JUNE 1967

ENGINEERING AND SCIENCE

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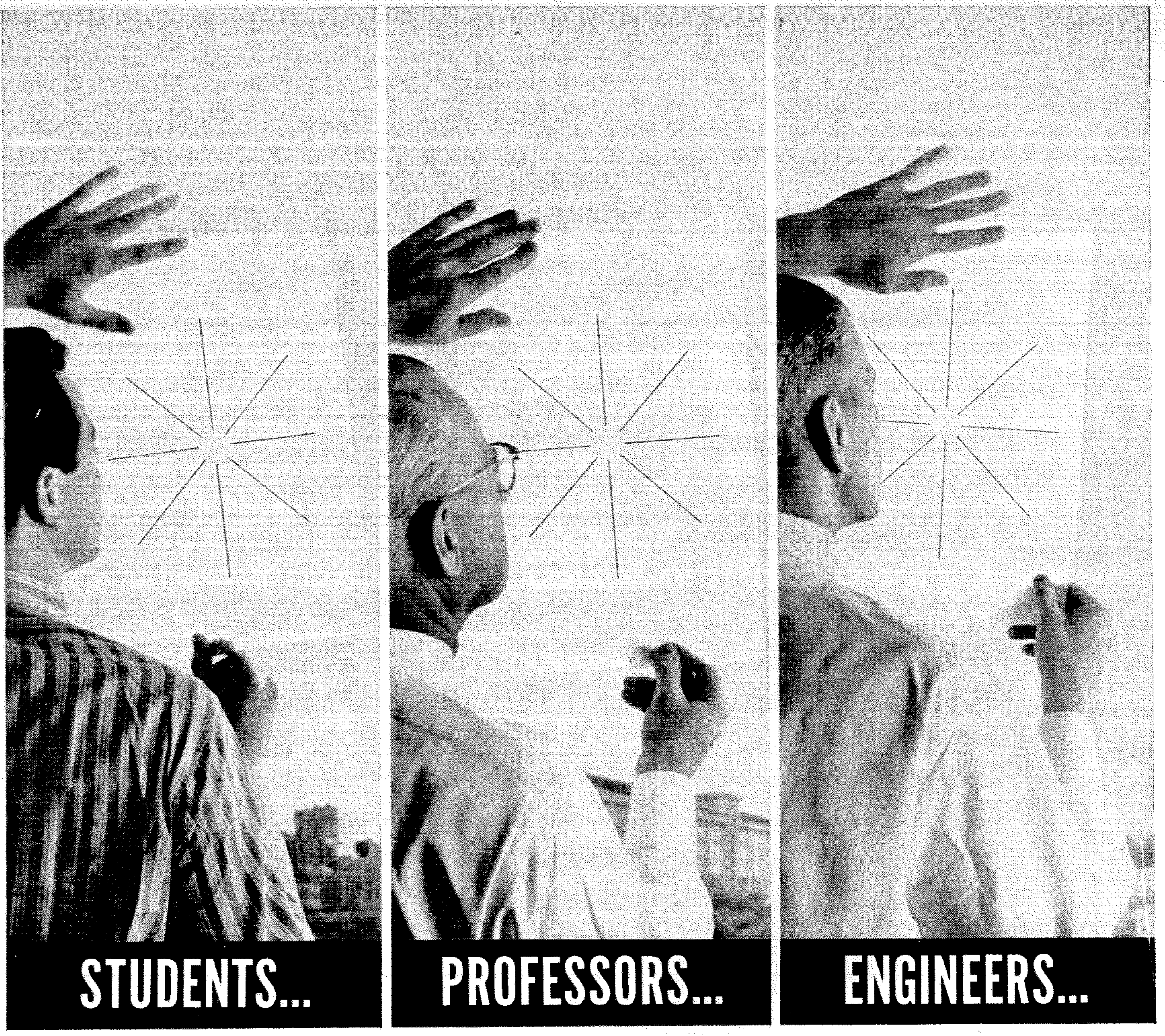

