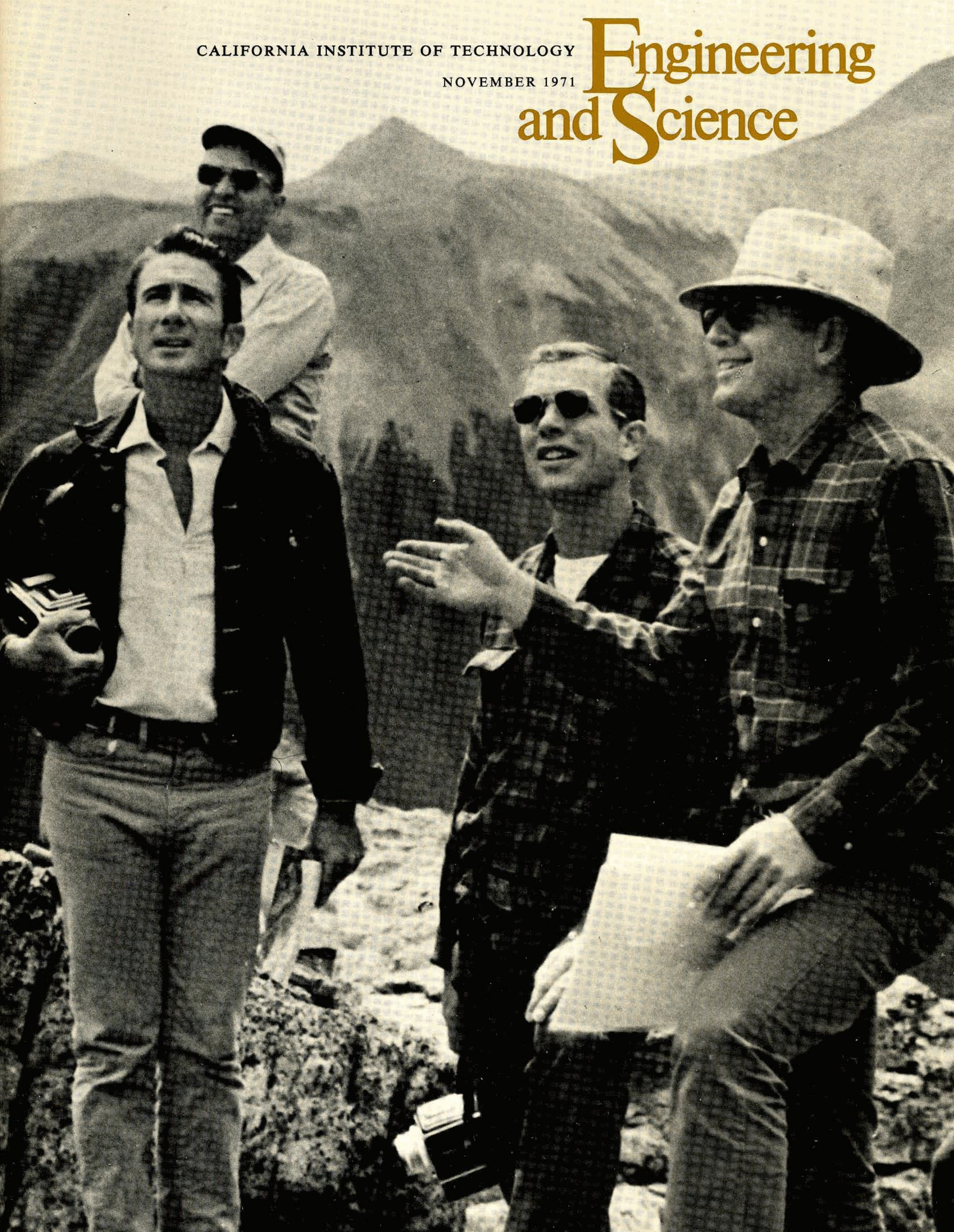
CALIFORNIA INSTITUTE OF TECHNOLOGY

NOVEMBER 1971

Engineering and Science



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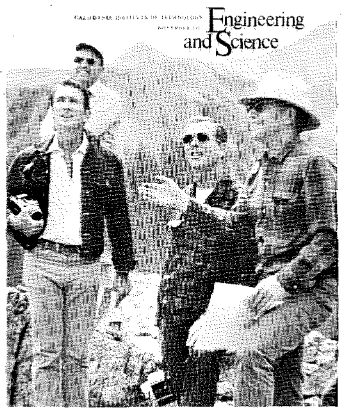

In this issue

Men with a Mission

Leon T. Silver is one of the men who tell astronauts where to go and what to do when they get there—geologically speaking. He has taken crews from the Apollo 13, 14, and 15 lunar missions over some of this country's most rugged terrain and helped them see it through a geologist's eyes. Our cover shows him at work high in the San Juan Mountains of Colorado with an attentive James Irwin and David Scott of the Apollo 15 crew—and in the background, an equally attentive Harrison Schmitt, a Caltech alumnus and member of the prime crew for the Apollo 17 lunar mission. "Geology on the Moon," page 4, tells about this exciting collaboration between earth-bound geologists and moon-bound astronauts in a program that is making possible increasingly significant scientific lunar exploration.

Leon Silver got his 1955 PhD from Caltech in petrology and geochemistry. He has been a member of the geological sciences faculty at the Institute ever since, becoming professor in 1965.

Silver is one of Caltech's principal investigators for lunar samples from the Apollo missions and is a co-investigator for the Lunar Surface Geology Experiment.

Toward Cleaner Air

In "Energy and the Environment in Southern California" (page 14), E. J. List, assistant professor of environmental engineering science and staff member of Caltech's Environmental Quality Laboratory, discusses energy-caused pollution in the South Coast Air Basin—and offers some alternatives for the development and use of non-polluting energy sources.

List, a native of New Zealand, is a graduate of the University of Auckland, with both BE and ME degrees. He received a PhD in applied mechanics at Caltech in 1965, and has been a Caltech faculty member since 1969.

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PICTURE CREDITS: Cover, 4—Joseph Allen/6, 11, 12—NASA/9—U.S. Geological Survey/29—JPL/34—Paul W. Diederich/All others—Floyd Clark.

Published seven times each year, in October, November, January, February, March, April, and May-June, at the California Institute of Technology, 1201 East California Blvd., 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

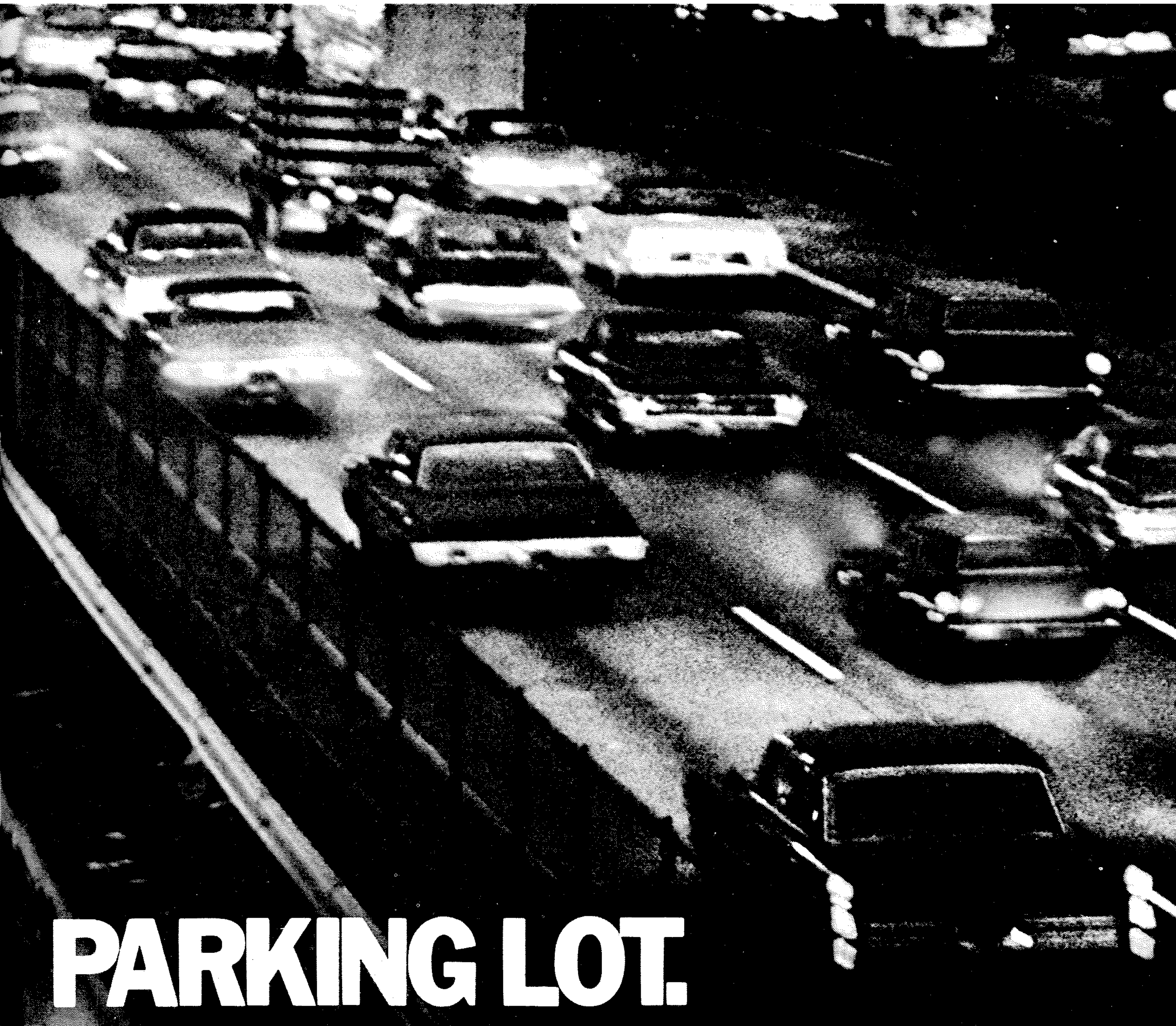
Soon 90-mph commuter trains will put a little more rush back in everybody's rush hour. And nickel's helping make it happen.

At last, true high-speed rail service is on the way. In mass transportation systems from New York to San Francisco.

And, by taking some of the pressure off our clogged highways, it promises to make life easier for motorists as well as rail passengers.

The progress of the Long Island Railroad is typical. Every week now, it replaces six or eight of its old cars with gleaming "Metropolitan" cars. About the middle of next year, after its entire new fleet of 620 cars has been put in service, it will start cutting commuting times throughout its system.

Both the frame and skin of the new Metropolitans are nickel stainless steel. The nickel's in there for several reasons. It makes the steel easier to weld and form, and adds toughness to insure car safety. It also helps arm the car against grime and corrosion. Maintenance can take place at the wash siding, instead of the paint shop.



And, because of the remarkable strength-to-weight ratio of nickel stainless, each new car is about 3,000 pounds *lighter* than if it had been built with ordinary steel. Which means quicker acceleration and braking, plus savings in power costs estimated at $2,700,000 for the fleet over a 35-year lifespan.

Just as our metal is a helper, one that improves the performance of other metals, so International Nickel is a helper.

We assist dozens of different industries all over the world in the use of metals. We offer technical information. And the benefit of our experience. Often, Inco metallurgists are actually able to anticipate alloys that will be needed in the future, and to set about creating them.

This kind of helpfulness, we figure, will encourage our customers to keep coming back to us.

And that helps all around.

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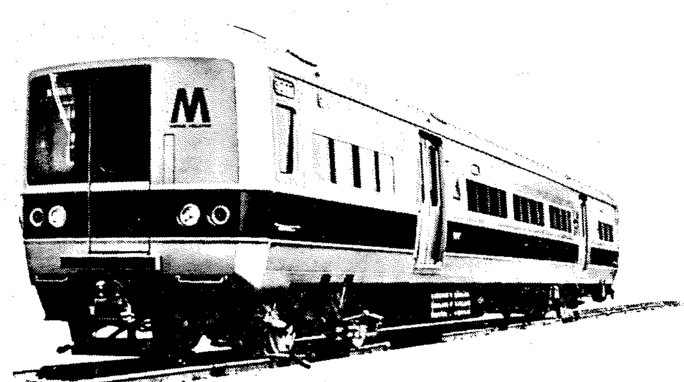


New "Metropolitan" car of nickel stainless steel.

INTERNATIONAL NICKEL HELPS

Geology on the Moon

Lee Silver has been teaching geology to Apollo crews for more than two years. For astronauts David Scott and James Irwin, the results were the impressive scientific achievements of the Apollo 15 lunar mission.

—got a boost on earth when Caltech's Leon Silver began sharing his professional skills and personal enthusiasm with the Apollo crews

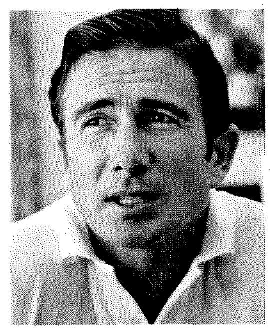
Lee Silver will probably never set foot on the moon. He'd like to, but he probably won't.

Yet he was there in a special way last August when Apollo 15 astronauts Dave Scott and Jim Irwin eased their lunar rover up along Hadley Delta and began investigating the moon's geology. He was there in spirit (only slightly less irascible than in the flesh) as head of geology field training for the Apollo program. With the beefed-up TV picture he was almost visible, a disreputable hat pulled low over his sun-sensitive nose and forehead, a bright red shirt on his back, his pockets stuffed with glasses, hand lens, and all the other bric-a-brac he carts along on geology field trips.

And Lee Silver was up to the old tricks that Scott and Irwin had come to know well—scolding, preaching, needling, wheedling, threatening, exhorting, praising, knocking—but above all moving the astronauts toward impossible standards, so that even if they fell a little short they would still surpass their own and everyone else's expectations. Everyone else, that is, except Lee Silver.

He's never satisfied. Ask anyone who has studied under him since he began teaching geology at Caltech in 1955. He piles on work. He makes outrageous demands. Morning field trips stretch into three-day survival tests. But through it all Leon T. Silver demands more of himself,

Interviewed at NASA's Manned Spacecraft Center in Houston, astronauts David Scott and James Irwin and Apollo 15 capsule communicator Joseph Allen comment on their geology training and trainer.

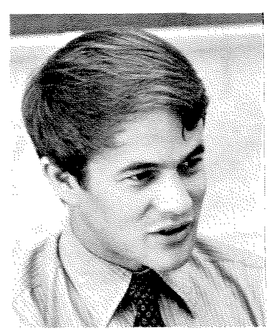


Irwin:

One thing Lee Silver always said was to step back and organize things in the proper perspective so you can relate them to the next scene that you see. I was thinking very much of him as I looked up at Mt. Hadley and saw all that organization in those layers up there. I thought: "Lee ought to be here to see this."

Scott:

Silver tough? Darn right! And I'm glad he's tough. He never let us get away with a thing.



Allen:

On a typical Lee Silver trip, he'd make arrangements wherever we were staying to open up the kitchen earlier because he wanted to get an early start. We'd be eating breakfast at five o'clock in the morning. Dave and Jim worked very hard and very, very long with Lee; and Lee, of course, was right in there working for hours and hours trying to get them up to the level of efficiency he wanted.

A simulated lunar traverse is almost as complex as the real thing—and closely monitored as well. Astronauts Irwin and Scott perform their assigned tasks at Rio Grande Gorge, followed and observed by Lee Silver and Gerald Griffin, an Apollo 15 flight director.

and gives more of himself, than anyone else. He's usually liked. Always respected. His colleague Robert Sharp, who was chairman of Caltech's geology division from 1952 to 1968, thinks he's also the best all-round geologist in the country.

When it was decided three years ago to provide formal geology training for the astronauts, Lee Silver was the man they came to. Characteristically, he accepted, beginning his work with the Apollo 13 crew. He's walked some of the roughest terrain in the world with the astronauts, taught them, and even cooked for them: on the high desert plateaus in the San Juan Mountains north of Durango, Colorado; in the Mojave; along the Rio Grande Gorge out of Taos, New Mexico; at Kilauea Crater on the island of Hawaii; in southern California's San Gabriel range.

At the same time, he has been getting more and more deeply involved in other aspects of the science portion of the missions. Apollo 15 brought him a sort of scientist's grand slam: In addition to training the crew, he took part in planning the traverses, manning the science back-room during the mission, and examining the lunar samples. He is now analyzing part of that collection. His Caltech teaching and research load is no lighter either.

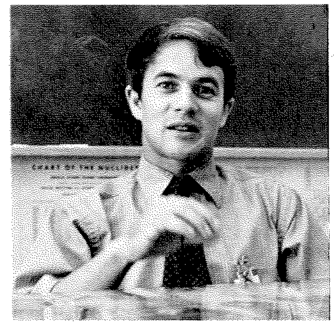
Silver probably didn't fully comprehend the eventual depth of his involvement when he began working with the prime Apollo 13 astronauts, Jim Lovell and Fred Haise, and the backup crewmen, John Young and Charles Duke. The idea started with Lovell, who had discussed his interest in geology training with fellow astronaut Harrison Schmitt, one of Silver's former students at Caltech (BS '57). Schmitt and Gene Shoemaker, now chairman of the division of geological and planetary sciences, suggested Silver as teacher and offered to approach him on the subject. As soon as Silver was signed on, Lovell made the decision that delivered the astronauts to the professor's tender mercies. There was no formal NASA approval at the time. As commander, Lovell had the clout.

Late September 1969 found the astronauts, Silver, postdoctoral fellow Tom Anderson, and a couple of others high in a remote mountain range of the Colorado desert. Nobody knew what to expect, creating a human vacuum into which Silver stepped to ramrod a full week of grueling instruction. ("I worked their tails off.") It was also a time of mutual testing, after which the astronauts endorsed the results and asked Silver to continue.

With Apollo 13 set for launch in April 1970, there was time for only a few field trips. After the last session in March, Young and Duke—already tabbed as the prime Apollo 16 crew—got Silver's promise to train with them. Meanwhile, Scott and Irwin were hatching a similar idea with the help of Harrison Schmitt. A quick trip to Cape Kennedy, dinner and a lengthy talk session, a trial period in the desert, and Silver found himself pledged as trainer for the Apollo 15 flight. (Apollo 13 never reached the lunar surface, but the masterful handling of that explosion-crippled ship by Lovell, Haise, and Swigert remains one of the most dramatic achievements in manned space flight.)

