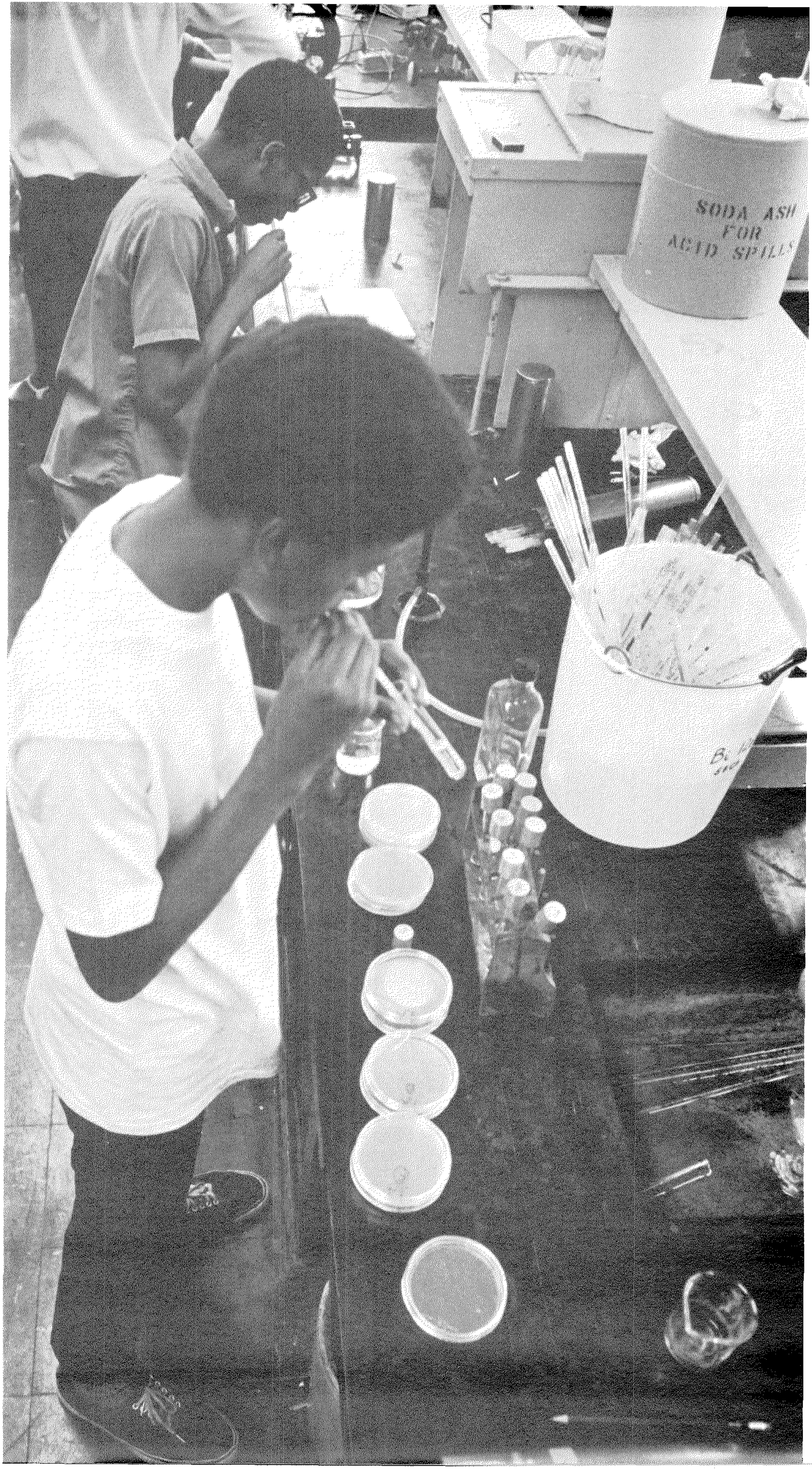
"Our freshmen and sophomore 'Feynman' physics courses are too difficult for many of our students. We shouldn't force all our students to take this very advanced and beautiful—but bewildering to some—treatment of physics.

"What's most important in education is not what you force the student to do, but what you can get him enthusiastic about doing on his own. If we sacrifice some of the formal course content doing this, I wouldn't consider it a serious loss."

In 1967 Christy spent six months at Cambridge University, partly to see how a good school in another country operates. He came back feeling that some aspects of the Cambridge tutorial system should be introduced at Caltech.

"They seemed to have less trouble than we do with students who lose interest and give up working. Students can get a tremendous education at Caltech if their interest doesn't flag. But too many of them give up. I don't think we're treating this kind of student right. They're not getting out of Caltech what they should."