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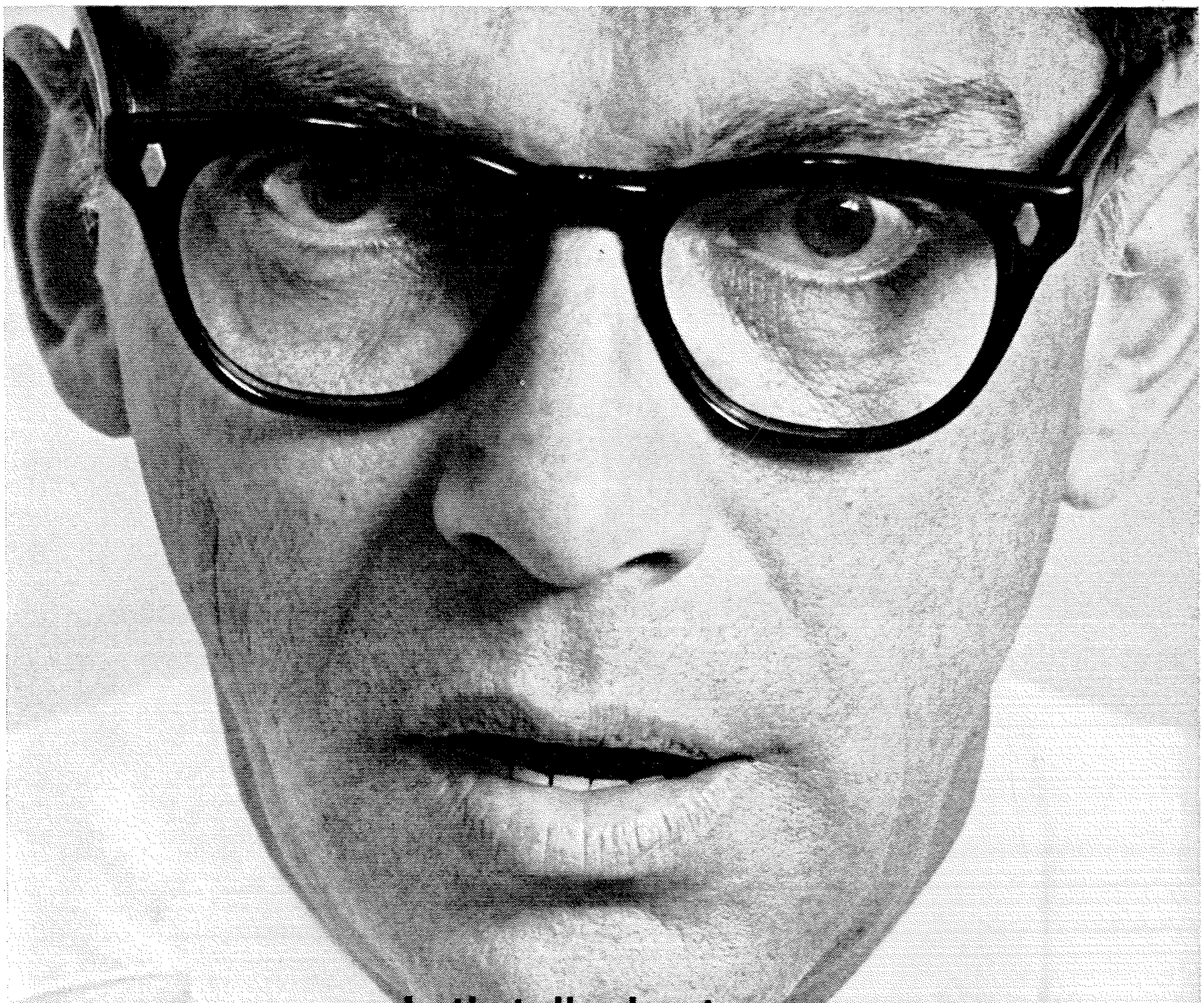

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COVER

When Surveyor III carried the surface sampler experiment to the moon in April, scientists got their first look—via television pictures—at excavated lunar soil. Behind this successful scooping operation is the work and direction of Caltech's Ronald F. Scott, professor of civil engineering and principal investigator for the experiment. In "Digging on the Moon," on pages 10-14, Dr. Scott describes the development of this initial lunar excavation.