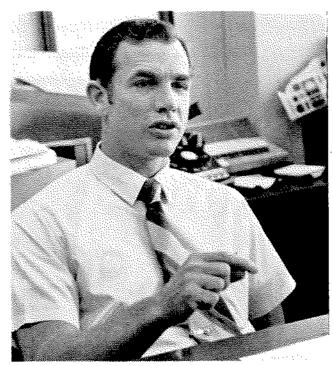
During the 15 months Silver spent on Apollo 15, the operation evolved into a combined U.S. Geological Survey and NASA institution, formalized by an official training document drafted by Dr. Tony England, mission scientist for Apollo 13 (and now for Apollo 16). Gone were the small groups of six or seven men jouncing around the outlands in Caltech carryalls. The complement had grown now to 40 people and included both mission scientists and flight directors who got their first real taste of what it means to get lost or to try to chip a sample off a reluctant rock or to overlook a potentially important find.

Basic geology was still central, but the exercises became more and more like dress rehearsals for the real thing. Traverses—or the routes over which the crews would pass—were being carefully thought out in advance. The crews worked from assigned maps like those carried on the actual mission, and there were assigned stations along the traverse, each station with its required tasks, each to be



Allen:

Right now we're at the point where the Apollo 15 material is going out to hundreds of laboratories all over the country. We took a strictly preliminary look at the samples here in our own labs—Dr. Silver took part in that, too—before they were divided up to be studied. A lot go out to Caltech, by the way, and Dr. Silver has his share of those.

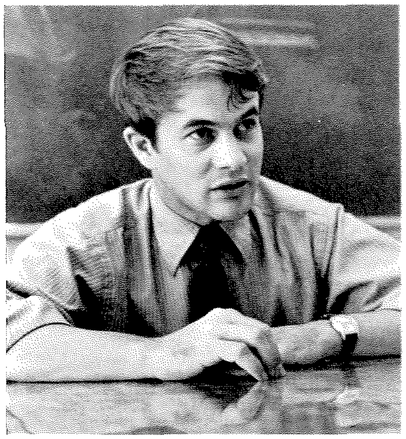


Scott:

Our crew had about 1,800 hours of formal training, 600 of which were devoted to science. We felt that the Apollo system was mature and reliable and that we no longer had to devote the time to engineering that we had on past flights. Now we know the system and we have confidence, not only in the manufacture and check-out, but also in the people on the ground during the flight. If we have a problem, we know there are experts down here who can come up with the answers.

So once you get this confidence in the system, you ask: "Where should I spend my time?" It was obvious to me that the time should be spent in learning the science. We had additional opportunity, too, because we were the backup crew on Apollo 12 and spent that time learning how to fly the machine. When our turn came on Apollo 15, we already knew how to work together. This gave us a great opportunity to devote our time to the science part.

That's the whole purpose behind Apollo. The original concept was to have test flights to make sure it worked, a few more to make sure we could land on the moon and return, and then, by golly, to get into the real meat of the subject. That was the whole purpose. We were lucky enough to be in the position to participate in the meat part.



Allen:

We started out on field trips just exactly like any student from Caltech. They weren't like a lunar traverse at all—more like a field trip you'd take in a lab course. The object was to learn terrestrial and observational geology, because after all, that's what's being applied on the moon. Then little by little, as we got closer to the mission, we got pretty proficient at doing the terrestrial geology. We started playing the game by lunar rules, not only to learn geology, but also to practice the situation we were going to find ourselves in when it came to the three days of the mission traverse. Dave and Jim would then use all the lunar tools and lunar procedures—cameras and everything else. And we'd have a backroom set up to try to direct and interpret and guide what was going on out there in the field—maybe a quarter of a mile or a mile away. One of the rules toward the end was that we in the backroom wouldn't be able to see them.

Irwin:

I guess I was most impressed with Lee's enthusiasm, his zest, his ability to keep going hour after hour without wearing out. He kept us very busy. We'd debrief late into the night, and as a practice, we'd always retraverse the path to review the things we should have seen. Sometimes we'd end up doing that after dark by flash-light.

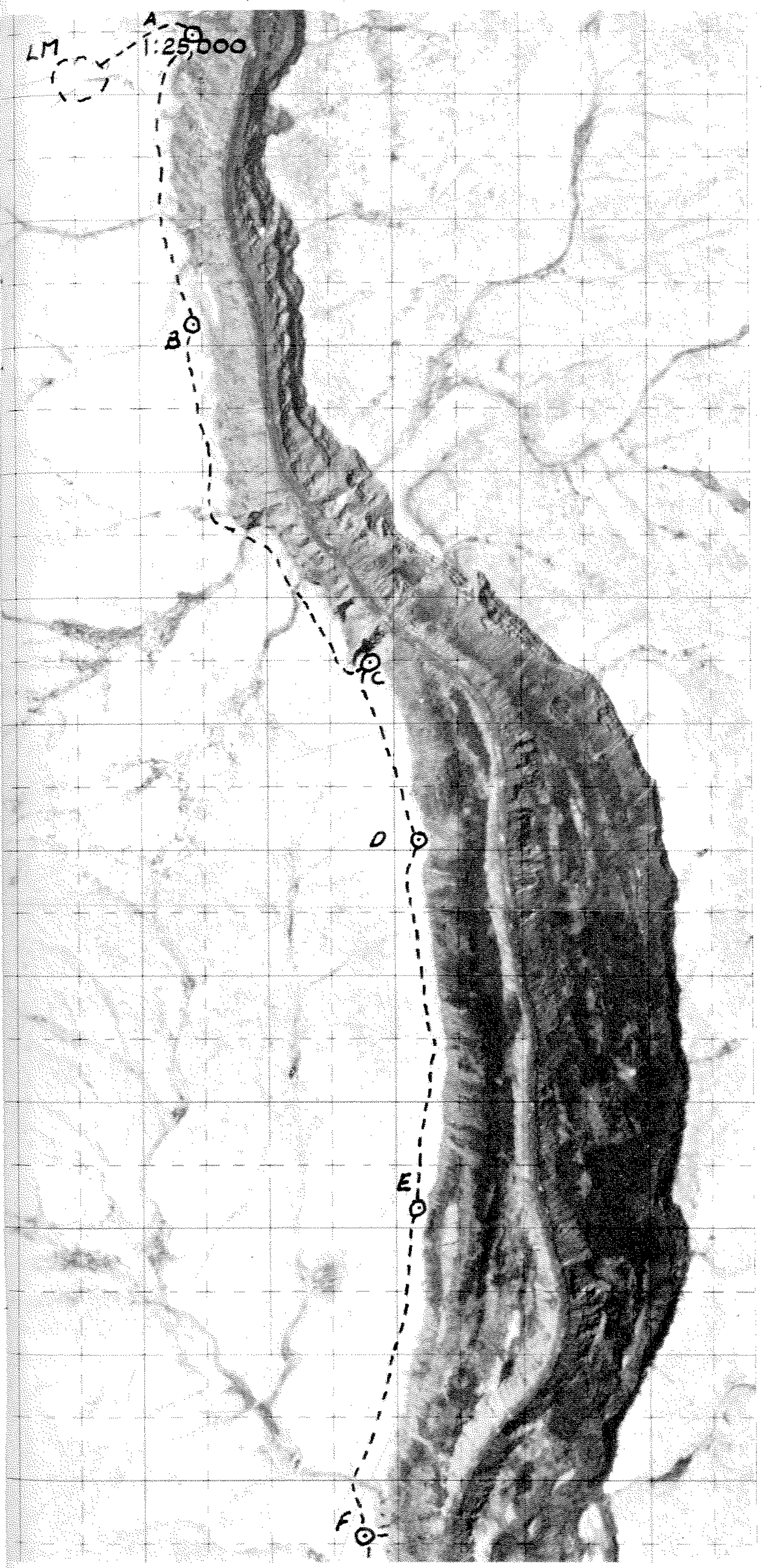
reached by a time specified in advance. Two science backrooms (one apiece for the prime and backup crews) were added to provide radio communications to and from the astronauts during the exercise. This wrinkle not only provided a higher degree of realism, but it also enabled crews and flight directors to apply considerable polish toward a more smoothly functioning communications system at mission time.

As for Silver, he was still out there observing the crews' performance as they walked the traverses or toured them in "Grover," the earthbound cousin to the lunar rover they would take along to the moon. The pace was hectic, the exercises no less challenging, and Silver's basic article of faith endured—demonstrating what geology can contribute as an integral part of the Apollo program and reinforcing his own appreciation of man as "the most incredible sensing and computing device we have at the moment."

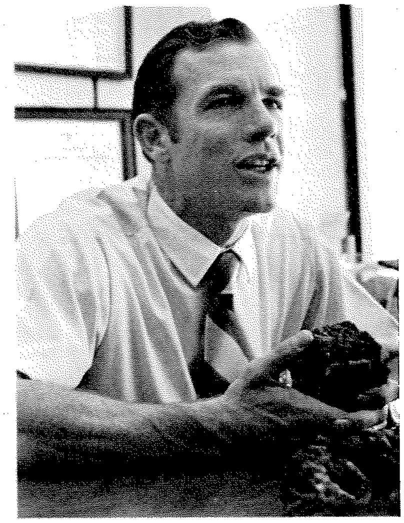
For someone as intensely committed to the program and these objectives as Silver, there are disadvantages in expanding the geology field training program. Geology has to compete with the other urgent lessons—learning how to use cameras and other special tools, refining communication techniques. And there's the added problem of maintaining continuity and format when the basic geological portions of the exercise are put together by experts who come aboard for a single field trip. But to Silver the major loss is the personal element, the opportunity to present geology as the singular personal science that it is. While Silver may regret this loss, he doesn't dwell on it—and he likes having someone else do the cooking now almost as much as the crews enjoy being off KP.

Silver made almost every field trip during the Apollo 15 preparation. As on earlier missions, he and other geologists—Caltech's Bob Sharp was one—carefully selected terrain that illustrated geological phenomena useful to the missions. As it turns out, this is no easy task. A forced analogy can create false impressions, and Silver and the rest of the highly qualified professional staff from the USGS and NASA's Manned Spacecraft Center were forced deep into their creative bags to come up with suitable field trip sites. To complicate matters further there was the challenge to fan interest and fuel motivation. To Silver, an interesting and attractive environment is the difference between a productive or unproductive learning experience. He's adamant on the notion that you don't have to do geology in ugly places, eat poorly cooked food, and go to bed dirty. All of this is calculated to promote student enthusiasm and momentum.

Of course, good teachers have always known this, and Silver carries a reputation as a good teacher. Astronauts, however, do present a special case. For one thing, they are disciplined achievers who labor mightily as long as they feel a sense of accomplishment. At the same time, the demands on their time don't permit any of it to be wasted.

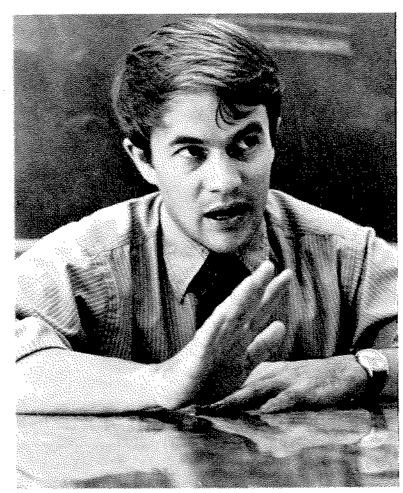


The Rio Grande Gorge near Taos, New Mexico, has some topographical similarities to Hadley Rille on the moon. Covering the traverse indicated along the west side of the gorge was part of the training for the Apollo 15 lunar mission crews.



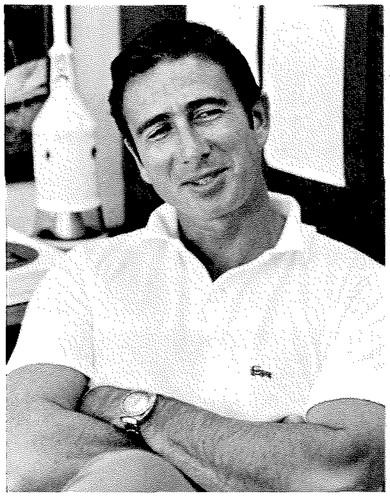
Scott:

We had four hours to go from A to B, analyze the geological setting, and bring back the samples and the photographs. We had station tasks just like on the moon. Our capsule communicator, scientist-astronaut Joe Allen, was with us. We had our radios, and after a while, we worked with the people in the backroom at CapCom. We did it just like we were on the moon. We'd run this excursion for four hours, come back and brief Professor Silver on what we saw and why we saw it. He'd listen, not saying anything until we were all through. Then he'd take us back and show us what the real story was.



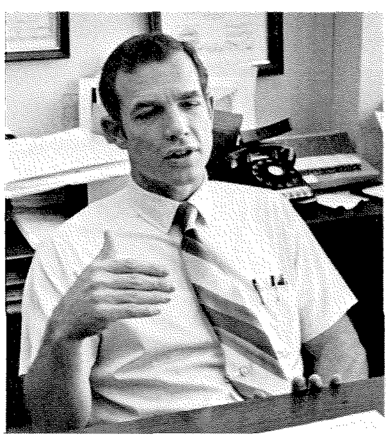
Allen:

Dr. Silver is one of the best teachers I've ever run across. He gets his subject across with enthusiasm and a lot of correct information. But the enthusiasm is always there, and that's got to be the key to any success a teacher has. Without it he can't teach anything. In this case Lee was dealing with people who are somewhat older than the average Caltech student, but that didn't seem to make any difference. The enthusiasm became mutual.



Irwin:

It's a matter of practice, so that doing the right thing is automatic. We'd practiced for so many hours in the field that we didn't know any other way to do it. And, of course, we'd had a lot of practice taking pictures also. When we got up there on the moon doing geology, we felt right at home using all the equipment. It was a little easier at 1/6th G, but we'd gone through it so many times that our actions were almost automatic. It was just like being out on one of the field trips to the mountains on the earth. I felt right at home. I had to remind myself frequently that I was really on the moon.



Scott:

We all agreed to start running our field trips exactly like we would conduct an excursion on the moon. Take the equipment with us that we use on the moon—except for the pressure suit, which was impractical. But take the tongs and the hammers and the bags and the cameras, and do an actual simulated lunar traverse. We were briefed on it beforehand, and we had photographs. The USGS at Flagstaff was really great in supplying lunar scale photos for us. We'd get to a locale in the evening and have a briefing to talk about the photographs and the excursion the next day. When we went on a geology field trip, we performed the lunar field geology experiment only. This was pure geology—nothing else.

Then too, they are mature, gifted, and sophisticated and must be approached on an individual level. In a very important way, effective training becomes a game of finding keys to unlock interests, curiosity, and responses. Silver clearly prefers to describe it as "creative instruction." He also clearly enjoys the test of wits.

In the Apollo geology field training program, terrestrial instruction is designed with much more in mind than introducing geologic features or learning names and geologic periods. Each exercise underscores geological principles: reliable observation, effective documentation, and scrupulous distinction between observation and interpretation. Silver and the astronauts rehearsed until running down the geology mental checklist became almost as instinctive to Scott and Irwin as running down the checklist before taking off in an aircraft: A rock. OK. Color? Shape? Pitted or smooth? Record how it looks before it's picked up. Detail, facts, data—Bob Sharp calls it "calisthenics"; not very exciting, but essential. As proxies for all the geologists in the world, however, the Apollo crews took their responsibility to heart. The astronauts gradually learned how to see the earth through Lee Silver's eyes. Last August they returned the compliment by showing us the moon through their own.

In the early training days, there was no set format. Teacher and students learned from each other, the students assimilating geology, the teacher how to crowd the most useful information into an already full schedule, to recognize operational constraints, to adjust to them. Together they honed the training procedures to a fine edge on the whetstone of basic principles. Then there was an element of spontaneity, with formal structure all but invisible. But no longer. Today there is extended advance study of specific mission traverses. Training exercises are run by the stopwatch. And Silver is only one of several outstanding USGS specialists active in this operation.

To simulate conditions that the Apollo 15 crew would confront at Hadley Rille, exercises were run at the rugged Rio Grande Gorge. Camera equipment was identical to that selected for the flight. Maps were simulated in the same format to be used on the lunar surface. The USGS staff prepared stations and technical problems that were facsimiles of those anticipated along the actual traverse. Exercises themselves took place at the precise time of day that duplicated light angles on the moon. Scott and Irwin snaked over the traverse on foot or in Grover, and flight directors monitored and directed from backrooms like those at Houston's NASA Manned Spacecraft Center. Silver says the operation has come a long way in sophistication, and he gives most of the credit to Dr. Gordon Swann and the U.S. Geological Survey staff in Flagstaff, Arizona. Swann is principal investigator for the Lunar Surface Geology Experiment; Silver is one of his co-investigators.