Christy, dissatisfied with some kinds of instruction at Caltech, is not likely to turn his back on the problem. Jesse Greenstein observes that "We faculty members are a diverse, splintered, individualistic bunch, and we have a tendency, sometimes, to deal with a problem by tossing it to a committee and hoping that it'll give up and go away. Bob likes to get on with matters at hand, and he can be impatient with people who let problems float around. In the next two years we may all get more done than we bargained for."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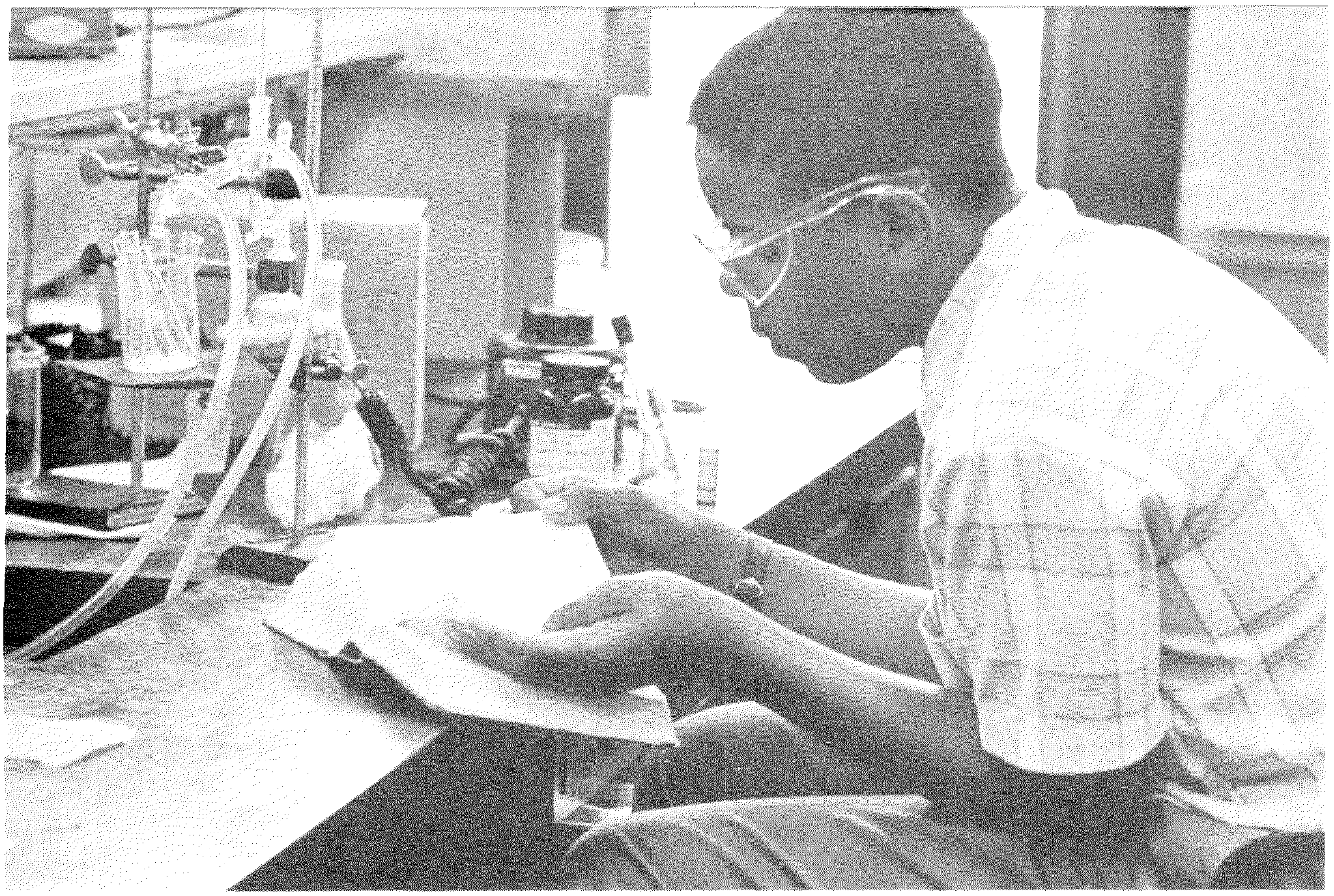


From Dancing Bees to Urban Housing—A Diversified Summer

Students and faculty attack some greater (and lesser) problems

High School Science Students

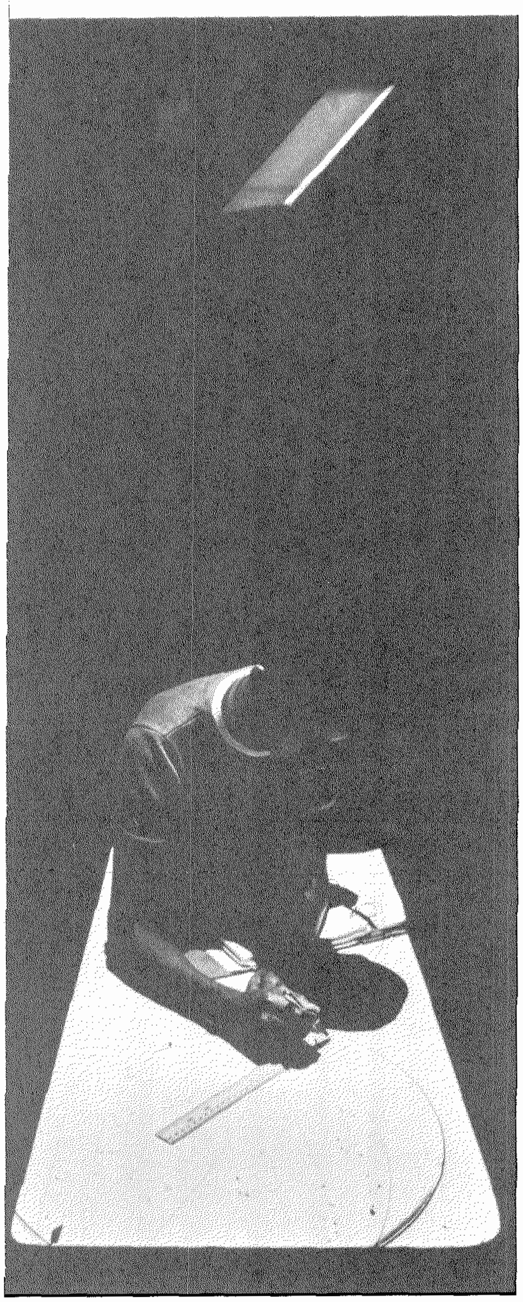
In one of seven special projects at Caltech this summer, ninth graders spent mornings helping in faculty labs, then worked in their own free labs in the afternoons. The program was aimed at identifying and interesting bright young minority students in science.