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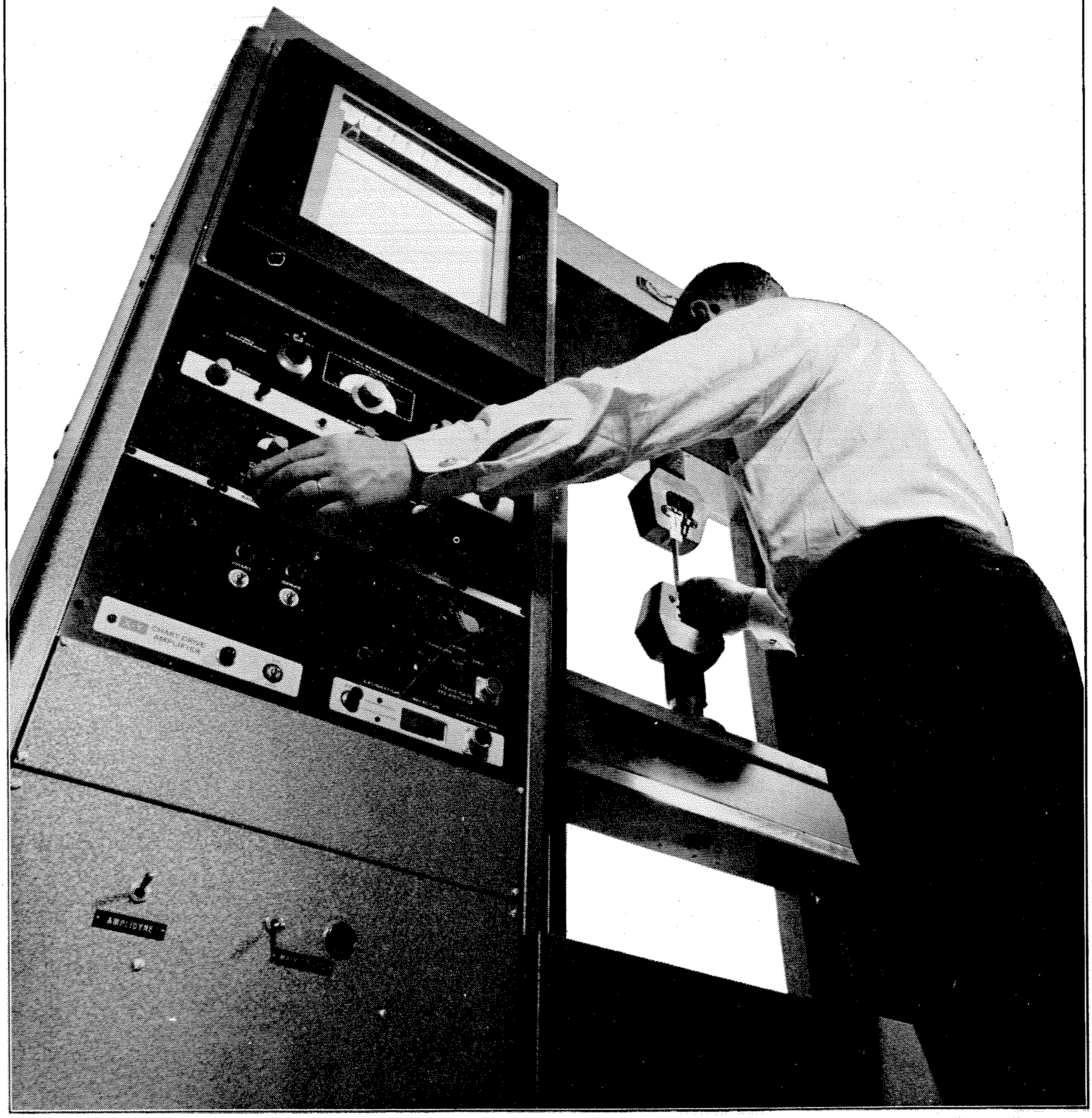


BOOKS

Rage or Raillery

by George P. Mayhew

Huntington Library *$6.50*

Reviewed by J. Kent Clark
professor of English

This book is the happy result of several years' study on some 60 Jonathan Swift manuscripts held by the Huntington Library in San Marino. It is at once a first-rate job of literary detective work, a lively contribution to Swift biography, and a significant addition to Swift criticism and bibliography. Although written primarily for professional scholars and advanced students of Swift, the book reaches the vast army of Swift amateurs, which includes practically all literate readers of *Gulliver's Travels* and *Tale of a Tub.*

As a literary detective, George Mayhew, who is associate professor of English at Caltech, traces the provenance of the manuscripts and places the undated or controversial documents in their biographical context. He succeeds, for instance, in establishing the probable date at which Swift composed an important portion of *The Four Last Years of the Queen* and in showing where Swift got the information which the autograph manuscript contains. He establishes the approximate date of an early Swift will and demonstrates how the terms of the will were altered as a result of a fierce controversy. He shows how scratch notes and cryptic jottings reappear, years later, transformed into literary satire and comedy. These discoveries, along with many others, illuminate facets of Swift's life and also throw light upon his methods of composition.

The general effect of Dr. Mayhew's biographical contributions is to correct the romantic distortions of 19th-century biographers and the pseudo-psychology of 20th-century critics. By showing Swift at close range and keeping him firmly placed in his 18th-century milieu, Dr. Mayhew lets us see a day-to-day Swift, who is more believable, more complex, and more interesting than the grand caricatures which have often been palmed off on us. Particularly valuable is the account of Swift's recurrent deafness and giddiness. Dr. Mayhew describes the illness which harrassed Swift throughout his adult life and explains its effects upon his activities and attitudes. He analyzes successive versions of Swift's poem "On His Deafness," showing how an original mood of despair and self-pity is transmuted into stoic irony. Equally fascinating as biographical information is the discussion of Swift's "Letter to a Young Lady on Her Marriage." It describes the Dublin social background, identifies the actual cast of characters involved, and elucidates some of Swift's idiosyncratic views on women and marriage.

Among the many textual and critical problems treated in *Rage or Raillery,* perhaps the most interesting is the analysis of Swift's Anglo-Latin word games. Swift, who was a good Latinist and an inveterate punster, made his first bilingual pun at the age of six and continued throughout his life to make wild combinations of Latin and English. By the time of *Gulliver's Travels,* he had constructed three separate comic languages with which to confound and amuse his friends. These languages have often confounded and seldom amused his critics, who have largely ignored them or dismissed them as the bagatelles of a senescent Swift. Dr. Mayhew has explained the systems, decoded some flagrant specimens, and pointed out the relevance of Swift's word play to his more serious literary compositions. In the word games one often sees the germ of a powerful satiric idea, and one always finds the fascination with words, the restless creativity, and the discriminating ear that make Swift one of the great masters of the language.