The work that Swann, Silver, and their colleagues perform seems complex enough, but Silver views it as

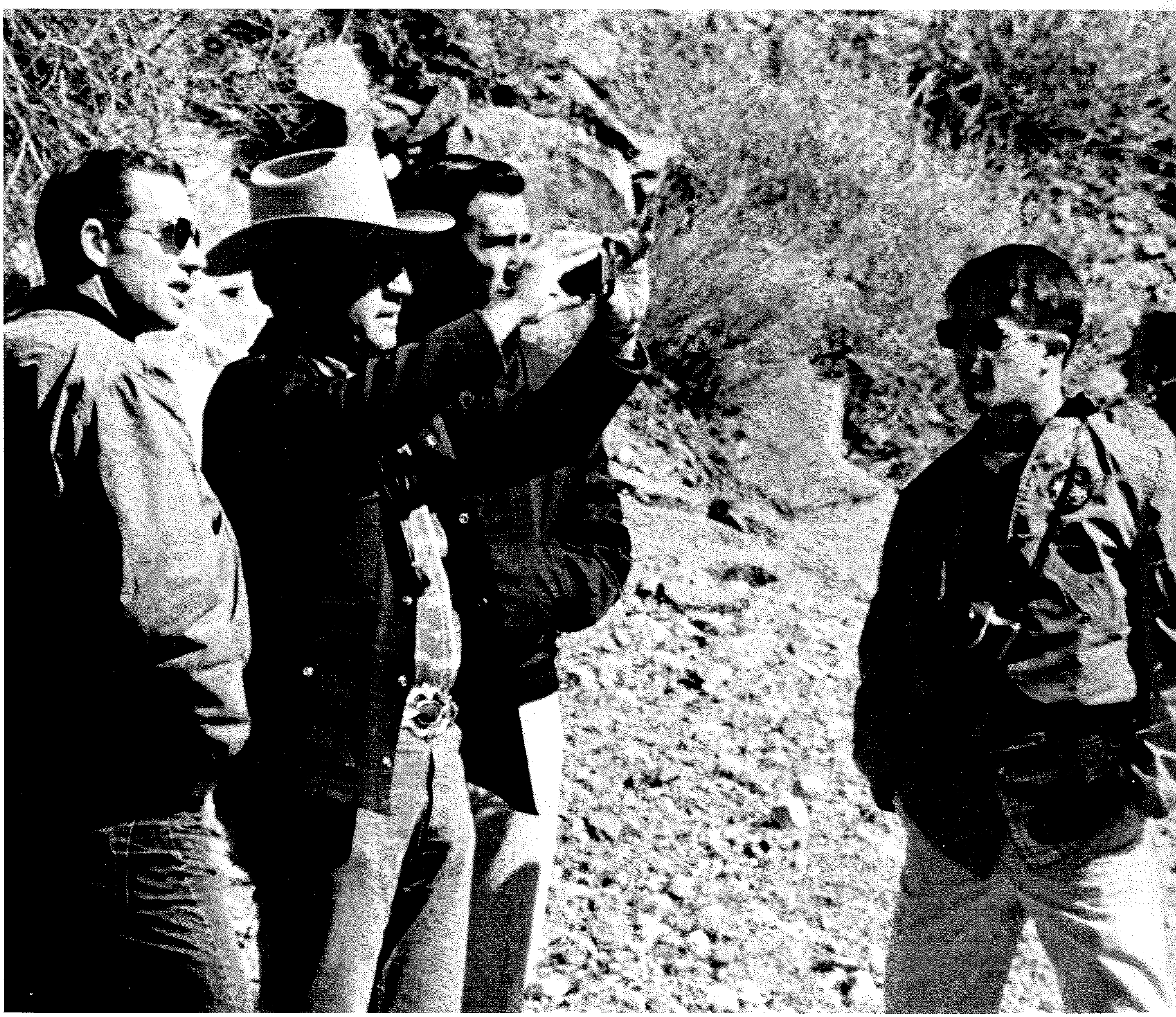
Parked on the rim of a 30-foot crater at Cinder Lake crater field in Arizona, astronauts Irwin and Scott survey the terrain. Their transport is the terrestrial version of the lunar rover—the "Grover."

just one part—albeit important—in an enormously involved scientific and engineering effort. He is also quick to point out that specific lunar missions, while both dramatic and important in their own right, are just part of a total Apollo experiment that will be many years in the unrolling. He would like to see it through, although its demands on him—added to his campus duties—have become formidable.

One of the sources of his perseverance is his attachment to the astronauts. He compares them with the best of Caltech graduate students and finds they have extraordinary powers of observation and response, of discipline and determination. "First-rate" is the label he attaches to their talents as engineers and fliers. One of the things that really impresses Silver is the ability of the crewmen to keep their spirits and interest from drooping. Scott and Irwin, for example, are now backup for Apollo 17; and Fred Haise, lunar module pilot for Apollo 13, now commands the backup crew for the upcoming 16 mission. Yet Silver has detected no loss of momentum from this prolonged pressure or from the towering demands of total mission preparation.

Beyond professional admiration, Silver carries an unmistakable personal regard for the NASA fliers. He

One indispensable piece of equipment for the geologist is a Brunton Compass—a leveling device to measure relative elevations. Looking across at a lava flow, Lee Silver utilizes the instrument for the benefit of David Scott, Raymond G. Zedekar (chief of the lunar surface procedures section for NASA), and Joseph Allen.



likes their spirit, their honesty, their lack of pretensions. It's the kind of friendship born of shared aspirations, mutual willingness to find the best way, and mutual satisfaction at achieving important goals. Bob Sharp says this is common among geologists who work on long-term projects that require a lot of time in the field. The astronauts fitted right into the pattern.

Silver and Sharp think the astronauts learned a lot of geology on their trips, and any casual TV viewer of the Apollo 15 proceedings will recall that their geology dazzled Walter Cronkite. Silver attributes some of this expertise to the fact that even prior to their assignments to Apollo missions the astronauts had had exposure to geology lectures, field trips all over the world, and an opportunity as fliers to develop their aesthetic appreciation of the earth's features. And as subsequent missions contributed to increased systems reliability in the spacecraft, there was time available for greater emphasis on geology. But the real key probably lies in the makeup of the students themselves. Achievers all, they thrive on understanding and personal mastery of new horizons that advance their contributions to the program.

Silver had a seat up front in the science operations room at Houston during the 12 days of Apollo 15. Typically, he was working—as part of the Science Operations Team. When Scott, Irwin, and Worden returned with 180 pounds of samples and the first interpretations began to come in, Silver was inundated by the press along with everyone else connected with the mission. He still grumbles that the printed stories sacrificed scientific content for dramatic impact.

On October 5 he was invited down to Houston again, and NASA Administrator James C. Fletcher gave him the NASA Exceptional Scientific Achievement Award:

> *For his significant scientific achievements in the development of highly precise isotopic compositions of uranium and lead in minerals and the applications of the age determination procedures in the analyses of lunar material. While diligently conducting these laboratory investigations of lunar material, he provided a major contribution by training the astronauts in geological sciences which, through his enthusiasm, leadership and guidance, has led to the successful exploration of the moon.*

The lunar traverse planning team of which he was a member received a NASA Group Achievement Award for its work.

For Dave Scott, Jim Irwin, Al Worden, Joe Allen, and many other friends of Lee Silver who were there looking on—and for Silver himself—it was a very special day.

—HARRY BAIN,
JACQUELYN HERSHEY

Irwin:

Well, we were exposed to a lot of geology. Lee really gave us both barrels every time we went out. He presented a challenge to us, and it all paid off when we got up there.

Scott:

We have so much to learn, so many different disciplines. We have to learn to fly a wingless vehicle and to fly with a vehicle that weighs six million pounds. We must learn how the pressure suit works, how the computer works, why it doesn't work if it doesn't. The number of different disciplines—to quote a phrase from Dr. Silver—is mind-boggling.

We had classroom study and field trips beginning early in 1964. These would be "show and tell" kinds of trips where prominent geologists demonstrated various samples and geological settings at different local sites. When we went out with Dr. Silver, for about the last year, each trip was a kind of "final examination." We would go out and demonstrate to our good professor what we knew—force ourselves to expound on what we knew. His enthusiasm was a significant factor in our ability to communicate. It rubbed off on us. You name the discipline, and I can force myself to learn it, but there's a difference between that and wanting to learn because you enjoy it. And that's what I got from Dr. Silver—the motivation. He made it fun. I can't go anywhere now without picking up rocks.

Energy and the Environment in Southern California

By E. J. List

Who's right about our highly publicized energy problems? The conservationists who shout about possible environmental crises caused by energy use, or the energy marketers who complain about energy crises aggravated by excessive environmental concern? Both are in some measure correct.

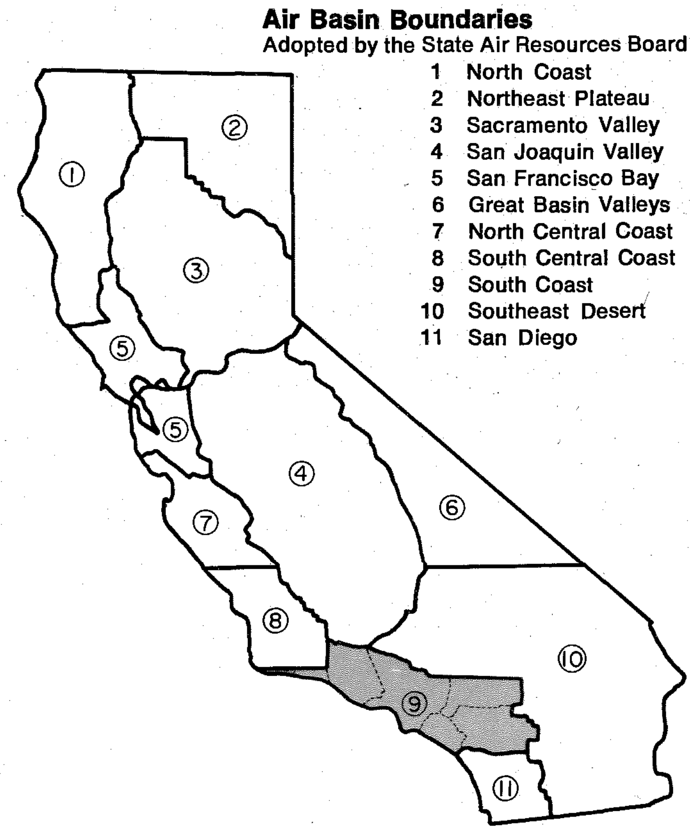
There *is* an energy crisis caused by such factors as dwindling domestic petroleum and gas supplies, cartel formation by oil-rich countries, increased tanker rates resulting from the Suez Canal closure, reduction in the depletion allowance, increased costs of mining coal, pressures on well drillers not to spill, and increased demands for low-sulfur fuels because of clean air requirements.

At the same time, the environmentalists are also correct. In some areas we are indeed reaching the capacity of the air and water to receive the heat and wastes we wish to dissipate. One region of the nation that is faced with severe environmental problems as a consequence of energy use is the South Coast Air Basin of California.

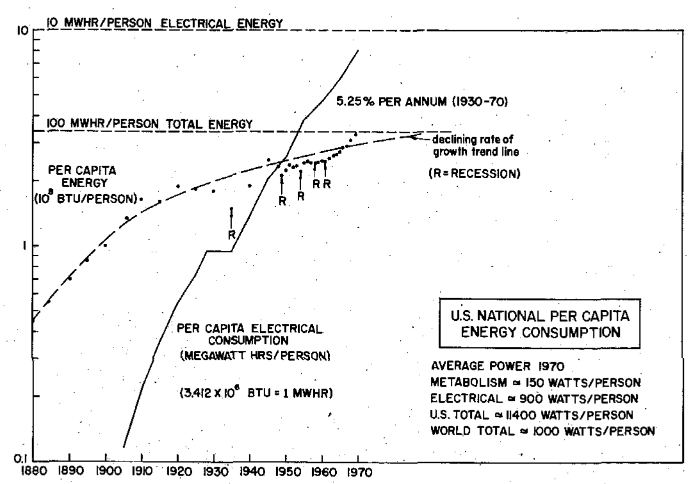
Energy Use

Nationally, our per capita energy use (right) has shown an almost continuous increase for the last 100 years, and, although the long-term trend appears to indicate a reduction in the growth rate, the high level of economic activity of the last ten years has meant a rather sharp departure from that trend. Growth in electrical energy consumption per capita shows little interruption in trend over the last 30 years. We assume that we can anticipate at least a 4 percent growth rate in per capita energy consumption over the next 10 to 20 years.

In 1969 the South Coast Air Basin accounted for almost one half of California's population, on less than 6 percent of the land area, and its residents operated more than 50 percent of the state's automobiles. The energy-use statistics for this group are given in the table at the top of the following page.



The first thing to note is that the total annual energy release within the South Coast Air Basin was 557 billion kilowatt-hours. Natural gas is the major contributing factor (over 50 percent), but gasoline also accounts for a substantial portion (26.8 percent) of that energy release. Since 96 percent of our energy is derived from fossil fuel sources, we can expect the supply problems to cause a substantial increase in energy costs over the current approximate $200 per person per year. This, of course, does not include the cost of food energy.



ANNUAL ENERGY RELEASE IN SOUTH COAST AIR BASIN

SOUTH COAST AIR BASIN — 1969

AREA: 9,200 square miles *(5.87% of California)*
POPULATION: 9,761,000 (49.4% of California)
MOTOR VEHICLES: 5,047,000 (50.2% of California)

ENERGY

			Billions kwh	% Basin
FOSSIL FUELS				
Gasoline	4,050	million gallons	149	26.8
Diesel	320	million gallons	13	2.3
Aviation*	40	million gallons	1	0.2
Jet*	128	million gallons	5	0.9
LPG	51	million gallons	1	0.2
Residual Oil**	20,720	thousand barrels	38	6.8
Refinery Gas	100,140	million cu. ft.	47	8.5
Natural Gas	910,240	million cu. ft.	280	50.3
ELECTRICITY				
Fossil Fuel *(included above)*	47,871	million kwh		
Imports	7,863	million kwh	8	1.5
Hydro	450	million kwh		
FOOD				
Metabolism†	9,761,000	people	14	2.5
TOTAL ENERGY RELEASE			557	100.0

*Includes only that burned below 3500 feet altitude.
**There is some argument about the accuracy of this figure.
†3200 Calories/day/person.

It is also interesting to compare the basin's total energy release with the incident solar energy (sunlight) represented by 5.0 billion kwh per square mile per year. In 1969 the 9,200-square-mile basin released energy representing about 1.2 percent of the incident solar energy. However, the energy release is by no means uniform over the entire basin, since 70 percent of the population lives in the unforested parts of Los Angeles County—an area of 2,300 square miles. The total energy released for this area is 425 billion kwh, representing 3.7 percent of the incident solar energy on an annual basis.

It is difficult to assess the effect of such energy releases on the basin's climate because so many factors are involved. Any estimate of a temperature increase depends, among other things, on the wind speed, inversion-layer height, temperature gradient between the coast and mountains, and the time rate of heat release. However, Lester Lees, professor of environmental engineering and aeronautics at Caltech and director of the Environmental Quality Laboratory, has developed a rough mixing-layer model of the basin in an attempt to get some indication of the temperature effect. Using his model and a conservative annual growth rate of 4 percent in energy consumption, we can estimate that by 1990 the increase in temperature could be as high as 5 degrees Fahrenheit. This is not surprising in view of the fact that such a growth rate could lead to energy releases by that date on the order of 8 percent of the incident solar radiation for the populated part of Los Angeles County.

Air Pollution From Energy Sources

The two primary sources of air pollution are combustion of fuels and non-combustion processes such as solvent evaporation and chemical processing. We will confine our discussion here to the combustion of fuels.

The total amount of pollutant of any kind, e.g., oxides of nitrogen, arising from combustion can easily be calculated if we know the emission factor for each type of fuel. To compare fuels in various uses we have compiled tables of emission factors in terms of grams of pollutant emitted in the combustion of the amount of fuel releasing the heat equivalent of 1 kilowatt-hour (3412 BTU). (This unit may seem an unusual way of measuring the energy of some fuels like gasoline—one gallon equals 37 khw—but it does put all fuels on a common basis.) The table below is such an emission factor matrix for oxides of nitrogen derived from published emission factors and fuel energy values. Since differences exist between continuous and intermittent operation and different conditions of loading, we have therefore given a minimum and maximum emission factor, representing the range of published values.

This table shows that an uncontrolled automobile operating on gasoline has by far the largest emission factor. By comparison, the emissions from the same automobile engine are much lower when operated on propane (LPG) or natural gas. It can therefore be seen that a conversion of automobiles to LPG or natural gas would have an enormous effect on the air pollution problem. One solution to the problem of what to do with the displaced gasoline would be to burn it in power plants, where the oxides of nitrogen would certainly be no larger than that for residual oil. Another significant gain from

GRAMS OF OXIDES OF NITROGEN FROM ONE KWH OF FUEL

FUEL	HEAT low	HEAT high	TRANSPORT low	TRANSPORT high	ELECTRICITY low	ELECTRICITY high
Gasoline			1.40	2.41		
Diesel			1.34	2.48		
Ref. Make Gas	0.22	0.22				
Aviation Gas			1.82	2.00		
Jet Fuel			0.18	0.51		
Residual Oil	0.74	0.83			0.37	1.23
Natural Gas	0.164*	0.33	0.22	0.46	0.28	2.47†
LPG			0.20	0.43		

*A kitchen range actually has the lowest emission factor (0.086 gms/kwh), but accounts for only about 5% of the gas consumed.
†Exceptionally high figure from one particular power plant.

burning the gasoline in power plants would be to eliminate the emission of unburned hydrocarbons from automobiles as well as the evaporative transfer losses, both of which are a significant part of the air pollution. We are simply using the wrong fuels for the wrong purposes from a pollution control point of view.

We can use the emission matrices such as those shown in the previous table for another purpose. Since we already have the fuel totals used to compile the first table on page 15, we can use the same emission factors to compute the range of air pollution emissions in the South Coast Air Basin as in the table below. The oxides of nitrogen are

ANNUAL AVERAGE COMBUSTION EMISSIONS
FOR THE SOUTH COAST AIR BASIN — 1969 (IN TONS/DAY)

EMISSION	LOW ESTIMATE	HIGH ESTIMATE
Organics	2,310	3,180
Nitrogen Oxides	1,260	2,250
Carbon Monoxide	12,360	15,420
Particulates	150	220
Sulfur Oxides	200	480

derived mostly from the combustion of gasoline and natural gas. The emission levels given in this table, when scaled to the ratio of energy consumption, agree reasonably well with the combustion levels calculated by the Los Angeles APCD. The spread in the results reflects the range of the reported emission factors, and it is worthwhile to note that the difference between using the highest and lowest published emission factors is not a fantastically wide margin in the computed emissions. It seems reasonably safe to assume that the actual pollution levels lie between the given levels. From this fact it is apparent that an *order of magnitude reduction* in emission factors will be necessary to attain a substantial reduction in total emissions in the air basin.

In view of the interest we all have in removing air pollution it is important that we calculate the residual pollution we can expect when the emission factors are reduced to a technologically and economically feasible minimum. Let us assume that *all* the natural gas and oil is burned at the low emission levels of a kitchen range, and that *all* vehicles have emission levels equivalent to those from the exhaust of a 1976 automobile. Furthermore, assume that this is accomplished by 1975 (a highly unlikely assumption) and that in the interim, energy from combustion has risen at 4 percent each year. The following table gives the results of such a calculation, and a comparison with the previous table shows that significant gains in air quality should be apparent. Just precisely what ambient air quality such emission figures represent

PREDICTED MINIMUM POSSIBLE COMBUSTION EMISSIONS
FOR THE SOUTH COAST AIR BASIN FOR 1975 (IN TONS/DAY)

FUEL	ORGANICS	NITROGEN OXIDES	CARBON MONOXIDE	PARTICU-LATES	SULFUR OXIDES
Gasoline	106	93	1,090	81	54
Diesel	9	8	16	7	27
Aviation	31	9	152	1	1
Jet Fuel	43	4	8	3	4
Residual Oil	4	24	—	21	120
Refinery Gas	1	15	—	3	9
Natural Gas	6	90	—	14	—
1969	2,310	1,260	12,360	150	200
1975 TOTAL	200	243	1,266	130	215

(See preceding table, low estimate.)