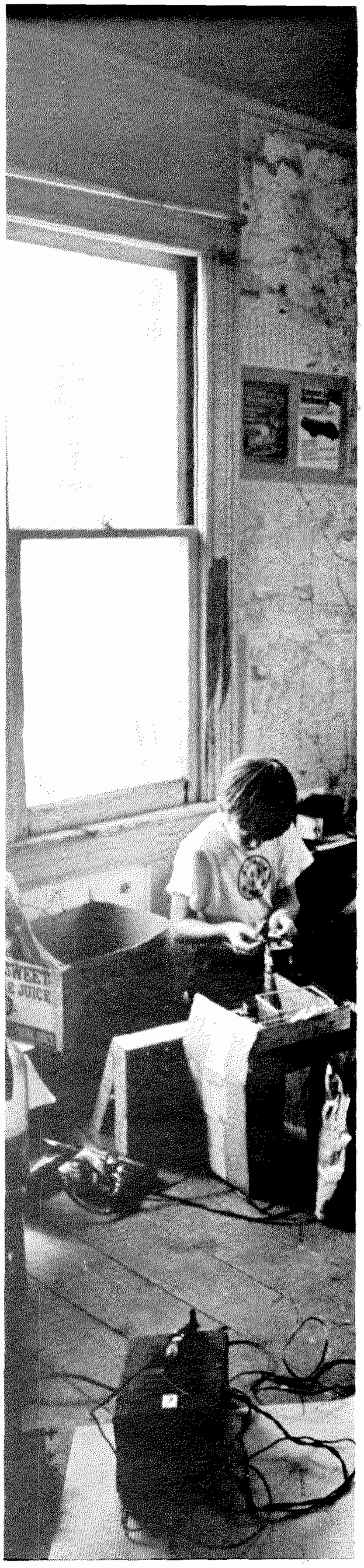
Summer used to be the quiet time at Caltech. A few dozen undergraduates got jobs in campus labs, but the other 700 took off for home while faculty and graduate students, free of classes for three months, busied themselves with research. But those lazy summer days may be over for good.

In 1968 the undergraduates discovered a new way to find summer jobs—they got a government grant to conduct their own research on campus. That year 60 students from Caltech and other colleges converged on Pasadena to study air pollution. This past summer there were seven separate student research projects on campus, involving more than 400 people, including about 50 Caltech undergraduates.

Five of the projects were initiated and managed by the students themselves through their ASCIT Research Center. One, Man and His Environment, was a continuation of the 1968 project, which this year grappled with problems of off-shore oil pollution, lead pollution, methods of public action against them, and hillside erosion. This group, with 45 people, was funded by the National Science Foundation and the Ford Foundation for about $46,000.

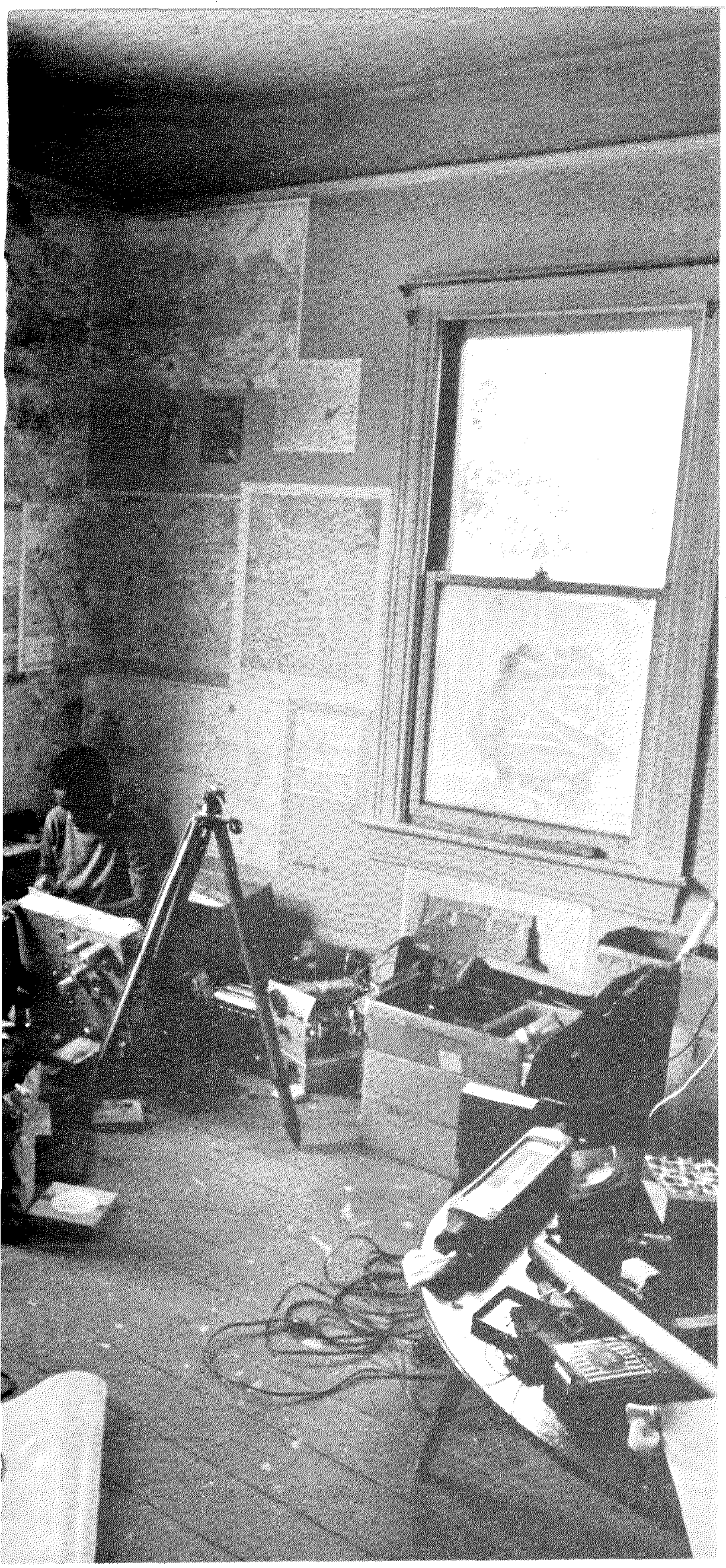
Three small programs were funded directly by the Research Center, which limits its own grants to $500. Six students camped out near Burns, Oregon, to "live with" and study a hive of bees. They hoped to make some