As befits a student of Swift, Dr. Mayhew writes with clarity and without rhetorical ostentation. *Rage or Raillery,* besides being handsomely produced, carefully indexed, and well documented, is a pleasure to read. It is sure to consolidate Dr. Mayhew's already strong position among contemporary Swift scholars.

The Character of Physical Law

by Richard Feynman

The M.I.T. Press (paperback) *$2.45*

Reviewed by Kip S. Thorne
research fellow in physics

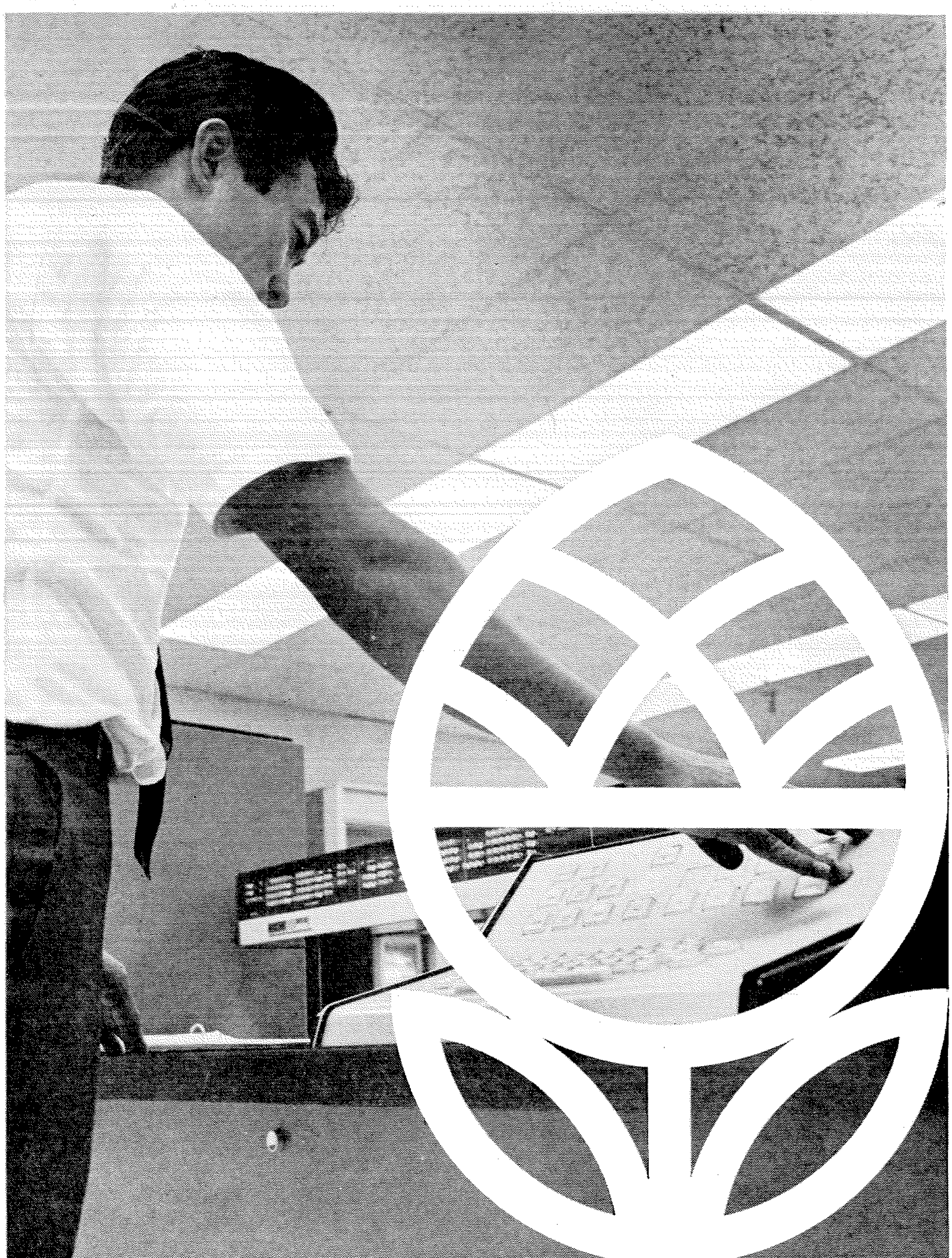
Richard P. Feynman, Caltech's Richard Chace Tolman Professor of Theoretical Physics, presented seven lectures, in extempore style, at Cornell University in November 1964, on "The Character of Physical Law." The lectures were recorded for television by the BBC, and a transcription was prepared and printed "to serve as a guide or memory aid for television viewers who may see the lectures and wish to have a permanent reminder to refer to." The transcription was an extremely lucid, self-contained account of Feynman's lectures, and, since you can't keep so good a manuscript hidden in the obscurity of BBC publications, The MIT Press has reprinted it in paperback form.