Compiled from federal and state statistics and data provided by numerous energy companies in the basin.
Data from U.S. Statistical Abstract.

is not easy to determine. However, John Trijonis, a Caltech graduate student in environmental engineering science, has developed an emission-level/air-quality model in an attempt to solve this problem. His model predicts that, even at the minimum emission levels resulting from the almost utopian assumptions above, the federal ambient air quality standards for ozone would be exceeded approximately 10-15 days per year. The disturbing fact is that the number of days could only increase from this level unless *all* energy consumption growth is absorbed by some non-polluting energy source. This raises the question of just what strategies one can use to attain clean air.

The amount of any pollutant X from combustion sources is given by:

Amount of X = (Energy from source a)x(Emission factor for a)
+ (Energy from source b)x(Emission factor for b)
+ .... x ....

Thus, to reduce the amount of X we have three options:

(A) Reduce the emission factors.
(B) Reallocate energy consumption to those energy sources with the lowest emission factors.
(C) Reduce the amounts of energy consumed.

Almost all air pollution abatement strategies follow plan A; certainly this has been the policy of the State of California Air Resources Board and the Los Angeles APCD. But, given energy consumption growth, air quality gains can only be made if the emission factors decrease at a faster rate than the energy multipliers are growing. However, there is a point when either the cost of reducing the factors becomes prohibitive or we reach the limit of our technological capability to reduce them.

We have every reason to believe that this point has already been reached both with respect to power plant boilers and automobiles powered by the internal combustion engine. It does not seem technologically possible to use air as the oxidant in a high-temperature combustion process without producing *some* oxides of nitrogen. We therefore conclude that the minimum emissions calculated in the previous table are related to the best air quality that Los Angeles can expect without implementation of plan B or C. What is more important, unless growth is absorbed by a non-polluting energy source, this minimum would only be transient, and the air quality would proceed to deteriorate again.

The essential point, which must be reiterated, is that our consumption of fossil fuels has now become so large in the South Coast Air Basin that our ability to reduce emission factors has been overwhelmed. To get clean air the emission factor has to be very small indeed when the numbers multiplying these emission factors are so large, viz., 150 billion kwh for gasoline and 280 billion kwh for natural gas. And this is quite apart from the fact that energy consumption keeps growing to compound the problem.

We therefore can conclude that plan A is only an interim strategy whose effectiveness is solely dependent on a steady succession of technological breakthroughs. Then why are all the pollution control agencies using it? The principal reason seems to be that order-of-magnitude reductions in emission factors were technologically and economically possible in the past and therefore, by extrapolation, should be available in the future! The other two possible methods of control—reallocation of energy sources and discontinued growth—require major social and economic changes that our political system seems unprepared to face at this time.

If we really want cleaner air, we must find ways either to reallocate energy supplies or to decrease the demand for energy. And we have already seen that flattening the growth curve alone will not clean the air if the existing fossil fuel combustion levels are maintained.

No society, to our knowledge, has voluntarily constrained its per capita consumption of energy in peacetime. At this stage of social development it does not seem likely that our society will accept such growth controls. This leaves us with plan B—the reallocation of energy sources to those energies with the lowest emission factors.

The minimum emission factors for fossil fuels appear to be nearly the same so that reallocation of energy sources would be a short-term strategy which can be exploited only until these lowest emission factors are attained; furthermore, it is only a one-time gain. Consequently, what is required is an energy source that has practically zero air pollution emissions, and fortunately two such sources exist.

Solar energy has always been available, but development of a technology to harvest it appears to be some time away. The other near-zero emission source is nuclear power, and luckily it is in an appropriate stage of development to come into widespread use. It is also apparent that an inadvertent outcome of the strategy to reduce emission factors has been to hasten the acceptance of nuclear power. Tightening emission controls on fossil fuel plants (as well as the fuel supply problems) are raising their costs to the point where nuclear power plants are becoming the most economic for a utility to purchase. Unfortunately, it is not easy to see what the outcome of the same policy will be in the automobile business. Will it be a shift to mass transportation systems powered by electricity produced by nuclear power?

Conclusions

An examination of energy use in the South Coast Air Basin has shown that:

1. While thermal pollution is not significant at the moment, if current rates of growth are maintained there is every possibility of modest temperature increases within the basin in the next 20 years.

2. Energy use of fossil fuels has attained such levels within the basin that the residual air pollution there will remain at a significant level, even when virtually all emissions from combustion processes have been reduced to apparent feasible minimums.

3. The current policies of air pollution control agencies that require the continual reduction of emission factors has almost attained the limit of its usefulness in large energy consuming areas.

4. The only other policies open for air pollution control are either the reallocation of energy demands to those energy sources with zero emission factors, or the curtailment of the use of fossil fuels as an energy source.

5. In the largest urban areas, such as Los Angeles, a simple policy of no growth still leaves the area with significant air pollution unless energy demand is reallocated to zero emission sources.

6. The only energy source with near-zero emission factor and able to accommodate the possible demand for energy at this time is nuclear generated electric power.

7. The only way a city such as Los Angeles will ever attain air satisfying federally promulgated ambient air quality standards is to replace fossil fuel combustion by nuclear power or solar energy sources.

8. Society must find new ways of encouraging the development and use of non-polluting energy sources.

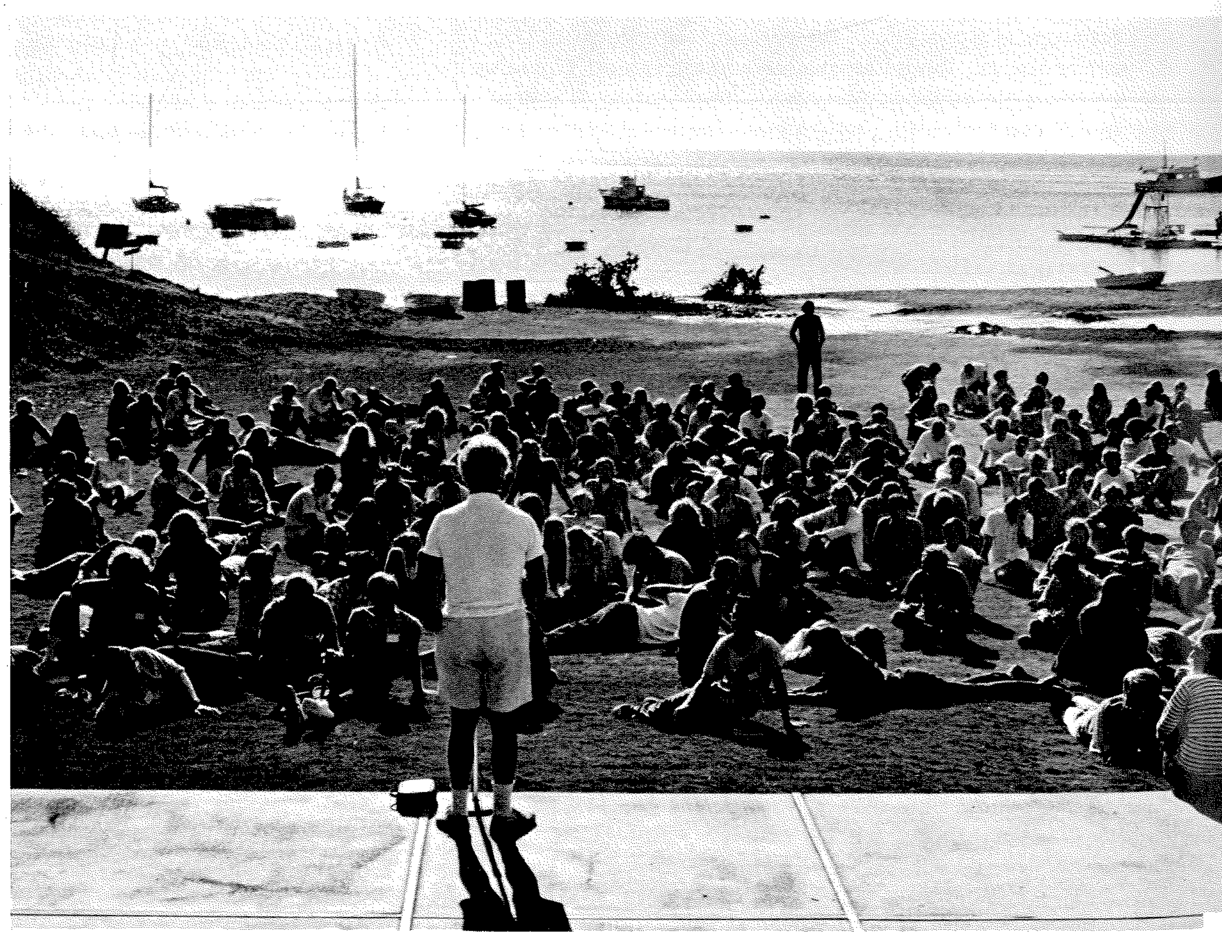
This article has been adapted from a more comprehensive report, "Energy and the California Environment" (available on request), prepared for the Environmental Quality Laboratory with financial support from NSF Grant No. GI-29726.

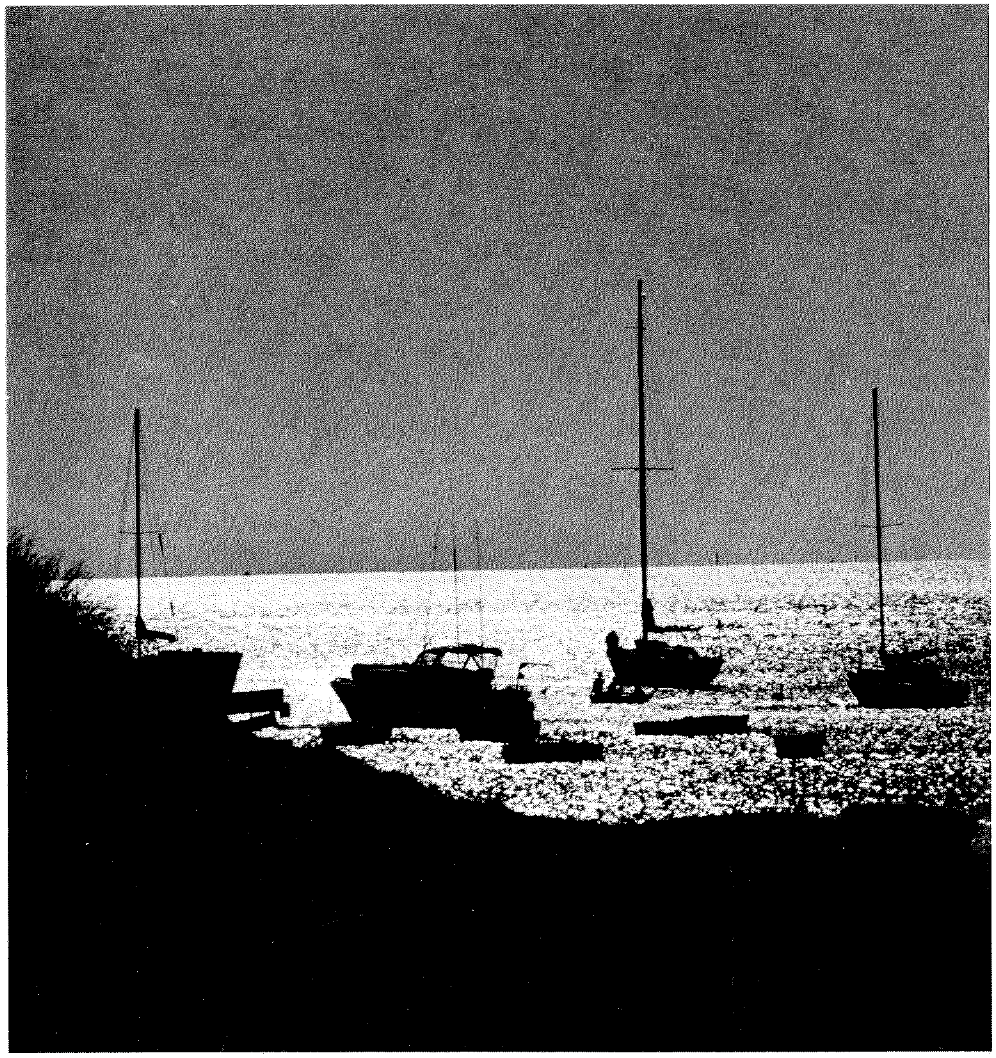
Catalina – For Starters

After a one-year break in a long tradition, Caltech freshmen started their first academic year at the Institute this fall in the unacademic atmosphere of New Student Camp.

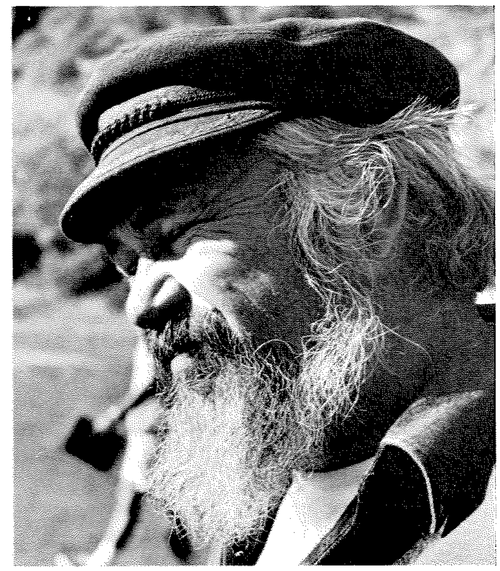
Last year's freshman class was the first since 1926 to have no camp. Instead, the class of '74 got a no-nonsense orientation right on campus. But no nonsense also turned out to be no fun. The class of '75, reaping the benefit of the reaction, was whipped off for three glorious days and two fun-filled nights at Camp Fox on glamorous Catalina Island.

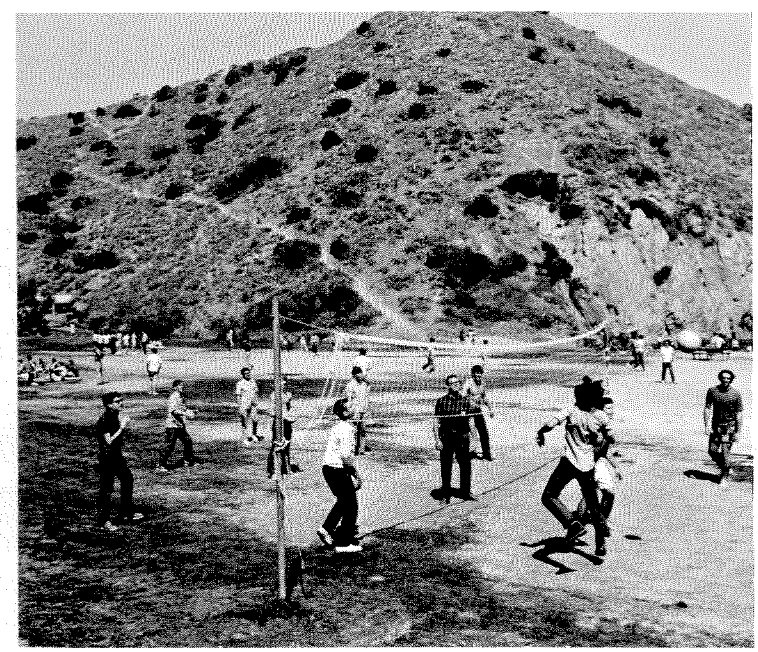
Dean of Students R. A. Huttenback taxis across the harbor. The oarsman is E. M. Shoemaker, chairman of the division of geological and planetary sciences.



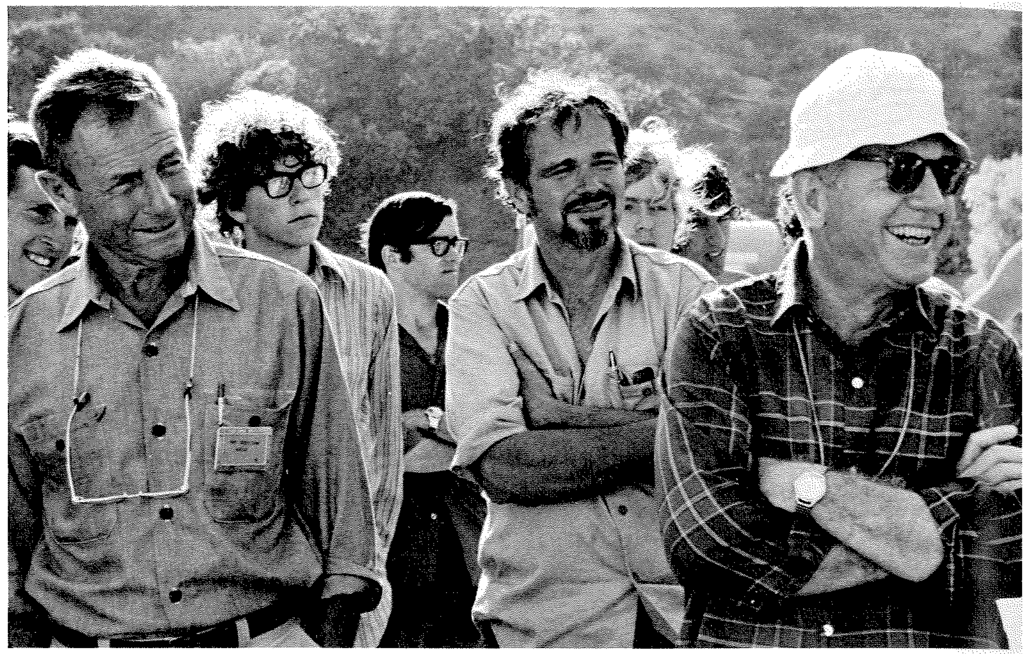


Straight out of Conrad, David Smith, master of student houses, sailed into camp on a 25-foot Coronado.