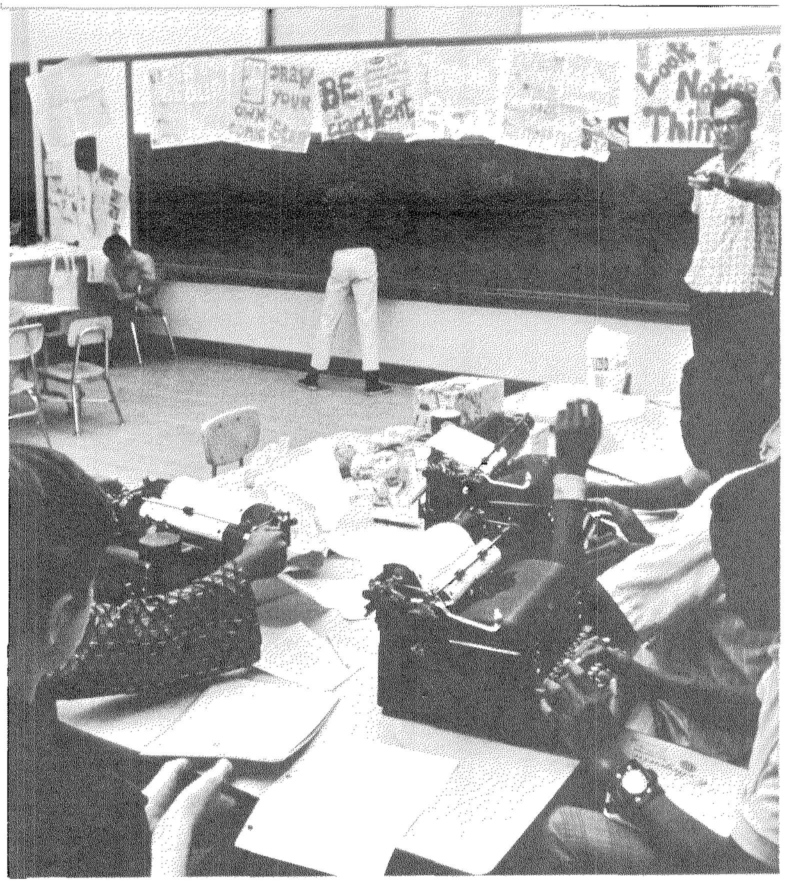




High School Science Students

24 boys lived on campus during the eight-week summer "science camp." Caltech faculty ran the successful project, which has now been extended into the fall.