In the lectures Feynman concentrates on the general characteristics common to most of the laws of physics: on the role of mathematics in physics; on the great conservation principles; on the symmetries of physical law; on the distinction between past and future; on probability and uncertainty in physical law; and on the techniques by which physicists seek new laws. Feynman makes his discourse vivid and clear by frequent examples taken, largely, from the theory of gravitation and from quantum theory.

The lectures are directed primarily at the layman, and for this reason considerable attention is paid to a detailed development of the gravitational and quantum mechanical examples. However, the careful attention to simple examples should not fool the scientifically educated reader into believing there is nothing here for him. On the contrary, by skipping lightly over the examples and concentrating heavily on the fundamental ideas, physical scientists and engineers can gain new insight into the character of physical law. Of particular interest is Feynman's discussion of the relation of mathematics to physics (chap. 2) and his description of methods for seeking new scientific laws when old ones fail (chap. 7).

A quotation which illustrates the flavor of Feynman's lectures appears in his discussion of the role of mathematics in physics (page 54): "If you have a structure [of physical laws] that is only partly accurate, and something is going to fail, then if you write it with just the right axioms maybe only one axiom fails and the rest remain, you need only change one little thing. But if you write it with another set of axioms they may all collapse, because they all lean on that one thing that fails. We cannot tell ahead of time, without some intuition, which is the best way to write it so that we can find out the new situation. We must always keep all the alternative ways of looking at a thing in our heads; so physicists do Babylonian mathematics, and pay but little attention to the precise reasoning from fixed axioms."

continued on page 24



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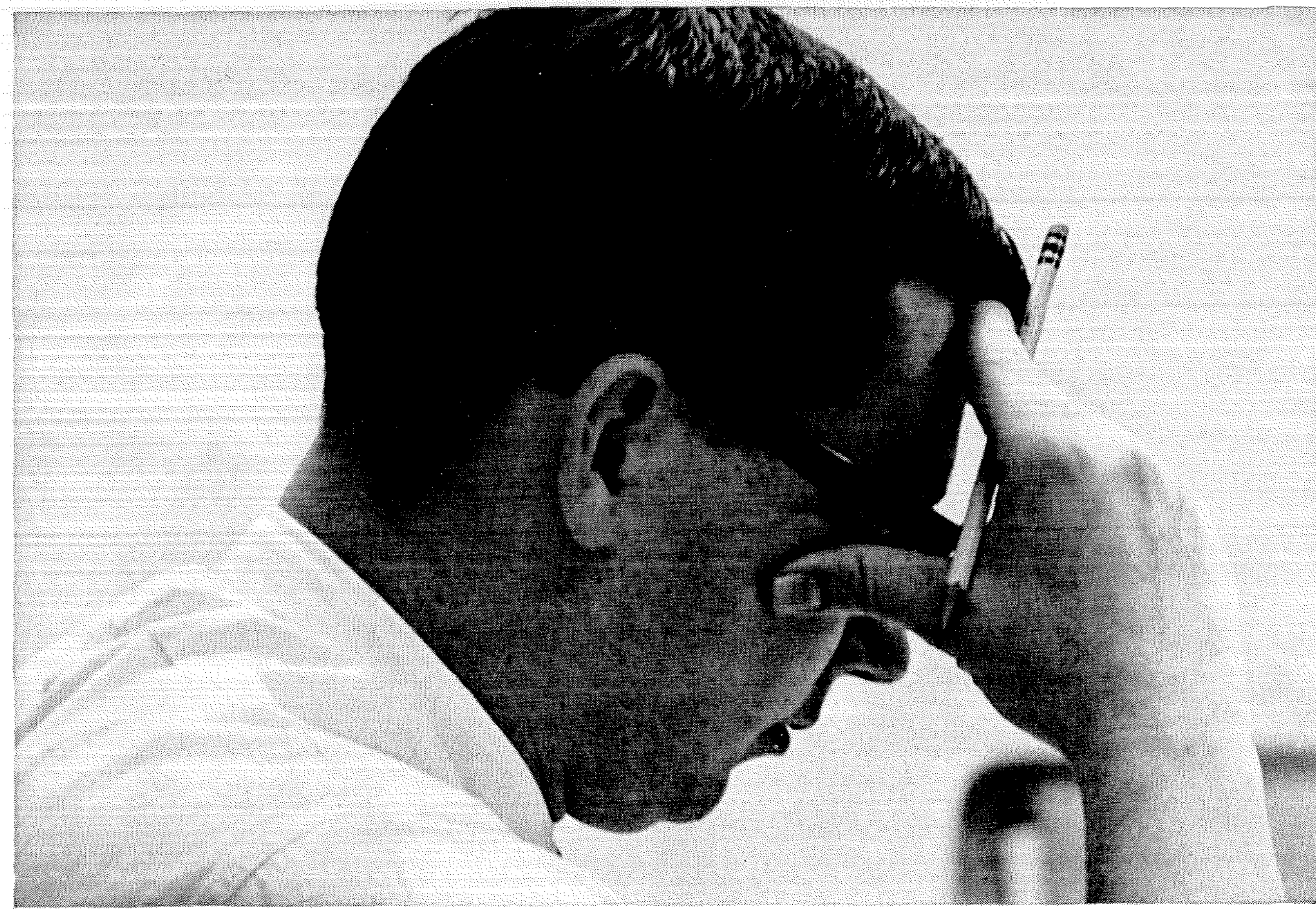