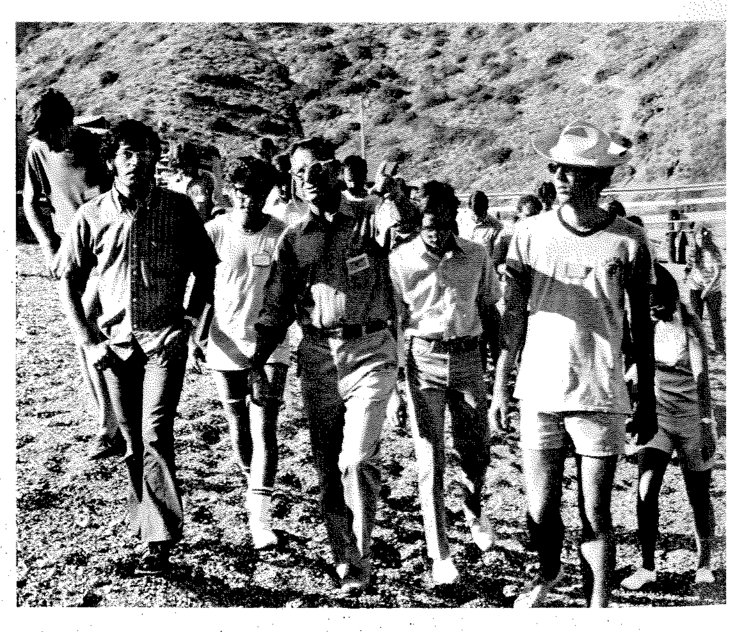


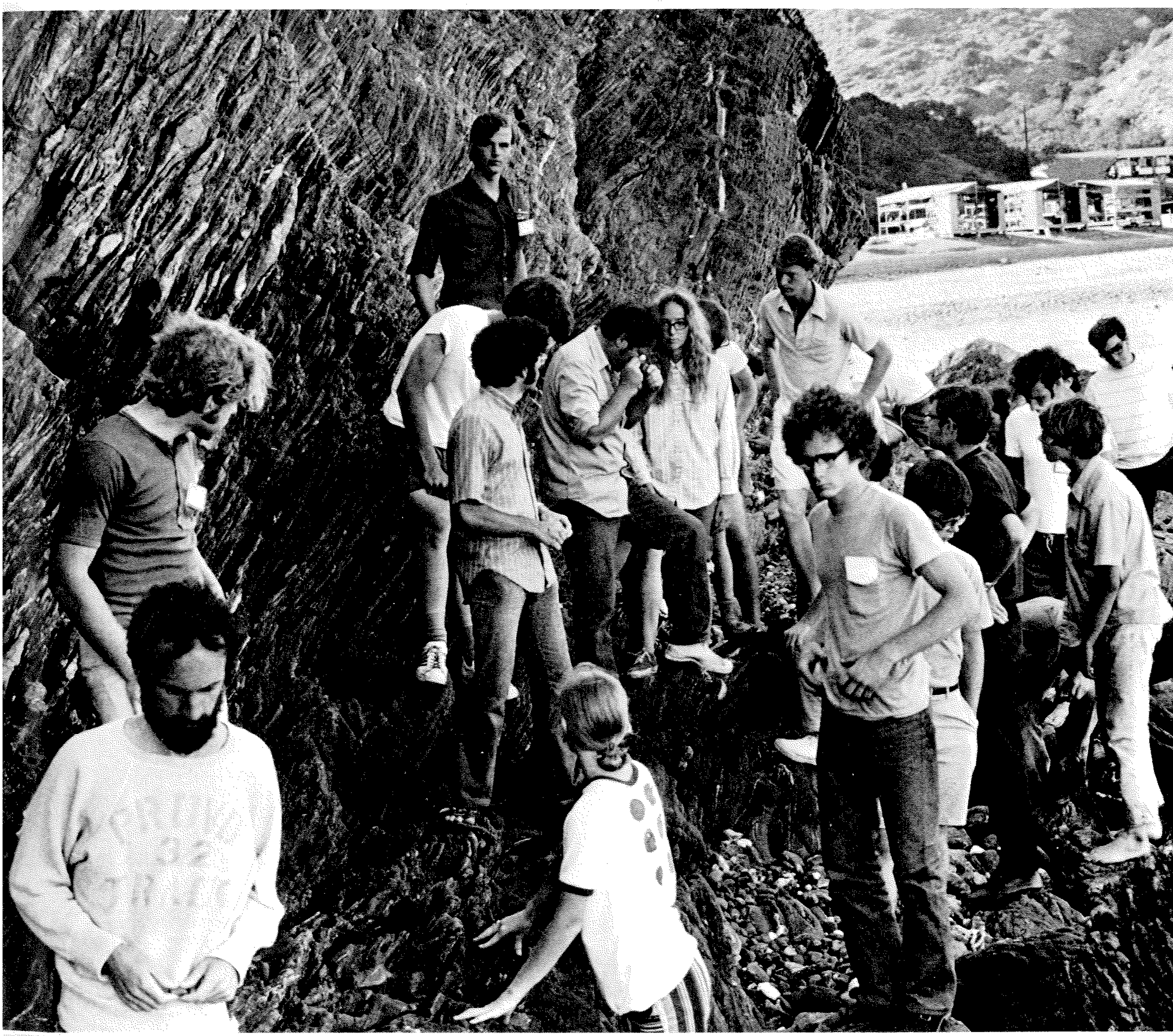
Speeches, discussion groups, and other formal activities were played down, land and water sports played continuously.



A SIDE TRIP

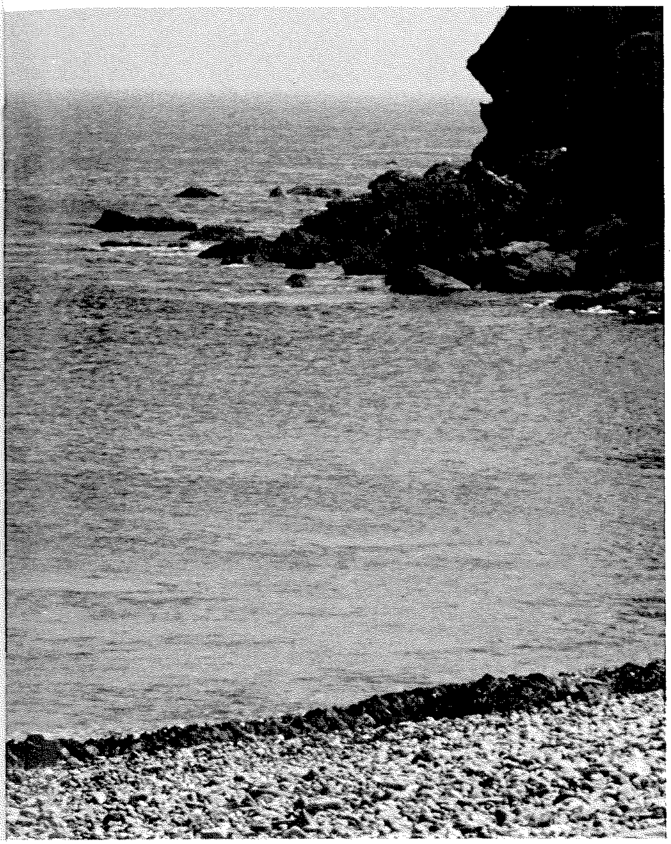
Get more than two geologists together and they'll probably organize a field trip. They did at Freshman Camp. Catalina, with all its exposed rock, is a geologist's delight, and R. P. Sharp, Leon Silver, and E. M. Shoemaker decided to explore a little of it. When they unselfishly invited any interested students to join them, however, the private expedition turned into an introductory geology lesson for a swarm of about 70 eager freshmen.

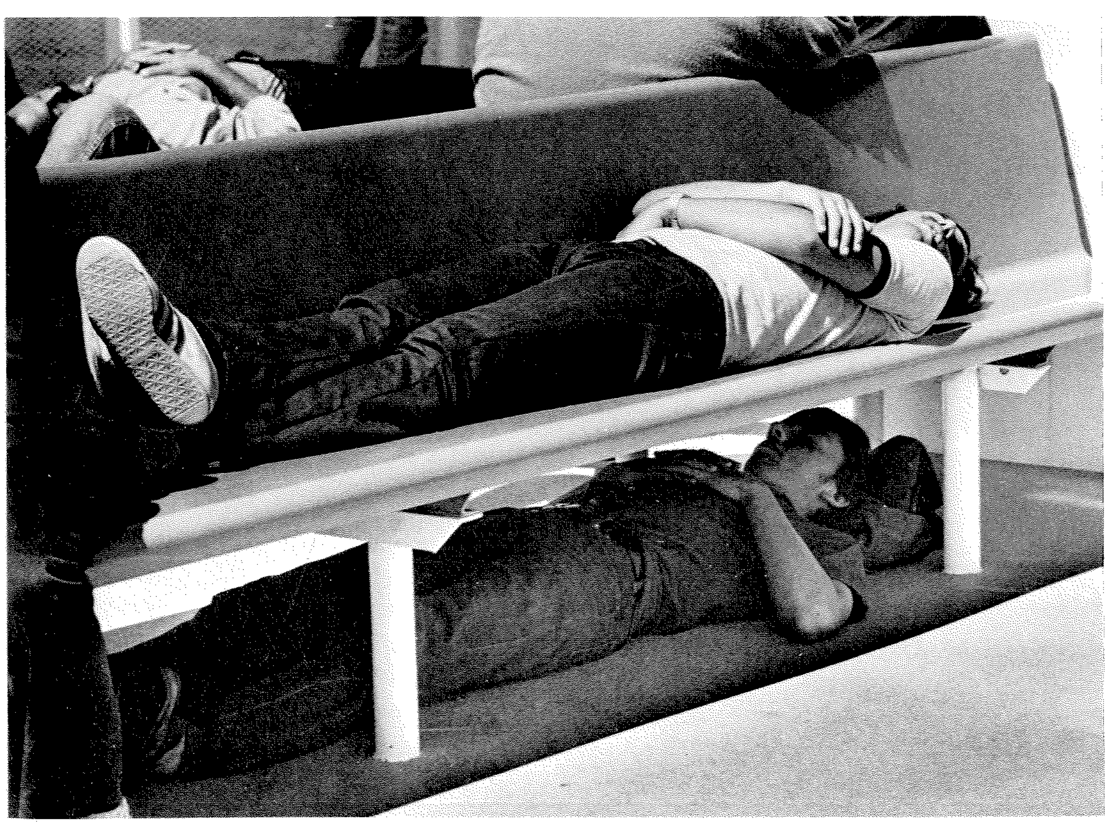




RETURN TO REALITY

After three days of play, Caltech's class of '75 reluctantly boarded the Catalina ferry for the short journey back to the mainland—a trip that runs directly from Irresponsibility to Reality.





ROBERT L. SINSHEIMER— A Concerned Biologist

At Caltech, and in all of science we have been, in a sense, children, spewing change into society with scant thought for the consequence. We in science are growing up now. Our toys become more potent. The little games we play with nature are for great stakes, and their outcome moves the whole social structure. We must accept our responsibility.

With these prophetic words Robert Sinsheimer, professor of biophysics and chairman of the division of biology since 1968, concluded his talk, "The End of the Beginning," at Caltech's 75th Anniversary Conference—Scientific Progress and Human Values—on October 26, 1966. A landmark speech at the conference, it summed up what is a dominant and recurring theme with Bob Sinsheimer: that a scientist is accountable to the society of which he is a part not only for seeking out knowledge but for doing so thoughtfully, humanely, and with due regard for possible consequences.

In a sense, the talk was a turning point in the life of Robert Louis Sinsheimer—or at least in some of his colleagues' views of him. Ray Owen, professor of biology and chairman of the division from 1961 to 1968, recalls having recommended that Sinsheimer be asked to make the speech; and he dates an accelerating change in Sinsheimer's outlook from that time. "The degree to which he's changed over the past few years is amazing," Owen says. "When he first came to Caltech, I saw him as a highly specialized kind of biophysical scientist. He was—and still is—a very guarded, thoughtful, and self-critical person, and much of his concern for social, moral, and ethical problems simply didn't show then."

Whatever the significance of "The End of the Beginning" in Sinsheimer's career, it was a moving statement of his philosophy. ("His way with words is almost Isaian," says Owen.)

Robert Sinsheimer was born in Washington, D. C., in 1920, but he grew up in Chicago. He was the second of three brothers and somewhat removed from both of them —from the older by a gap of six years in age, and from the younger by very different interests. Always an excellent student, he was eventually in a number of advanced classes in school, and handled some of the problems that went with being ahead of his age group scholastically by finding outside interests. For about a year he attended classes at the Chicago Art Institute ("My hand-eye coordination was inadequate for the artistic expression standards of the time."), and he did extensive reading. Some of the books that impressed him belonged to his older brother, who was attending the University of Chicago by the time Bob was in high school. *The Science of Life* by H. G. Wells, Julian Huxley, and G. P. Wells made him realize for the first time that one could talk about living processes in scientific terms.

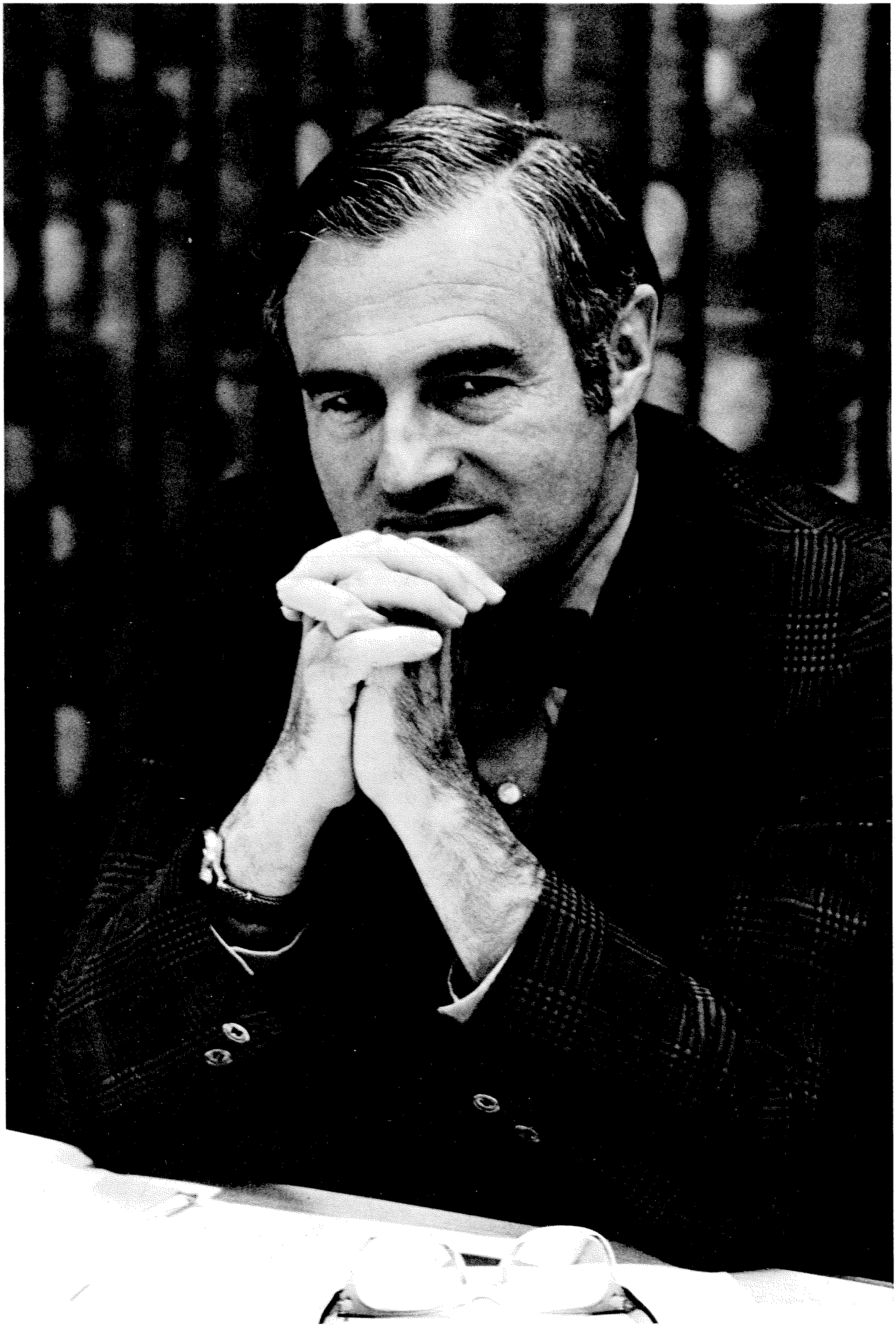
He went in for sports—particularly tennis and golf. He was captain of his high school chess team, which won the city championship. During the summers of 1933 and 1934, he spent a lot of time at the Chicago World's Fair—a good deal of it, predictably, in the Hall of Science. By the time he graduated from high school in 1936, he knew definitely that he wanted to go into science.

Sinsheimer had been stimulated by an excellent high high school chemistry teacher, and he wanted to become a chemist. But there had never been a scientist in the family, and his father didn't see how anyone could hope to make a living being one. In the depression economy of the thirties this judgment was a potent deterrent. When he enrolled at MIT, Sinsheimer designated chemical engineering as his option—a compromise between his real interests and practicality.

At that time all freshmen at MIT took the same basic course, so it was not until he was a sophomore and actually introduced to chemical engineering that Sinsheimer realized it was not for him. Quite coincidentally, just at that time MIT was overhauling its old, public-health-oriented biology curriculum. In a manner unique for the time, the new approach to biology was biology combined with physics—and it looked fascinating to Sinsheimer. Fascinating is just what it turned out to be. He happily remembers taking a course in atomic physics one hour and human physiology the next, and delighting in the mental agility it took to leap from one subject—and one mode of thought—to the other.

"There is an enormous difference," he says, "between learning how something works, theoretically, and the kind of diagnostic thinking it takes to find out why something is not working. In physics you end up reading a meter or adjusting something. In biology you end up with a complicated set of slides to try to make sense out of. You have to ask yourself what kind of measurements you should make to give yourself a clue to what is wrong."

MIT's new biology course took five years, so Bob Sinsheimer received his SB in 1941. His SM was awarded



The imminent intrusion of biological engineering in human life makes you question every value you have.

in 1942, just as World War II broke out, which made the problem of what to do next fairly simple. He followed one of his professors into MIT's Radiation Laboratory and spent the next four years designing and testing airborne radar—a lot of it actually in planes or at military airports. He recalls the job as socially isolated, restrictive, anomalous, and not very interesting. The bright spot of those years was his marriage in 1943 to Joan Hirsch.