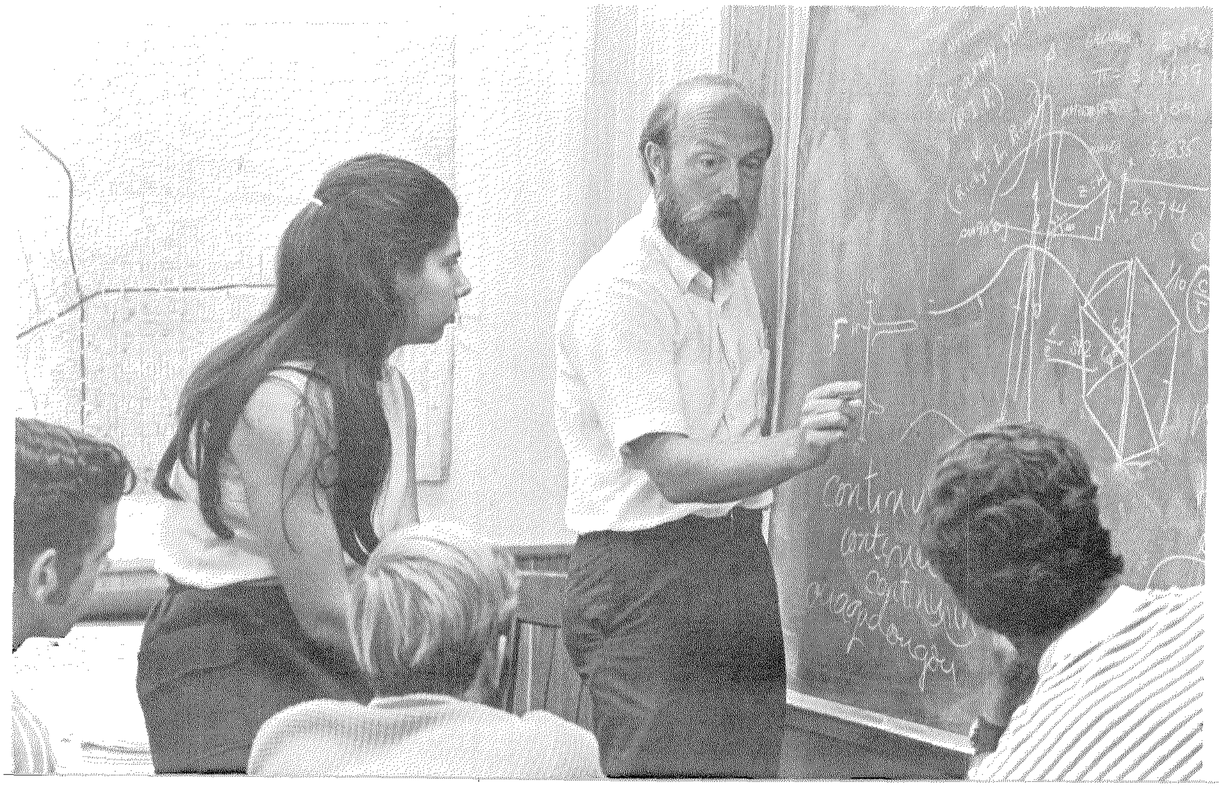
Institute for Educational Change

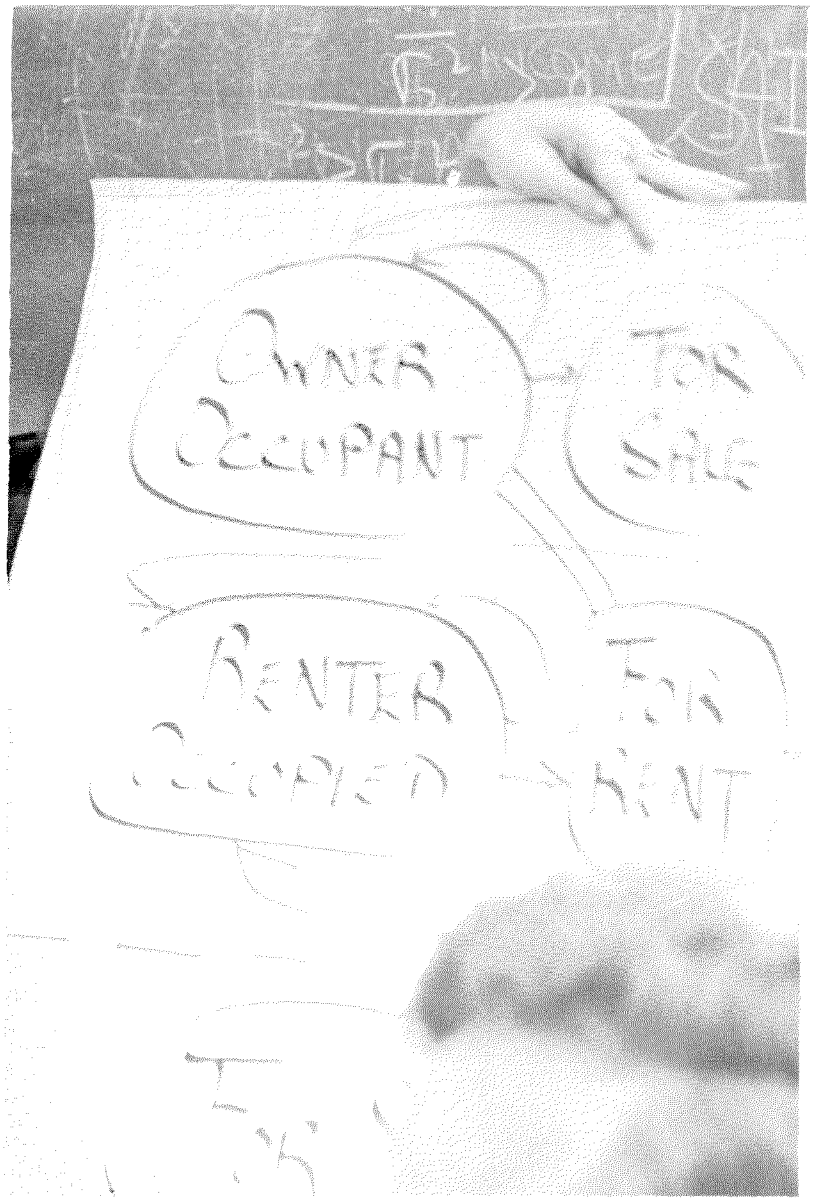
In the summer's biggest project, students working through the ASCIT Research Center brought together *200 schoolchildren and 100 teachers and older students* for an experimental summer school. Most of the activity took place in a northwest Pasadena school and several empty houses near there.

sense out of the dances that bees do to direct other bees to food supplies near the hive. The Research Center also sponsored two local high school students in a study of the photochemistry of lead, and it helped finance a three-man investigation of a possible overseas study program for Caltech students.

The Research Center's Summer Institute for Educational Change seemed to attract most notice. Spurred by the work of Gregg Wright and others last spring [see page 18], 40 college students, 20 teachers, 30 high school and junior high students, and 200 grammar school students comprised an experimental summer school at Pasadena's Cleveland Elementary School.

For the two weeks before and after the five-week school session at Cleveland School, the 90 staff members met at Caltech for planning and evaluation. The junior high students, who were being paid by the Neighborhood Youth Corps to take part in the program, apparently had too little to do and, as a result, made their presence well known around campus. Complaints—mostly of noise and horseplay—came from diverse quarters, and tended to unduly influence non-participants' views of the program.





Urban Studies

In a JPL program on campus, engineers and college students, using a systems analysis approach, tried to devise a dynamic model of urban housing to see how technology might be applied to social problems.