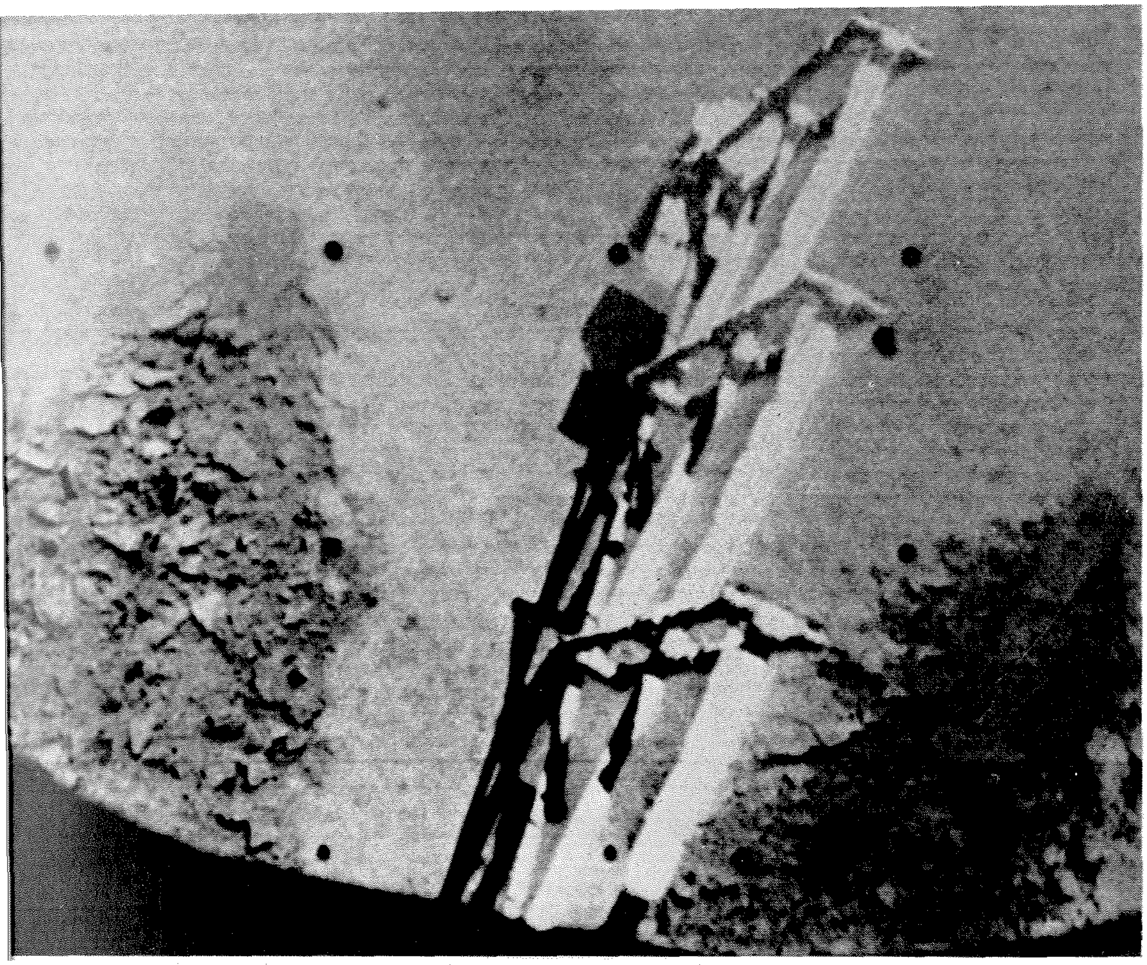

The depth of these trenches excavated in the lunar soil by the surface sampler is not apparent, as the picture was taken with the sun almost over the spacecraft.

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DIGGING ON THE MOON

by Ronald F. Scott

Prior to the flight of Surveyor I in June 1966, plans had been made to launch seven "engineering" Surveyor spacecraft before flying any Surveyors with scientific apparatus aboard. These seven were to evaluate the feasibility of the soft landing technique. After the success of Surveyor I, however, the plans were changed to include the carrying of scientific experiments as early as possible.