Deciding what field of biology to study after the war took a good deal of thought, but he finally made what he calls a "good guess about what would turn out to be important"—research on nucleic acid. With PhD in hand, in 1948 he became a research assistant at MIT for a postdoctoral year, meanwhile looking around for a permanent job, which turned out to be a firsthand learning experience in some of the problems associated with being a pioneer. No university seemed to be offering molecular biology or biophysics, so Bob Sinsheimer had to find a school that wanted to hire an innovator. He finally went to the physics department at Iowa State College—and spent the next eight years in a frustrating attempt to build a biophysics program there.

George Hammond, chairman of Caltech's division of chemistry and chemical engineering, has known Sinsheimer since they were both junior faculty members at Iowa State more than 20 years ago, and he considers him "one of a handful of people who can legitimately be called a scientific pioneer . . . Even as a physicist at Iowa State he did things that physicists weren't supposed to have anything to do with.

"When Sinsheimer talks about the philosophy or the future of science," Hammond says, "he shows enormous imagination—and his mode of expression is truly poetic. Yet, at the same time, he is something of a scientific puritan about what constitutes intellectually decent scientific activity. For instance, I think some of the environmental research doesn't excite him very much—at least as science."

At Iowa State, Sinsheimer continued his personal research on nucleic acids, but largely in the chemistry and physics of the subject—the photochemistry of nucleic acids and their components, for example. Eventually, to make further progress, he had to do some biological work on a bacterial virus. The exciting place to do this, in 1953, was at Caltech with Max Delbrück, and the six-month leave of absence Sinsheimer spent here then as a senior research fellow greatly enhanced his understanding of genetics. (He is also appreciative of Delbrück's successful efforts to have this appointment funded—something that various restrictions at Iowa State made impossible.)

"Back at Iowa after that experience I really felt isolated from many aspects of life," Sinsheimer recalls, "and it continued to be literally impossible to get a sensible program in biology going there. So, when the opportunity to come to Caltech permanently arose, making the change should have been easier than it turned out to be. Academically and scientifically there was no question, but for eight years we had made our lives up out of other people, and they were very hard to leave."

At Caltech in 1957 and working for the first time permanently in a biology department—and with a good deal of the basic work in purifying the virus Phi X 174 already accomplished at Iowa—Sinsheimer's research began to move more quickly. He found then (and, according to his graduate students, still finds) that work always goes more slowly than he anticipates. What he is trying to do is to understand viral growth in molecular terms, and he is making progress.

In 1967, using methods developed by Sinsheimer, Arthur Kornberg and Mehran Goulian at Stanford succeeded in making a perfect copy of the DNA of the natural virus Phi X 174—the virus Sinsheimer had isolated and purified back in the late 1950's. Kornberg and Goulian made a number of versions of their synthetic DNA and shipped each one to Sinsheimer so he could test its ability to replicate the complete virus. The final version displays the full biological activity of natural DNA in living organisms; it can infect bacteria and reproduce itself just as the natural virus does.

This is probably as close as anyone has yet come to creating life in the laboratory, and the news media reported it widely. The research was, in President Johnson's words, "an awesome accomplishment." Sinsheimer, however, deplores the oversimplified view the public often gets of DNA research. "Scientists don't really understand the basic processes yet," he says. However, in 1968 at The Far Reach of Science symposiums sponsored by Caltech and *Life* magazine, Sinsheimer did say that this century is likely to be the one in which, for the first time, a living creature will understand its origin.

"We are the heirs of Icarus," he said. "We have become the latter-day Prometheus. But even in the ancient myths men were men and the gods were gods, and man could not rise above his nature to chart his destiny. Now we can begin to confront that chance and choice; soon we shall have the power consciously to alter our inheritance, our very nature. Not even the Greeks had a word for DNA."

The words for Sinsheimer in 1968 were "in demand," and he began getting offers of administrative positions outside Caltech. "How much he was tempted to accept any of them I'm not sure," Owen recalls, "but I wanted out of the biology chairmanship, and I wanted to hold onto Bob against outside enticement. I always felt that the last successful move a division chairman could make would be to arrange for the smooth succession of someone who wanted the job and would be acceptable to the rest of the division. And this worked out perfectly with Sinsheimer."

As a division chairman, Sinsheimer turned out to be "an extraordinarily gifted administrator—wise in the vision of future needs and very sensitive at the same time to the personal needs of the person for whom he was responsible," according to Robert Edgar, now provost of Kresge College of UC Santa Cruz and formerly professor of biology at Caltech.

Sinsheimer's one-word summary of the job of the division chairman is "endless." Though he has reduced the size of the research group he supervises and has a new executive officer to assist him in the administrative work of the division, time (or the lack of it) is still a major problem in his life. He is constantly torn between feeling obliged to accept administrative jobs—both at the Institute and for national committees and organizations—and personal preference for study, research, and leisure to think. He is, for instance, a member of the council of the National Academy of Sciences and recently completed a term as president of the Biophysical Society. "I'm asked to do things outside my immediate sphere," he says, "and I usually end up saying yes more than I probably should."

The results are, of course, continuous dilemmas and choices—alleviated somewhat by his ability to plan ahead. Geraldine Cranmer, secretary to the last three biology division chairmen, testifies to Sinsheimer's sense of organization. "Whatever needs his immediate attention gets it," she says, "and we never have last-minute mad rushes to meet deadlines."

Under Sinsheimer's chairmanship the major thrust of the biology division is in behavioral biology—that is, in trying to understand how the central nervous system functions and how this in turn affects and is responsible for behavior. He sees the advances that are being made in molecular biology as containing within them the potential for large medical advances, and he feels this is something Caltech should be involved in. He also thinks there are great potentials in the application of advanced forms of engineering and systems analysis to medical problems. He would like to see biology develop a more extensive interaction with engineering and information science than it has had in the past, and he suggests that systems analysis also has major contributions to make to the understanding of basic biology. After all, he points out, when you talk about biological components, you talk about systems—the nervous system, the endocrine system, the vascular system, for instance—and their full understanding really requires applications of systems analysis.

"I think there could be a kind of engineering that was derived from biology," he says, "in much the same fashion as it has traditionally been derived from physics at Caltech. In fact, I think it would be sensible—looking ahead 50 years—for biology and biological applications to come to occupy a significantly larger portion of the total activities of the Institute."

Right now a problem that is occupying a lot of Sinsheimer time and thought is how to do a better job of combining education in science and technology with humanities. "We get very intelligent students here," he says, "and we don't damage them too much. We give them a good technical education, but many of them come out untrained to think in areas where value judgments enter in. I think it's our responsibility to try to do something about that. And somehow the teachers in the sciences have to get involved in it; we can't leave it all up to those in humanities."

Something about which Sinsheimer has very deep convictions indeed is that of the imminent intrusion of biological engineering in human life and the gravity of its moral implications. "It's coming on us," he says, "and it makes you question every value you have. Everywhere we are suffering the consequences of the thoughtless introduction of new knowledge and technology into our society, and many of those consequences are grievous and becoming more so. With similar lack of forethought, the consequences of the introduction of the knowledge that is at hand in biology and psychology can be disastrous. It's equally disastrous to take the attitude that we can stop where we are. We have to make a responsible choice about the extent to which we want to design our existence."

He was, of course, saying just that back in 1966 at the 75th Anniversary Conference:

> *After two billion years this is the end of the beginning. It would seem clear, to some achingly clear, that the world, the society, and the man of the future will be far different from that we know. Man is becoming free, not only from the external tyrannies and caprice of toil and famine and disease, but from the very internal constraints of our animal inheritance, our physical frailties, our emotional anachronisms, our intellectual limits. We must hope for the responsibility and the wisdom and the nobility of spirit to match this ultimate freedom. . . . We must ask that the changes we introduce be orderly and with humanity aforethought.*

—Jacquelyn Hershey

Research Notes

Controlling the Shakes

About the last thing any of us want to experience is an earthquake right under our feet. But if a joint research project with several petroleum companies materializes, that's exactly what Charles B. Archambeau, professor of geophysics, will be working toward. In fact, he and several other researchers will be hoping for a number of small earthquakes, or microquakes, the study of which will shed light on the possibility of controlling major shocks by inducing strategically placed lesser ones.

Archambeau expects microquakes to result when a group of oil companies try to beef up petroleum output in a Santa Fe Springs oil field by pumping great quantities of water at high pressure down the shafts of oil wells. Called repressurization, the technique has two effects: It forces the oil toward other wells where it is more easily pumped out; and it seems to reduce the "locking pressure" on faults or fractures, permitting the rocks on either side to slide, and resulting in the small earthquakes.

A similar test last year by the U.S. Geological Survey touched off nearly 1,000 microquakes in a Colorado oil field. When Geological Survey personnel reversed the process and drew the water out, the microquake activity turned off.

What Archambeau and the oil companies are doing in Santa Fe Springs needn't worry local residents. The shocks they induce won't even be felt on the surface. The important factor will be what's going on one to two miles beneath the surface, and Archambeau will use several delicate, highly sensitive seismometers to find out. The seismometers will record changes in the microquake pattern before, during, and after repressurization. The records will be transmitted to Caltech's Seismological Laboratory in Pasadena.

Charles Archambeau is testing the theory that inducing strategically placed microquakes might give the data that will make it possible eventually to control major earthquakes.

A computer there will use data on microquake and stress pattern changes and water flow dynamics to produce a model of the process. Archambeau expects to use the model to assess in detail what effects water has in causing or inducing earthquakes.

Ideally, repressurization will set off from 20 to 30 microquakes in the first six months of the year-long test. Archambeau estimates that 10 is a more realistic figure, but maintains that even as few as that should supply enough information to pinpoint the active areas, to learn the orientation of the stress field, and to outline the faults.

He is optimistic that lessons learned at Santa Fe Springs will bring us a step closer to earthquake control, and he theorizes that the ultimate outcome could be to replace the violent snap in the earth's crust that occurs in major earthquakes with slow or creeping movements that produce small harmless earthquakes. He hopes to find out if water can do the trick.

Associated with Archambeau in the experiment are David G. Harkrider, associate professor of geophysics; Donald Helmberger, assistant professor of geophysics; Wolfgang Knauss, associate professor of aeronautics; Ronald F. Scott, professor of civil engineering; and Robert L. Kovach, professor of geophysics at Stanford and now on leave at Caltech.

Mapping a Mystery

For centuries the planet Venus remained veiled, its secrets secure behind dense clouds that stubbornly turned aside the telescopic probings of astronomers.

But, in the last decade, Venus has grudgingly begun to surrender its anonymity to a new breed of astronomers who use radar waves to pierce the thick clouds to "see" the surface below. As a result, the mystery shrouding our next-door interplanetary neighbor is slowly being unraveled, and Richard M. Goldstein, manager of JPL's communication systems research section, and visiting associate professor of planetary science at Caltech, is contributing as much toward this unraveling as anyone in the field.

Venus, which is about 68 million miles from the sun and never closer to earth than 26 million miles, was the subject of Goldstein's doctoral dissertation, written in 1961. The problem then was to map the planet, and his plan was to get the job done by bouncing radar beams off its surface. He devised a technique that enabled him to do this, and while it has been honed considerably since then, it remains the basis of his current research.

Step number one in the operation is to direct radar waves toward Venus from the huge transmitter at the JPL-operated Goldstone Tracking Station in the Mojave Desert. The waves, about 12.5 centimeters long, are launched into space by the 450-kilowatt transmitter in a narrow-angle searchlight beam. By the time the waves reach Venus, they are so dispersed that most pass right on by. The rest are either absorbed by the planet's surface or deflected into space. However, a small but critical fraction return to earth as a barely audible echo, a tiny fraction of a watt. The round trip takes about 4½ minutes. Despite the feeble signal, Goldstone's 64-meter (210-foot) parabolic antenna and receiver provides enough sensitivity to allow Goldstein's team to determine quite a lot about where the signals have been.

If the signals bounce back unpolarized —that is, with their electric fields scrambled—they indicate rough terrain. Unscrambled echoes mean smooth surfaces. Goldstein draws other inferences from variations in the time it takes the signals to return—an indication of changes in distance—and from Doppler shifts, which are changes in wave frequency caused by the rotation of the planet.

A computer then processes these inputs to produce a two-dimensional map, composed of 40,000 mapping cells, that forms a visible trace of the planet's surface features. Each cell is one-half degree square and encompasses a 35-square-mile patch on the face of Venus.

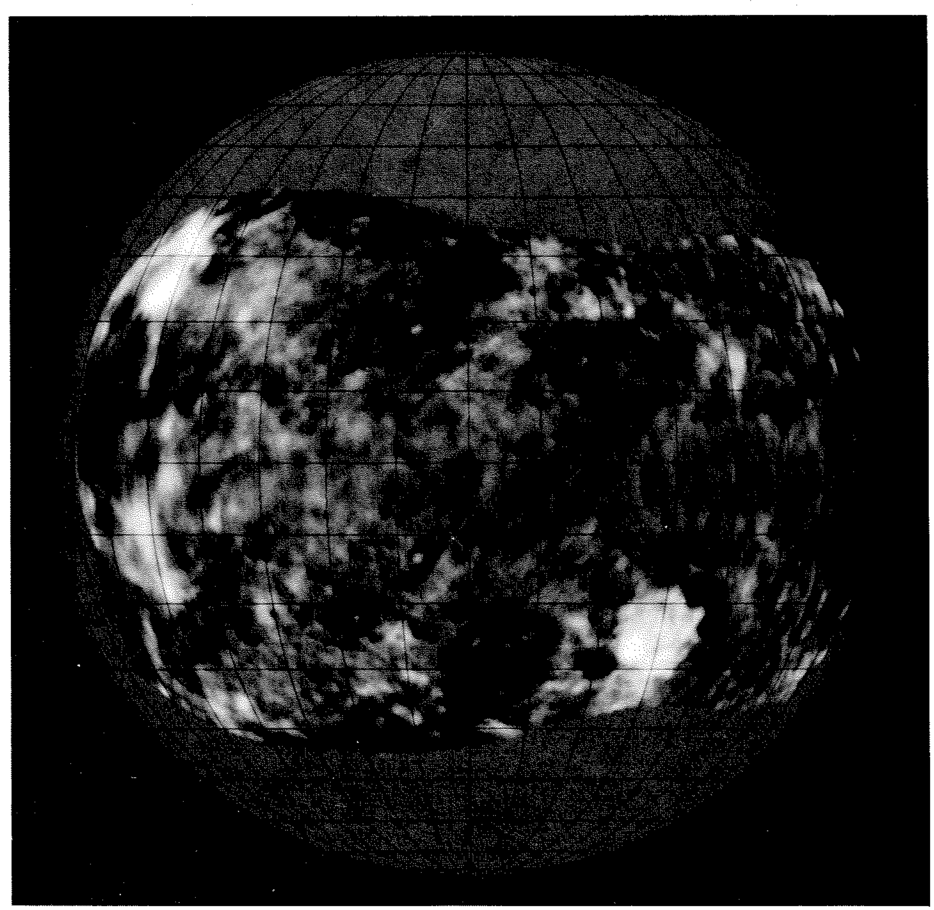
Goldstein has a long wait between mapping observations, because the most productive mapping occurs at 19-month intervals when Venus makes its closest approach to Earth. He has performed a radar experiment at each of the six opportunities since 1961. (*E&S*, November 1967).

Although dramatic increases in radar power and resolution techniques have vastly improved the maps, they are not without defects. One problem that faces Goldstein is his inability to determine the nature of surface features by the way they show up on the map. Radar-bright areas on Venus' surface could be the result of mountains, boulder fields, canyons, lava flows, and craters. He is seeking a way to tell them apart.

Goldstein may have found that way in interferometry, a new technique that he may use in June 1972 when Venus makes its next close pass to Earth. The technique will team Goldstone's 26- and 64-meter dishes to provide simultaneous readings as the basis for calculating the altitudes of surface features. The prospects are exciting, and Goldstein thinks the result may be the most conclusive surface map ever made of Venus.

Goldstein's romance with Venus has endured through his college days at Caltech and at JPL. Much of what he has done has influenced the development of new technology for the Deep Space Network (DSN) that JPL runs for NASA. Residual benefits like new transmitters, receivers, weak-signal processing techniques, and information about the orbits and rotations of the planets have had a strong influence on spaceflight navigation.

What comes next will depend a great deal on the direction of the space exploration program at JPL. Current priorities have Goldstein looking at Mars and Mercury and then making studies of Jupiter and Saturn. For the time being, however, Goldstein will be keeping at least one "eye" on Venus.



The latest map of Venus is actually a composite of two mappings made a year and a half apart. Then almost nine months of computer processing went into producing this final radar image.

Vanishing Silver and the Fall of Rome

A Caltech geochemist has come up with a new explanation for the fall of Rome. Clair Patterson, research associate in geochemistry, thinks the Roman Empire may well have gone under because it lost its supply of silver.

Dr. Patterson is convinced that the gradual accidental loss of silver stocks played an important part in determining the course of history. Fortunately, vanishing silver supplies do not upset national economies today because of the use of paper money and bank credit.

In ancient times, silver was lost in the form of coins and jewelry that were dropped and covered by soil or ashes, sunk in shipwrecks, buried in graves, or hidden away in undisclosed hoards. When the metal reached the moist earth, it corroded and was irrecoverably dispersed as silver salts.

Patterson's discovery of the high accidental loss rate of coined silver was made during his earlier research on air pollution. He discovered that lead from gasolines had infiltrated the atmosphere at both the north and south poles. In connection with that work, he began looking into lead production in ancient times. This meant he had to study old records of silver production because few records were kept for lead. Lead was obtained as a byproduct of silver—about 400 tons of lead being produced for every ton of silver.

Silver production was roughly inferred from silver stocks, such as the size of a king's treasury. However, silver production could only be accurately determined if the size of the stocks and the rate of the loss of silver were known. Patterson obtained that rate from data about modern silver losses, modified by physical conditions that might affect silver losses in those early times. He found that the loss rate figure in past times was surprisingly high—about 2 percent a year—and was due largely to the accidental loss of silver coins.

The general use of silver coins around 600 B.C. by the northeastern Mediterranean nations and their loss by handling caused silver stocks to begin to decline irrecoverably, with a half life of about 35 years. That is, every 35 years half the silver stocks vanished. Mine production had to equal this loss to maintain a steady level of stocks. The magnitude of the problem is illustrated by a case involving 2,200 tons of silver bullion plundered from Persia by Alexander the Great. The entire stock was put into coins by about 300 B.C., but by 160 B.C. this particular mass of silver had shrunk from handling losses to only 90 tons.