The staff learned a few lessons—particularly that teenagers had better be kept busy, and that permissiveness has its limitations. The children benefited too, and learned some journalism, sewing, African history, simple auto mechanics, music, and even cinematography. The Summer Institute was funded by the Department of Health, Education, and Welfare, by the Rockefeller Foundation, and by private subscriptions. The total amount spent was about $57,000.

The summer project that seemed to come closest to meeting the expectations of its planners was, not unexpectedly, organized and run by about ten Caltech faculty. Aimed at generating interest in science and engineering among minority students, this "summer school" took 24 ninth graders under its wing for eight weeks. A few of the students were high achievers from middle-class homes, but most came from culturally disadvantaged homes. All the students were bright, and most were black.

The 24, along with four counselors, lived in the student houses during the week and went home on weekends. Mornings they learned simple lab techniques and were paid a small stipend to work in various labs under the guidance of Caltech students. Afternoons they had their own free lab with a chemistry graduate student in charge. Off-hours were occupied with sports, games, hikes, movies, and short trips.

At the start of the summer the faculty leaders were prepared to continue the program into the school year if even a few of the 24 students were interested. At the end of the summer 23 students wanted to go on. It looks now as if the free lab will continue on Saturdays, and, to help the students improve their verbal skills too, informal evening seminars devoted to writing and readings in humanities will be held once or twice a week. The summer program, which cost about $14,000, was financed about one-third from Institute funds and two-thirds from friends of Caltech.

The seventh summer program was run and financed (almost $100,000) by the Jet Propulsion Laboratory; it employed students from Caltech and nine other colleges. Twenty people, including several JPL engineers, tried to apply systems analysis to problems of housing, particularly in Pasadena. The group got cooperation from the local poverty agency, Pasadena business groups, the city's planning department, and a few Caltech faculty experienced in urban affairs. One goal of this urban studies project was to explore new ways in which Caltech and JPL can use their skills to improve the community.

Although most of the summer's programs were categorized as research, not much new information was added to the body of knowledge. It would be more realistic to rate the work according to how much the participants learned about the job of doing research or teaching. By that standard, most of the people involved—who admit their share of failures along with the successes—are satisfied that their time was well spent.

Letters

EDITOR:

On page 12 of the June 1969 issue of *Engineering and Science* ("Nuclear Astrophysics—Today and Yesterday") I am identified as number 61 in the Caltech math and physics group of 1926. I am pleased that you are honoring my prodigious talents: I was 11 years old in 1926!

For the record, the picture is of my brother, Hervey C. Hicks, PhD '28.

BRUCE L. HICKS, PhD '39

Faculty Books

ATLAS OF SOLAR MAGNETIC FIELDS
By Robert Howard, Vaclav Bumba, and Sara F. Smith
The Carnegie Institution of Washington *$12.50*

The study of magnetic fields in the sun and stars has been one of the prime interests of the Mount Wilson and Palomar Observatories since Hale's discovery of sunspot magnetic fields 60 years ago. In recent years astronomers have become more and more aware of the importance of magnetic fields in channeling the otherwise unorganized energy of the stars into highly energetic and interesting phenomena.

The *Atlas of Solar Magnetic Fields* presents in an organized way the results of seven years of observation with the Babcock magnetograph on Mount Wilson. Although many other magnetographs have been built over the years, the Mount Wilson magnetograph under the direction of Robert Howard has been the only one in regular service recording the grand pattern of the evolution of magnetic fields on the surface of the sun. In addition to the intense fields in the sunspots, this instrument measures the widespread weak magnetic fields on the solar surface, which have a stronger effect on the interplanetary medium. The results of this work are presented here in a series of colored synoptic charts showing the appearance of the sun for a single rotation. Because only half the sun is visible at once and because there are many cloudy days, the observations have been laboriously filtered and reassembled to produce the synoptic charts. A set of charts showing sunspots and plages for comparison is included.

When Bumba and Howard first assembled these maps, they immediately discovered large regions of uniform magnetic polarity growing out of the remnants of large sunspot groups and spread out by the sun's differential rotation. Wilcox at Berkeley was able to find a strong connection between these regions and the magnetic structure of the solar wind and the interplanetary magnetic field. Thus we now have a unified picture for the magnetic field structure between the sun and the earth.

Although undoubtedly many new complexities will be discovered, the data are now available in this atlas for anyone to work with. The authors are to be congratulated on this great work and on making the data available.

—Reviewed by Harold Zirin, professor of astrophysics and staff member, Mt. Wilson and Palomar Observatories.

CHEMICAL DYNAMICS
By Joseph B. Dence '69, Harry B. Gray, George B. Gray, George S. Hammond
W. A. Benjamin, Inc. *$2.95*

Designed for use by college chemistry teachers, this small book reflects the belief of the authors that the study of chemical dynamics should be introduced at an early level. It is suggested as a conclusion to the introductory chemistry course for freshmen to balance the subject matter. Dence is now assistant professor of chemistry at Florida State University in Tallahassee; Gray is professor of chemistry at Caltech; Hammond is Arthur Amos Noyes professor of chemistry and chairman of the division of chemistry and chemical engineering at Caltech.

ADVANCES IN PHOTOCHEMISTRY VOLUME 5
Edited by W. Albert Noyes, Jr., George S. Hammond, and J. N. Pitts, Jr.
Interscience *$17.00*

This volume contains four separate papers written by experts and pioneers in the field of photochemistry, a field that has received increased attention over the last 25 years. Each addition to this series of books contributes stimulating ideas reflecting the changing frontiers of photochemistry. Noyes is a chemist at the University of Texas; Pitts is a chemist at the University of California, Riverside.