Among the experiments which had been proposed and brought to an advanced stage of development was the surface sampler device. This instrument had originally been constructed to obtain a sample of the lunar surface for analysis by other equipment on board. The analysis apparatus, however, proved to be too heavy to be accommodated and was left out of the scientific payload plans in the early 1960's.

Subsequently, I proposed that the surface sampler be employed as a tool for measuring the *mechanical* properties of the lunar surface material. For this purpose it was suggested that the sampler be instrumented with strain gauges and an accelerometer to record the forces applied by the sampler to the lunar surface. At the time the experiment was conceived, the nature of the lunar surface, as it would be viewed by a landed spacecraft, was completely unknown. Materials ranging from extremely soft powders through vesicular rocks and lavas to solid rocks had been postulated. It was important, therefore, to have a device capable of yielding information on any of these materials. The surface sampler had this versatility.

Ronald F. Scott, Caltech associate professor of civil engineering, specializes in the fields of soil mechanics and foundation engineering. Through his association with Caltech's Jet Propulsion Laboratory he became interested in the mechanics of soil behavior on extraterrestrial bodies and, in 1963, proposed to NASA a soil mechanics experiment to be carried to the moon on a Surveyor spacecraft. When this experiment flew with Surveyor III in April, Dr. Scott, as principal investigator for the experiment, was largely responsible for directing its operations. "Digging on the Moon," has been adapted from a civil engineering seminar lecture given at Caltech by Dr. Scott on May 25.

In the summer of 1966 a study was made which indicated that a modified version of the surface sampler could be carried on Surveyor III. The sampler was to be substituted for an approach television camera which had been planned for the spacecraft but which, after the success of the Orbiter lunar pictures series, was concluded to be unnecessary. However, in order for the surface sampler to take the place of the camera, in the time remaining before launch it had to be modified to fit all the existing electrical and mechanical arrangements made for the camera. Consequently, the strain gauges and the accelerometer had to be abandoned.

In looking for a substitute measurement of the force applied by the surface sampler to the soil in a bearing or trenching test, engineers investigated the behavior of the d.c. electric motors used for operating the sampler. They found that the force could be estimated by measuring the amount of current taken by each motor during its operation. This, then, would be the only information of a quantitative nature that could be obtained from the device after it was modified.

Surveyor III was launched in April 1967. Its total scientific payload included a television camera and the nine-pound uninstrumented surface sampler. In spite of some difficulties following an abnormal landing, in which the vernier engines did not turn off at the planned height of 13 feet above the surface, the surface sampler and the television camera were successfully operated throughout the ensuing lunar day. However, the condition of the spacecraft telemetry prevented making measurements of the motor currents as had been intended.

The surface sampler consists essentially of a bucket which has a small door and is mounted at the end of an extensible trellis. Four electric motors control the operation of the sampler, moving it in specific ways: left and right, up and down, extension and retraction, and opening and closing the bucket door. Each motor can be operated on command to run for either 2.0 seconds or 0.1 seconds.

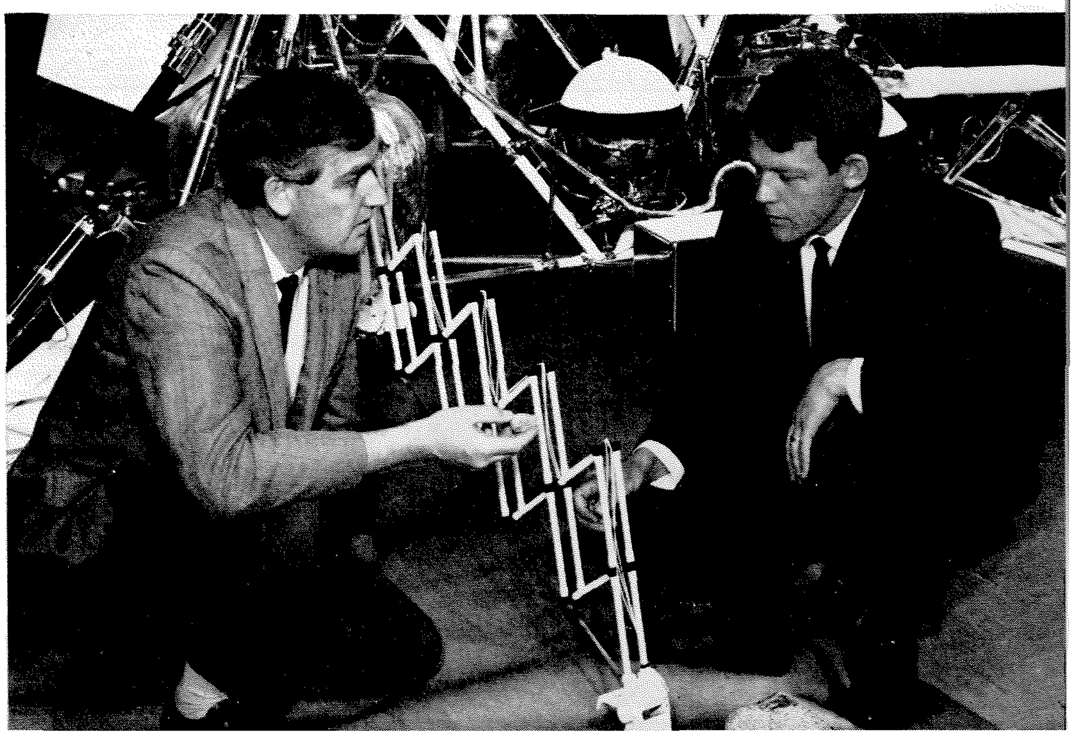
The distance moved by the scoop itself depends on which motor is being used, on the extension distance of the scoop, the load on the motor, and the temperature at the time the command is received. Since, on the lunar surface, the temperature of each motor can be approximately estimated, and since it is possible, from looking at the television pictures, to estimate the distance that the surface sampler has moved, an approximate calculation can be made of the force acting on the surface sampler scoop during that motion increment.