The development of coins after 600 B.C. was a strong impetus to the growth of the Roman Empire. It provided the Romans with the "mobile capital" they needed to evolve from the barter system of economy. With its new-found flexibility Rome was able to extend economic control over a vast empire and to govern the economy of most of the civilized world.

Rome's wealth was founded on the silver deposits of Spain, where slaves were used to boost the world's production rate of the ore nearly eight-fold. But, Rome's financial position began to slip when its production of silver failed to keep pace with the growth of the unexplained losses. Rome finally exhausted all her silver deposits. Within 150 years the Romans were forced to revert to the cumbersome barter system. In short, the Roman economy collapsed. After Rome's demise, the Dark Ages gripped Europe until rich German silver mines were opened about 900 A.D.

The fraction of total silver mined from ores and added to world monetary stocks from 1885 to 1938 was about 210,000 tons, plus 50,000 tons existing in 1885. But the total of world monetary silver stocks at the end of 1938 was only 160,000 tons—indicating a loss of 100,000 tons in 53 years.

The actual loss was even greater when the loss by industry was added to this tonnage. Today there are almost no silver coins in circulation. There are two reasons for this. One is the industrial demand for silver. The other is that, in this country at least, the silver in U. S. coins is worth about twice as much as their face value.

Although only about one millionth of the silver in the earth's crust has already been mined—most of it in the past 60 years—it represents most of the mineable silver. Like many other metal ores, the rich silver deposits were near the earth's surface and thus were easily extracted.

About another millionth of the silver in the earth's outer crust may be obtainable with present mining and smelting technology, but additional amounts beyond that will require new recovery techniques. The quantity of silver that still can be extracted from the earth in the form of very lean ores will depend upon demand—and technology.

Clair Patterson, research associate in geochemistry. His research on air pollution led to studies of silver.

The Month at Caltech

Lauritsen Lecturer

British cosmologist Fred Hoyle came to Caltech last month to give the second annual C. C. Lauritsen Lecture—"Recent Developments in Cosmology"—on October 18 in Beckman Auditorium. Three days later he spoke to an overflow audience in Bridge Laboratory on the question "Is the Gravitational 'Constant' Variable?"

Hoyle's qualifications both for delivering the prestigious Lauritsen lecture and for drawing a full house for anything else he has to say are exceptional. He became a Fellow of St. John's College in 1939, and after six years of service in radio research for the British Admiralty during World War II, returned to Cambridge to serve as University Lecturer in Mathematics. This appointment was superseded in 1958 when he was appointed Plumian Professor in Astronomy and Experimental Philosophy.

In 1967 Hoyle founded and became the first director of the Institute of Theoretical Astronomy in Cambridge—now one of the highest ranking international institutions in astrophysics and cosmology. He was elected a member of the Royal Society in 1957 and served as its vice president in 1970; and he is currently president of the Royal Astronomical Society, and a Foreign Associate of the U. S. National Academy of Sciences and the American Academy of Arts and Sciences. In 1968 he was awarded the Kalinga prize and the Gold Medal of the Royal Astronomical Society.

Although Hoyle is an originator of steady-state cosmology and a contributor to the concept of nucleosynthesis in stars and supernovae, his interests extend far beyond astrophysics. Subjects on which he has written books range from politics and sociology, through abstract science, to science fiction. He has also written a space play for children and a space serial for television. In addition, he is the author of an opera libretto.

Fred Hoyle

Hoyle is a visiting associate in physics at Caltech—an association that dates back to 1952 when he walked into Kellogg Radiation Laboratory and announced that his calculations on the structure of Red Giant stars convinced him that there was an excited state in the carbon-twelve nucleus near the threshold for formation from three-helium nuclei. Experiments quickly proved him right, and he has since returned frequently to the campus to confer with Institute physicists and astronomers. In recent years he has been working with William A. Fowler, Institute Professor of Physics, on supermassive objects in the universe.

Here to Stay

There are 29 girls in the new freshman class—the same number as last year. (There are also three transfer students this year: two sophomores and one junior.) There were more applicants this year, 86 compared to 77; and 44 of these were accepted, compared to last year's 39. A look at the application files for both sexes shows that the girls' science interests and experience are indistinguishable from those of the male applicants. Even their hobbies are similar—scuba diving, fencing, photography, and music, for example.

All but one of Caltech's first freshmen women weathered their first year at the Institute, and all but one have come back for their sophomore year. Even the girl who is not returning plans to come back after one year at another college.

Each of the sophomore girls seems to have the same basic attitude toward her first year—the nadir of the experience came in the second term when it was hard to have any perspective on their first term's work. In spite of the solace of the pass-fail grading system, most girls felt they were skating on thin academic ice. In fact, one girl—her bags packed—went to the dean's office and announced that she was a failure and would leave that same day. A check-up on her work revealed that her test grades were no lower than a majority of the others in her classes—male *or* female. She had just run into that old nemesis of the straight-A high school student at Caltech: enduring the change from being a big frog in a relatively small scholastic pond to being a little frog adrift in a big, deep lake.

Caltech's first coeds ran into heavy social pressures during the first term too; all too many of the male students were so intrigued by their novelty that they almost haunted the girls. ("You've got to admit," said one young woman, "that the ratio of 50 men to one girl is pretty weird.")

But the situation eased as soon as (a) the boys realized that in many ways the girls were no different from themselves and (b) the girls, getting a taste of the academic work load, faced up to holing up with the books or flunking out.

What the girls appreciate most—and had not expected—is the concern and the attention given them by faculty members. "It's amazing how personalized the whole atmosphere is," one girl says. "I can't get over how many people here seem to care whether I make it or not." (This is the girl, incidentally, who applied for Caltech because her current boy friend was applying. She made it; he didn't.)

Admission standards were not lowered in the slightest for the girls, so no girl came to Caltech unless she was really strong on science and interested in pursuing it. One girl pointed out that a lot of her mother's friends assumed she was at Caltech in order to catch a husband. "It's a laugh," she declares. "If that's what I was in college for, I wouldn't be at Caltech. I'm here because I want to learn science."

Graduate Studies

Stirling L. Huntley, former administrator at the University of Hawaii, has been appointed associate dean of graduate studies. He succeeds Harold Lurie, professor of engineering science, who is on leave of absence, and he will assist C. J. Pings, Caltech's vice provost and dean of graduate studies.

Huntley went to the University of Hawaii in 1969 as director of admissions, and later became director of participant services. From 1959 to 1969 he served in Stanford University's admissions office, the last four years as director of transfer and graduate admissions.

Born in Los Angeles, Huntley received his bachelor's degree from UCLA and a PhD in speech and drama from Stanford.

Some Faculty Honors and Awards

Harrison Brown

Harrison Brown

Harrison S. Brown, professor of geochemistry and of science and government, was elected president of a UNESCO-sponsored Intergovernmental Conference for the Establishment of a World Science Information System (UNISIST) held in Paris in October. UNISIST is an acronymic term that stands for both the proposed system and a three-year feasibility study that preceded the Conference.

The Conference, attended by delegates from more than 70 nations, was held to review the recommendations made by the UNISIST Committee and published in its report. The feasibility study, which lasted from 1967 to 1970, was headed by Brown and conducted jointly by UNESCO and the International Council of Scientific Unions.

Harold Brown

President Harold Brown has been elected to the board of directors of the Times Mirror Corporation.

Dan Campbell

Dan H. Campbell, professor of immunochemistry, has been honored by the California Museum of Science and Industry's Committee for Advance Science Training for the intensive training in biomedicine that he has provided for students. Campbell is internationally known for his research in allergens and skin-sensitizing antibodies. He received a plaque in a special ceremony on October 16 at the museum in Los Angeles.

Dan Campbell

Robert Huttenback

Robert A. Huttenback, professor of history, dean of students, and acting chairman of the division of humanities and social sciences, has received the third annual Walter D. Love Memorial Prize for his book *Gandhi in South Africa*. The Conference on British Studies made the selection for the award, which consists of a citation and an honorarium, and it was presented at Roosevelt University in Chicago on October 30.

Jack E. McKee

Edwin S. Munger

Jack E. McKee

Jack E. McKee, professor of environmental engineering, has been named an honorary member of the Water Pollution Control Federation. McKee, who is acknowledged as one of the world's foremost experts on water quality, was cited for his "distinguished career as a teacher and consulting engineer." The Water Pollution Control Federation, of which McKee was once president, is a technical group whose 23,000 members and subscribers offer the most authoritative cross section of views on the subject of water pollution control.

Edwin S. Munger

Edwin S. Munger, professor of geography and a specialist on sub-Saharan Africa, is the new president of the L. S. B. Leakey Foundation. The Los Angeles-based foundation, named in honor of the famed anthropologist, L. S. B. Leakey, was set up three years ago to support the study of man, his origins, evolving nature, and the future of the environment.

George S. Hammond

George S. Hammond, Arthur Amos Noyes Professor of Chemistry and chairman of the division of chemistry and chemical engineering, is one of ten recipients of the 1971-72 E. Harris Harbison Awards for Gifted Teaching. The grants, in the amount of $10,000, are given by the Danforth Foundation and are named for a former member of its board of trustees. The award was presented to Hammond at a dinner in St. Louis on November 6.

Caltech's official nomination of Hammond for the award emphasized two aspects of his career as an educator: first, the close professional and personal interaction he has encouraged and maintained with his undergraduate and graduate students throughout his distinguished scientific career; and second, the tremendous contribution he has made to the growth of chemical education in general through public lectures, writing, and restructuring both individual courses and entire undergraduate curricula. These efforts have influenced the education of thousands of students in the United States and abroad.

Olga Taussky Todd

Olga Taussky Todd, professor of mathematics, has won one of the annual Lester R. Ford Sr. awards of the American Mathematical Association. A maximum of six of these awards are given yearly for articles published in the *American Mathematical Monthly* and selected for honor by a panel of judges.

Olga Todd received recognition for her article, "Sums of Squares," which covers a wide mathematical survey of algebra, number theory, analysis, and topology. The article discusses very modern mathematical theories, links between older theories, and other aspects of Dr. Todd's work.

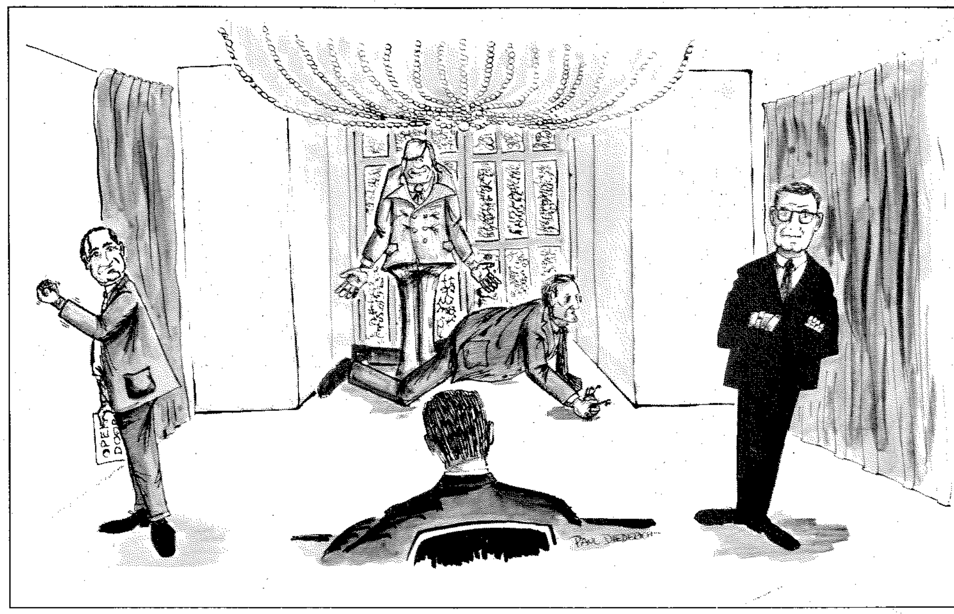
Roger W. Sperry

Roger W. Sperry, Hixon Professor of Psychobiology at Caltech since 1954, has received the Distinguished Scientific Contribution Award of the American Psychological Association. The award, which includes a $1,000 honorarium, was presented to Sperry at the Association's 79th annual meeting in Washington, D. C., this fall. It recognized Sperry for advances in the study of brain function resulting from the split-brain surgical technique that he developed.

Out of his work has come the discovery that animals and man have two personalities, and the knowledge that man's two cerebral hemispheres are specialized—the left hemisphere dealing with language and the right hemisphere with special problems and some forms of creativity.

The Life in a Day with the Faculty Board

Ever wonder what goes on in higher academic circles? An exclusive inside report by C. J. Pings.



The first meeting of the Faculty Board for the 1971-72 academic year was called to order by the Chairman of the Faculty, GEORGE W. HOUSNER, *in the Millikan Board Room at 3:05 p.m. on Monday, October 8, 1971. The call to order was delayed slightly while the Secretary of the Faculty,* PROFESSOR DONALD HUDSON, *moved to the back of the room to close the main doors to the Board Room. Present were various elected and ex-officio members and guests, including undergraduate and graduate student representatives and several faculty members having specific items on the agenda.*

After approval of the minutes of the meeting of May 3, 1971, the chairman called on the president and then the provost for various announcements, which took perhaps 25 minutes in view of the accumulation of business over the summer months. The chairman then announced the appointment of several individuals to the Graduate Studies Committee, and separately the membership of the newly approved Student Housing Committee.

At this point the student body president, STEVEN WATKINS, *quietly arose and left his place at the table.*

HOUSNER: "I have one last announcement. Since two members of the Faculty Board, Professors Gell-Mann and Pine, will be away this year I should designate replacements."

WATKINS: (*returning to the middle of the room*) "Can anybody tell me how I can get out of here?"

There is a somewhat nervous silence while several people shuffle papers, and finally PROVOST CHRISTY *replies curiously:*

"Do I understand that you no longer wish to attend Faculty Board meetings?"

WATKINS: "No, I just want to get out of the room."

CHRISTY: (*relieved*) "Oh. That door is rather heavy; just give it a good push."

WATKINS: "I did. It's locked. And there's no handle on the inside."

CHRISTY: "There's a telephone in the cloakroom. You might call the librarian and ask him to have the door opened from the outside."

HOUSNER: "Perhaps we can get along with our business. As I said, in view of the absence from the campus this year of Professors Pine and Gell-Mann—"

WATKINS: (*returning to the room*) "The cloakroom is locked."

PROVOST CHRISTY *and* PROFESSOR INGERSOLL *arise and accompany* WATKINS *to the back of the room. They push briefly and impotently at the door.*

HOUSNER: "Perhaps while this is going on we can continue. I was suggesting again—"

The attending members are less than fully attentive as they all watch CHRISTY *attack the cloakroom. The door is finished beautifully flush with the paneling of the entry hallway, and there is no protruding handle. However, there is a lock some 18 inches from the floor.* CHRISTY *is now down on his knees trying all the keys at a provost's disposal.*

HOUSNER: "Perhaps while this is going on we can continue."

He is interrupted by CHRISTY *returning to his seat, shaking his head in defeat.* PROFESSOR ROBERT HUTTENBACK *leaps to his feet.*

HUTTENBACK: "I'll get us out of here."

He goes to the north window, shoves aside the drape, and begins pounding on the window. A student passes by. HUTTENBACK *pounds more loudly, gets the student's attention, then waves his arms frantically. The student smiles broadly, waves back, and proceeds on up the stairs to the Millikan Library.*

HUTTENBACK: "We're really trapped. They can't even hear us on the outside."
HOUSNER: "Perhaps we can proceed."
HUTTENBACK: "Yes, yes. Go ahead with the meeting. I'll get somebody's attention."
HOUSNER: "In view of the vacancies—"

He is interrupted by HUTTENBACK *firmly pounding with both fists on the window as a group of three Oriental students passes by. They stop and stare, fascinated, at the Dean of Students and Acting Chairman of the Division of Humanities and Social Sciences pounding wildly on the window, with several other faculty members standing behind him.*

HUTTENBACK: (*shouting in a loud voice*) "We're locked in. Get somebody to open the door."

He points in the direction of the locked back door. As he shouts louder—still unheard on the outside—and points more forcefully, the students nervously edge away and finally turn their backs on the whole proceedings and stride quickly out of sight.

HUTTENBACK: "They simply can't hear us. We need a sign."

VICE PROVOST PINGS *turns over his copy of the agenda and scrawls on the back side in large letters:* "OPEN DOOR." *He hands this to* HUTTENBACK, *who holds it up to the window and waits expectantly for another passerby.*

HOUSNER: "While we are waiting—" *but he is interrupted.*
PROFESSOR BERGMAN: (*rather nervously*) "Is it true there is no fire exit in this room?"
PRESIDENT HAROLD BROWN: "No . . . I guess . . . there is not. If we were really in trouble, I suppose we could throw a chair through the window and wade out through the moat."

HUTTENBACK *starts pounding again as another group of three students, again principally from the Far East, comes into view.*
HUTTENBACK *shouts, pounds on the window, and points to the sign. The students stop, try in vain to hear* HUTTENBACK, *and with some interest look at the sign. They talk to each other, smile knowingly, and walk off, perhaps feeling that* HUTTENBACK, *the distinguished professor of history, is belatedly advocating a new foreign trade policy for the United States.*

HUTTENBACK: "We'll have to put more information on the sign."

PROFESSOR SHAIR *writes out a more detailed message which he hands to* HUTTENBACK, *who now holds both signs in the window and waits, only briefly, until an undergraduate emerging from the library passes by.* HUTTENBACK *pounds vigorously. Without really breaking his pace, the student nervously looks the situation over out of the corner of one eye, elects for non-involvement, and keeps moving with a determined step.*

HUTTENBACK: "@#~/%&!"
PRESIDENT HAROLD BROWN: "Perhaps he has gone to tell other students, and they will make demands for our release."
HUTTENBACK: "Ah! I think I have somebody this time."

He begins to gesture and pound at two passing employees of Physical Plant. They respond quickly to the pounding, gesturing, and the sign, and move on—can it be?—in the direction of solving the problem.

HOUSNER: "I suspect that our problem will shortly be solved now and perhaps we can return—"

It is to no avail, as three or four board members arise and stand expectantly on the inside of the Board Room doors, and a somewhat excited random dialogue goes on in the background.

VOICES: "Well, even *they* may not be able to get us out immediately. The lock is some sort of an electronic device."

"Well, at least it wasn't the *trustees* that were locked in."

"Nice image for an engineering faculty, I must say!"