SEVEN COMEDIES BY MARIVAUX
Selected by Oscar Mandel
English versions by Oscar and Adrienne S. Mandel
Cornell University Press *$10.00*

The Mandels' translations of this 18th-century playwright's work succeed in capturing the spirit that has kept his plays alive for two centuries. Included are a biographical and critical introduction to the man and his work, a bibliography, and a record of first performances of all the plays. Oscar Mandel is professor of English at Caltech.

ORGANIC SYNTHESIS
By Robert E. Ireland
Prentice-Hall, Inc. *$6.95*

This is one of the few systematic treatments of organic synthesis available at the undergraduate level. Ireland attempts to teach by example, and the principles presented are illustrated through discussion of appropriate recorded syntheses. This volume is included in the publisher's Foundations of Modern Organic Chemistry Series. Ireland is professor of organic chemistry at Caltech.

SOIL MECHANICS AND ENGINEERING
By Ronald F. Scott and Jack J. Schoustra
McGraw-Hill *$8.95*

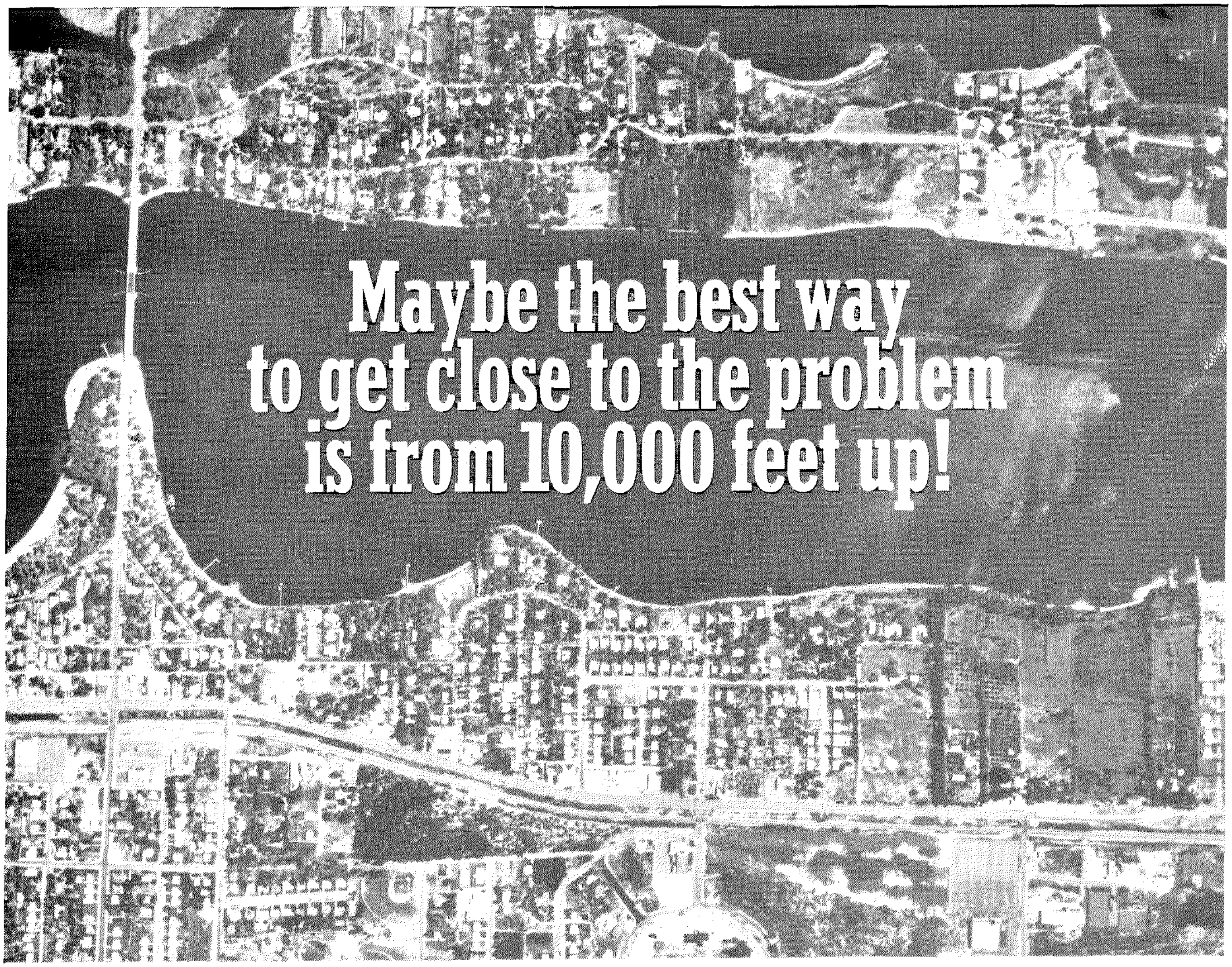
This short book was designed to fill the need for a text for practicing civil engineers, architects, and technicians who must deal with soil engineering problems. The format offers a systematic development of theoretical knowledge followed by practical applications. Scott is professor of civil engineering at Caltech; Schoustra is chief engineer, Converse Foundation Engineers, Pasadena.

TWENTIETH CENTURY INTERPRETATIONS OF THE TEMPEST
Edited by Hallett Smith
Prentice-Hall, Inc. *$4.95*

This collection of critical essays analyzes the influences, style, genre, structural elements, artistic influences, and historical background of Shakespeare's noted play. The interpretations range from the most allegorical to the most practical and theatrical and are evidence of the continuing diversity among scholars as to what the play means. Smith is professor of English and chairman of the division of humanities and social sciences at Caltech.