There is a babble of excitement at the door and then a sigh of relief from everybody in the room, as one side of the massive door swings open. Several step outside to inspect the door from the exterior, but it slowly starts to swing closed again. The resulting gasp in unison from everyone in the room causes somebody to grab the closing door, open it all the way, and firmly latch it in an open position.

WATKINS *and several faculty members leave.*

HOUSNER: "Gentlemen, it will come as no surprise to you that I am filling the Pine and Gell-Mann vacancies on the Faculty Board by the appointment of Professors Leverett Davis and James Gunn to serve for this year. Now that the announcements are out of the way, perhaps we can move to the next item of business on the agenda."

Books

MODELS IN CHEMICAL SCIENCE
An Introduction to General Chemistry

*By George S. Hammond, Janet Osteryoung, Thomas H. Crawford, and Harry B. Gray**

W. A. Benjamin, Inc. *$10.95*

Reviewed by David H. White
Graduate fellow in chemistry

Models in Chemical Science is a successful attempt to present chemistry at the introductory level as a human intellectual process instead of the authoritative every-question-has-a-right-answer approach common to undergraduate textbooks. The thesis of the authors is that "everyone in science uses models in thinking about experimental data. We scientists tend to focus not on the real thing but on the behavior of our own mental constructs."

Hammond, Osteryoung, Crawford, and Gray believe that reality is always more complex than we can visualize or even fully understand. Thus, we use models, or theories, which are always approximate and tentative, and may have to be revised or discarded as new evidence is found.

This is a concept that few students encounter until they reach advanced studies (if, indeed, they ever encounter it at all) when it comes as a shock to realize that science doesn't provide any sure answers. So this book is welcome, as is any presentation which shows science as a fallible, open-ended, human enterprise instead of a superhuman certainty. Such an orientation encourages a healthy questioning of established ideas and established experts, and is necessary to understand the basic nature of science.

The only mathematical background required for understanding this book is algebra, and mathematical derivations are minimized but not avoided altogether. Difficult topics such as thermodynamics and reaction dynamics are clear and understandable. Organic and inorganic examples are combined to illustrate many concepts in a way that makes them both seem integral parts of the whole of chemistry.

One especially colorful example is used to illustrate a number of concepts in reaction dynamics. Two tennis players, George and Eileen, take 1,000 tennis balls to the court but forget their rackets, so they make up a game. Starting with 500 balls in each court, each begins picking up and throwing the balls on his side over to the other side as fast as possible. They soon reach a dynamic equilibrium, resembling many chemical reactions.

The book is designed for non-chemistry-major students who have never taken a chemistry course before and will probably never take another, and it serves this purpose well. It de-mystifies science while presenting a solid enough background to understand what chemistry is and to begin to cope with the increasing numbers of chemical problems appearing in the newspapers every day. Regrettably, the discussion of "relevant" topics, such as air pollution and drugs, is rather sketchy and undetailed. However, the authors do a fairly thorough job of presenting the theories that chemists actually use in their work.

Perhaps the book would also be useful as a high school text. Those students bound for scientific majors in college would be well prepared by it to handle the concepts and the more rigorous techniques of a college chemistry course.

*George S. Hammond is Arthur Amos Noyes Professor of Chemistry and chairman of the division of chemistry and chemical engineering at Caltech; Janet Jones Osteryoung (Caltech chemistry PhD '67) is now assistant professor in the department of civil engineering at Colorado State University; Thomas H. Crawford is professor of chemistry at the University of Louisville; and Harry B. Gray is professor of chemistry at Caltech.

OSCAR MANDEL'S COLLECTED PLAYS, Volume 1

Unicorn Press . . . . *Clothbound $7.50*
Paperbound 2.95

Reviewed by J. Kent Clark
Professor of English

In some ways, the drama of Oscar Mandel (Caltech professor of English) seems too intelligent, witty, polished, and literate to be contemporary. Its crisp, tight organization, its clear definition of dramatic issues and characters, and its cool satirical edge sometimes seem closer to the world of Molière than to the worlds of Miller, Albee, Beckett, Ionesco, and Pinter—to say nothing of the murky worlds of the *now* theater. It is not neurotic, psychotic, confessional, guilt-ridden, sex-ridden, or absurd; it avoids merely topical "relevance" as it would adolescent acne. Furthermore, the setting of the plays is often remote from the contemporary scene: Homeric Greece, Saxon England, Roman Spain. And even settings that are ostensibly modern have been removed by at least one level of abstraction from naturalistic realism.

Finally, Mandel's plays show a sense of style—the incisive word, the deceptively "inevitable" phrase, and the subtly poetic speech—that is almost unknown in contemporary American drama. This stylistic artistry, it should be added, not only makes the plays delightful to read or hear but also serves in classical fashion to keep the proper dramatic distance between the audience and the characters.

But if the style, the angle of approach, the restraint, the finish, and the organization of Mandel's plays derive from the classical European tradition, the subject matter and the psychological concerns of his drama are the preoccupations of twentieth century humanity: loneliness (cosmic and personal), war, death, moral responsibility, idealism, and general human cussedness. Paradoxically enough, Mandel, with his ironic detachment and his scorn for passionately topical drama, writes plays of wider relevance and more genuinely modern substance than do many relentlessly contemporary playwrights. His *General Audax*, for example, though set in Spain about 140 B.C., has more to say about the issues raised by twentieth century existentialism than Sartre's *Dirty Hands*, which has already become a preachy period piece of the 1940's. Similarly, Mandel's *Island*, though it never mentions the word "scientist," examines the human problem of the scientist and the military in more philosophical and emotional depth than does *In the Matter of J. Robert Oppenheimer*.

In such plays, of course, Mandel is obliged to pay the price for removing his drama from the naturalistic contemporary scene. He must devote more time and ingenuity to exposition—to setting up situation and character; he must get along without stock audience responses, topical references, and local color; and he must trust his audience to make the connections between timeless dramatic action and current dilemmas. The fact that he can pay this price and still produce effective, moving drama testifies to his skill as a writer and his sensitivity to central modern problems.

Whether comic or serious, or both, Mandel's plays are characterized by a lively energy. Occasionally, in fact, Mandel is too lively and inventive for his own good. His comedies are sometimes so loaded with wit and paradox that they are hard to assimilate at a comfortable speed. The audience is apt to find itself panting behind the turns of phrase, situation, and character motivation. This is particularly true of *A Splitting Headache* and *The Virgin and the Unicorn*. Occasionally, too, his invention lures him into overdeveloped speeches which impede the action for the sake of an elegant or subtle thought. In general, however, he controls his wit, invention, and rhetoric remarkably well, with an instinctive appreciation for dramatic values.

The publication of the first volume of Oscar Mandell's plays reveals a first-rate, mature talent. The second volume, which will be published shortly, should be equally exciting to devotees of modern drama.

THE NAME ABOVE THE TITLE
An Autobiography by Frank Capra

The Macmillan Company $12.50

Reading Frank Capra's autobiography is just as good as seeing a Capra movie—and that's still pretty good. Like a Capra movie script, it's got everything—action, suspense, spunk, sentiment, honesty, patriotism, vitality, gags, guts, good guys to root for, and bad ones to hope that they get their just deserts.

The book is, naturally, mainly concerned with Capra's 40-year career in motion pictures. (He made about 60 of them.) From the day he bluffed his way into the business in San Francisco and made a one-reel film of Kipling's "Ballad of Fultah Fisher's Boarding House," the story moves at a breakneck pace through Frank's days as gag man for Hal Roach's *Our Gang* comedies, then for Mack Sennett, into directing with Harry Langdon, on to Columbia Pictures and the great days of *Lady for a Day, It Happened One Night, Mr. Deeds Goes to Town, Lost Horizon, You Can't Take It with You, Mr. Smith Goes to Washington*. There was *Meet John Doe* after that, and *Arsenic and Old Lace,* before World War II, when Frank volunteered his services, was commissioned a lieutenant colonel by the Signal Corps, and —against constant opposition—made the classic series of troop information films, *Why We Fight*. Then came *It's A Wonderful Life* (Capra's favorite of all his pictures) and *State of the Union*, before a couple of Bing Crosby pictures, a Sinatra one, a catastrophic remake of *Lady for a Day*, and Frank's retirement from the New Hollywood.

Capra is 74 now, living in La Quinta. His family emigrated to Los Angeles from Sicily when Frank was 6. Everyone else in the family went to work, but Frank wanted to go to school. He was allowed to do this as long as he paid his own way. So he sold papers, worked as a janitor, played guitar in a bar, got through high school, saved $700—and entered Caltech in February 1915. (It was Throop Polytechnic Institute then.) The family had a lemon grove in Sierra Madre by this time, and Frank rode back and forth to school on a second-hand motorcycle. He was a waiter in the campus dorm, ran the dormitory laundry agency, and worked (for 25¢ an hour) for the night engineer at the Pasadena Light & Power plant.

His daily routine should make thoughtful reading for Caltech undergraduates today:

"This was my twenty-four-hour day: up at 3:00 A.M. at ranchhouse, lit small bonfire under motorcycle crankcase to heat up cold oil. Lit acetylene headlight (about as much light as a modern flashlight), then pushed the Flanders down dirt road until single cylinder sputtered into action; leaped on the seat and noisily raced eighteen miles in the dark to the Pasadena Light plant. On rainy nights, the rides were half-drowned ordeals of slips, slides, and muddy spills.

"3:30 to 7:30 A.M.: checked boiler fires, polished miles of metal at the Light plant. Then raced three miles to school to help other four waiters wash breakfast dishes for sixty-five dorm students. Ate breakfast while working.

"8:00 A.M.: ran to my first class. 11:55: ran with four other waiters to serve lunch at dorm; washed dishes, ate lunch while working. 1:00 P.M.: ran back to class.

"5:00 P.M. to 6:00 P.M.: glee-club or football. Then set tables, served dinner, washed dishes, ate dinner.

"7:00 P.M.: jumped on motorcycle, raced fifteen miles to Sierra Madre. Last quarter mile of dirt road was so steep had to jump off and push the Flanders. On a rainy night, it was a wrestling match with a wild steer.

"7:30 P.M.: backed motorcycle into shed, put paper and sticks under crankcase for bonfire in morning.

"7:30 P.M. to 10:00 P.M.: study and homework. 10:00 P.M.: to bed. 3:00 A.M.: up and lit bonfire under crankcase.

"What did this schedule do to my studies? Nothing. I won the Freshman Scholarship Prize: $250.00 and a trip around the country, and the sincere congratulations of my proud teachers: Dr. Bates (chemistry), Dr. Van Buskirk (mathematics), Dr. Beckman (German), Professor Sorensen (electrical engineering), Professor Clapp (geology), and proudest of all, Professor Judy (English)."

Statement of ownership, management and circulation (Act of August 12, 1970: Section 3685. Title 39. United States Code). 1. Title of publication: Engineering and Science. 2. Date of filing: September 29, 1971. 3. Frequency of issue: 7 times a year. 4. Location of known office of publication: 1201 E. California Blvd., Pasadena, Calif. 91109. 5. Location of the headquarters or general business offices of the publishers: 1201 E. California Blvd., Pasadena, Calif. 91109. 6. Names and addresses of publisher, editor, and managing editor: Publisher: California Institute of Technology Alumni Association. Editor: Edward Hutchings Jr., Managing Editor: Jacquelyn Hershey, 1201 E. California Blvd., Pasadena, Calif. 91109. 7. Owner: California Institute of Technology, 1201 E. California Blvd., Pasadena, Calif. 91109. 8. Known bondholders, mortgagees, and other security bolders: none. 10. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during the preceding 12 months. 11. Extent and nature of circulation: A. Total no. of copies printed: average during preceding 12 months, 9074; actual number of latest issue, 8700. B. Paid circulation: 1. Sales through dealers and carriers, street vendors and counter sales: average during last 12 months, 20; actual number of latest issue, 20. 2. mail subscriptions: average during last 12 months, 5803; actual number of latest issue, 5720. C. Total paid circulation: average during preceding 12 months, 5823; actual number of latest issue, 5740. D. Free distribution by mail, carrier, or other means: 1. samples, complimentary, and other free copies: average during preceding 12 months, 2951; actual number of latest issue, 2760. 2. copies distributed to news agents, but not sold: none. E. Total distribution: average during preceding 12 months, 8774; actual number of latest issue, 8500. F. Office use, left-over, unaccounted, spoiled after printing: average during preceding 12 months, 300; actual number latest issue, 200. G. Total; average during preceding 12 months, 9074; actual number of latest issue, 8700. I certify that the statements made by me are correct and complete. Edward Hutchings Jr.

EINSTEIN: THE LIFE AND TIMES
By Ronald W. Clark

World Publishing Company $15.00

The special distinction of this new biography of Einstein seems to be its bulk. There have been plenty of books about Einstein the scientist, Einstein the public figure, or Einstein the man, but this one deals with all three. The result is a massive book of more than 700 pages. Obviously, the book involved an enormous amount of research, and in trying to crowd it all in the author often creates considerable confusion.

Mr. Clark is a British writer who has produced a number of books on scientific subjects—including *The Birth of the Bomb*, and biographies of such British scientists as J. B. S. Haldane, the Huxleys, and Sir Henry Tizard.

As a non-scientist, Mr. Clark makes Einstein's scientific contributions fairly comprehensible to an interested layman —and his accounts should not unduly outrage any physicist readers.

In dealing with Einstein the man, Mr. Clark has to deal with the fact that Einstein always went to great pains to keep his private life just that. ("When a man after long years of searching chances upon a thought which discloses something of the beauty of this mysterious universe," Einstein once said, "he should not therefore be personally celebrated. He is already sufficiently paid by his experience of seeking and finding." And again: "Personally I consider it indecent to delve into people's private affairs and the world would certainly fare better if newspapers cared more for things that really matter instead of dealing with trifles.")

Mr. Clark, then, has to rely pretty much on the printed record, and his comprehensive research uncovers the trifles along with the important events in Einstein's life (including the familiar, and possibly apocryphal, trifle concerning the Einsteins' visit to Mt. Wilson, where Mrs. Einstein was told how the big 100-inch telescope was needed for establishing the structure of the universe. "Well, well," she replied, "my husband does that on the back of an old envelope.").

A considerable portion of this biography is devoted to the public Einstein and his attempts to deal with such social and political problems as pacifism, Zionism, and the atom bomb. But the particular interest for Caltech readers will probably be in the accounts of Einstein's two visits to the Institute in 1930 and 1932. Even though he does refer to Caltech's predecessor as "Troop College of Technology," and locates the Mt. Wilson Observatory "high in the Sierra above Pasadena," Mr. Clark provides some interesting glimpses of life at Caltech in the early thirties, and an intriguing, gossipy account of some "financial sleight of hand" by R. A. Millikan and Arthur Fleming—which apparently caused Einstein to turn down a permanent position at Caltech.

notes & news

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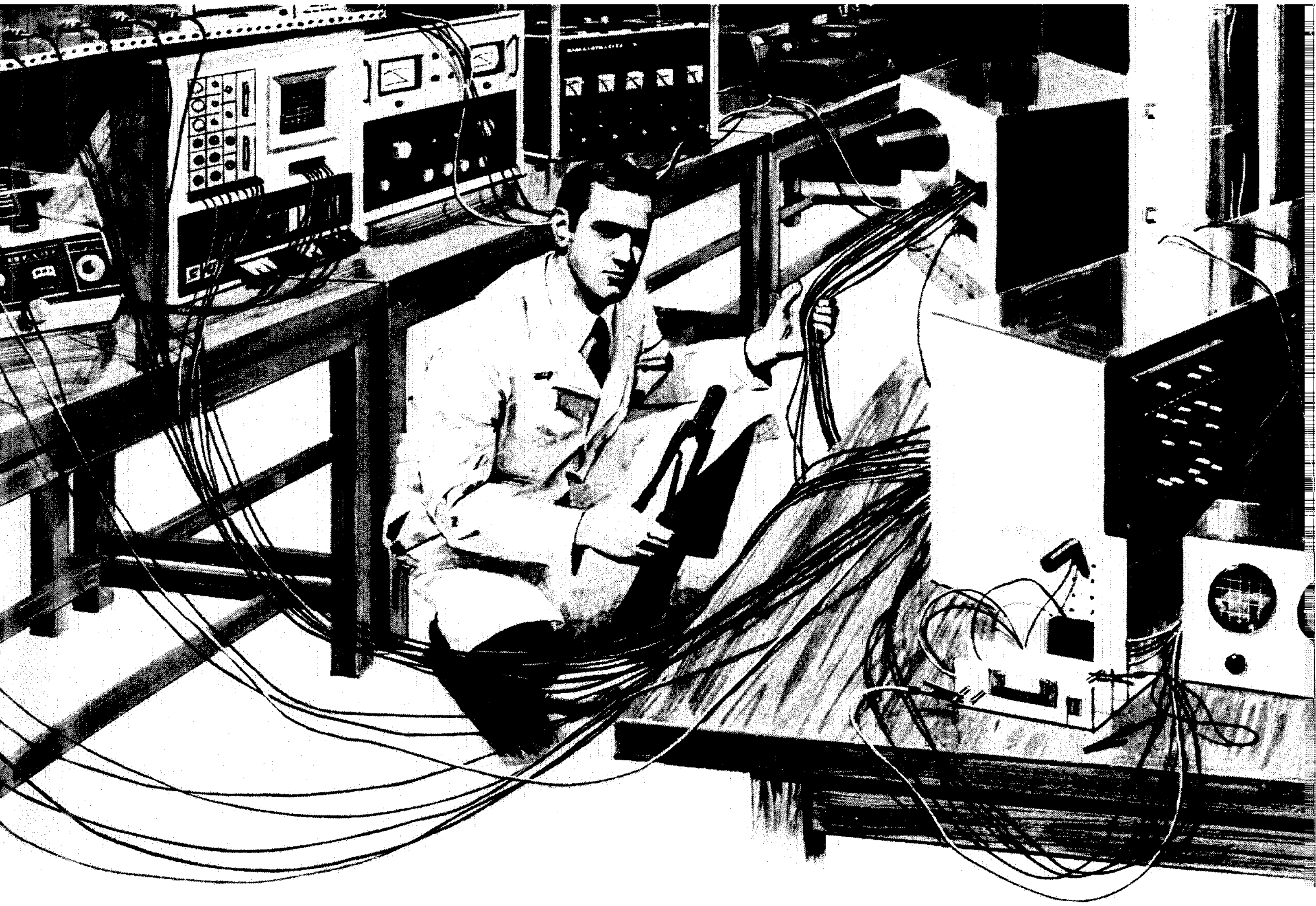

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