SOUTHERN AFRICA AND THE UNITED STATES
Edited by William A. Hance, with Leo Kuper, Vernon McKay, and Edwin S. Munger
Columbia University Press *$6.50*

Four authorities on Africa present here their assessments of the factors that bear upon U.S. relations with southern Africa. Despite the complex problems they uncover, the authors are agreed that the United States should stand by the principles supporting human rights and racial equality. Hance is professor of geography and chairman of the department of geography at Columbia University; Kuper is professor of sociology at UCLA; McKay is professor of African studies at the school of advanced international studies of The Johns Hopkins University; Munger is professor of geography at Caltech.



Almost everyone has seen an aerial photograph. But what isn't always seen is how to apply aerial photography as a tool for modern business. The key to this application is photointerpretation—the ability to pull amazing amounts of accurate data from aerial photos.

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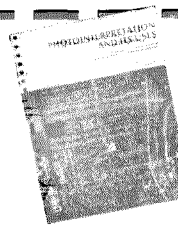
Aerial photography has many other uses as well. City planners really see all of their city, often for the first time—at a glance. Oil companies see where to drill—exactly. Strip miners calculate exact tonnage removed without weighing anything. Utility companies inspect extensive rights-of-way, yet never leave the office. The list goes on and on.

These techniques and others could benefit your company. For specific information on how you can put photointerpretation to work, fill out and mail the coupon below to receive your free copy of Kodak's new book, PHOTOINTERPRETATION AND ITS USES. Send the coupon to Eastman Kodak Company, Dept. 412L, Rochester, N. Y. 14650.



I would like to see if photointerpretation can help my business. Please send me a copy of your book, PHOTOINTERPRETATION AND ITS USES— Code M-42.

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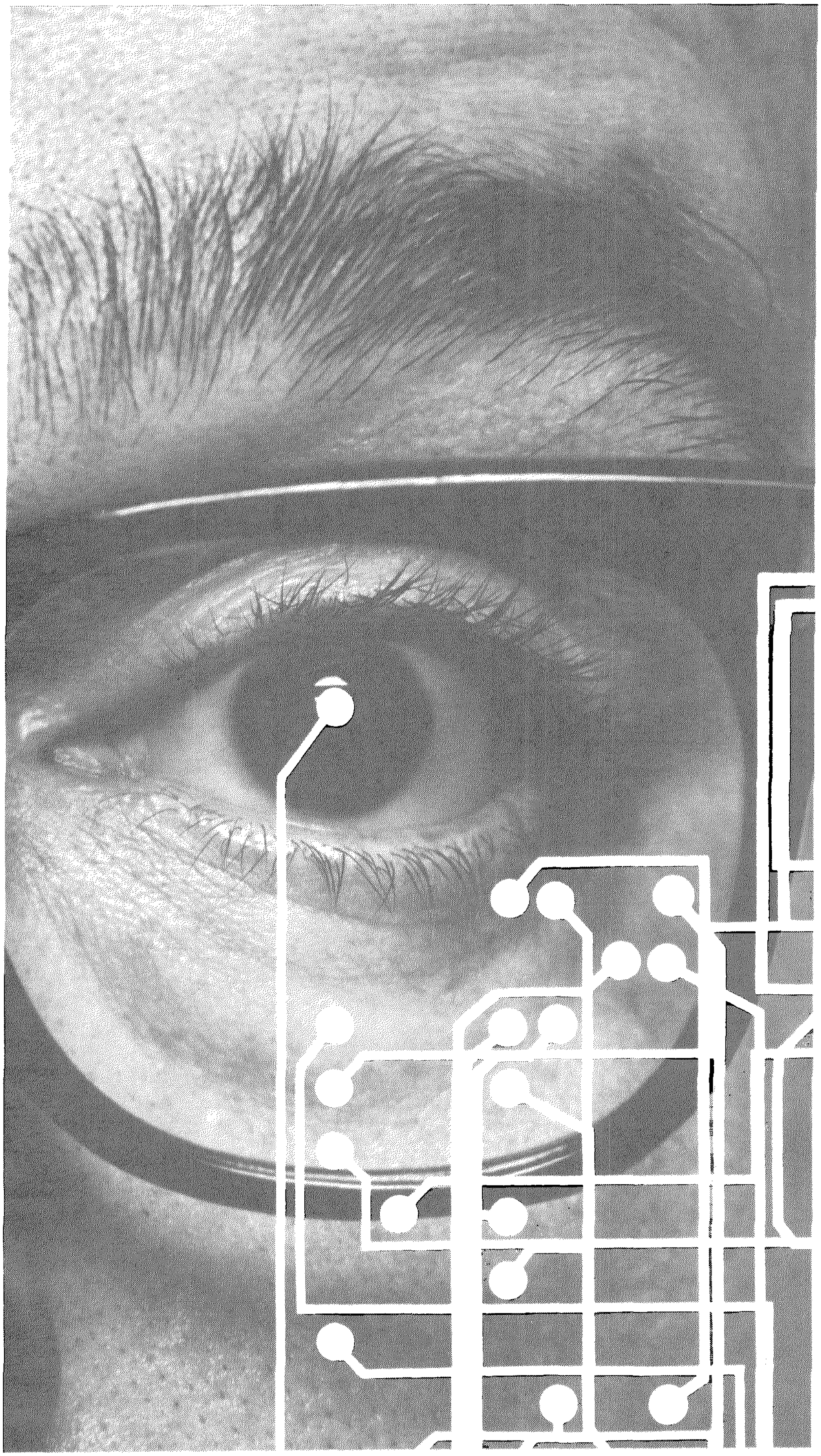

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