In addition, information can be obtained on the maximum forces applied to the lunar surface by a knowledge of the conditions under which each motor stalls. In some of the tests carried out, motor commands were sent until no further motion of the surface sampler was observed, indicating that a stall condition had been reached.

The area of the lunar surface which is accessible to the surface sampler is a space of about 24 square feet between spacecraft legs two and three. The sampler can touch the surface at a minimum distance of about 30 inches from its axis and can be extended to a maximum of about 60 inches.

The base of the sampler door is a small rectangular area measuring 1 by 2 inches. The sampler can be pushed into the lunar surface with the scoop door either open or closed and can be lifted and dropped to the surface from any height up to 30 inches.

On the first lunar day of operation, the surface sampler was directed in this way: First, narrow



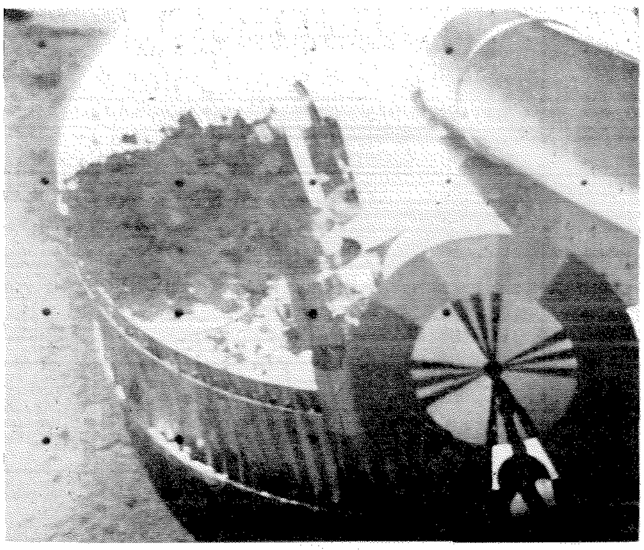
Floyd Roberson (right), JPL engineer and cognizant scientist to the surface sampler experiment, and Ronald Scott examine the sampler mounted on the full-scale model of Surveyor at JPL. The two engineers have worked together on the experiment since 1963. Roberson translates the requirements of the experiment, as described by Scott, into forms for the apparatus design engineers to work with.

angle surveys of the lunar surface in the area of the sampler operations were taken with the television camera. These were used to select suitable locations for the surface sampler testing.

Under normal conditions, a standard sequence of preprogrammed sampler operations would have begun at this time, starting with motion calibration tests. However, by the time the sampler temperature was high enough to begin operations, some difficulty had been experienced in rotating the mirror of the television camera. Consequently, after the calibration sequence had verified that the sampler was, in fact, operating in a reasonably normal manner, it was decided to make the first test on the lunar surface at a point within the field of view of the stuck television camera. (The difficulty with the camera was subsequently overcome.)

At a desk in the Surveyor Space Science Analysis and Command (SSAC) section of the JPL Space Flight Operations Facility (SFOF), Floyd Roberson, cognizant scientist for the surface sampler, and I were watching a television monitor which showed pictures of the sampler within a few seconds after they were taken. In addition, a polaroid picture was immediately taken of each television image and was handed to me to be referenced and cataloged. Next to us sat JPL's Jack Linsley, SSAC director, through whom all commands to the spacecraft passed.

Using the polaroid photograph and each picture as it appeared on the television screen and comparing them with our planned operations for that period, Floyd (and, at critical times, both of us)



The pile of lunar soil dumped on footpad two by the surface sampler came from a clod which the sampler tried to pick up, but crushed. The circular object in the right foreground is the color calibration chart. Behind it is one of the attitude control jets.

decided how many 2.0-second or 0.1-second commands were required to move the surface sampler to the point we had selected for a test. Floyd wrote down the commands necessary to move the sampler the required distance and handed them to Jack Linsley for verification. He passed them on to the controller for transmission to the spacecraft via the Goldstone Tracking Facility—all within seconds.

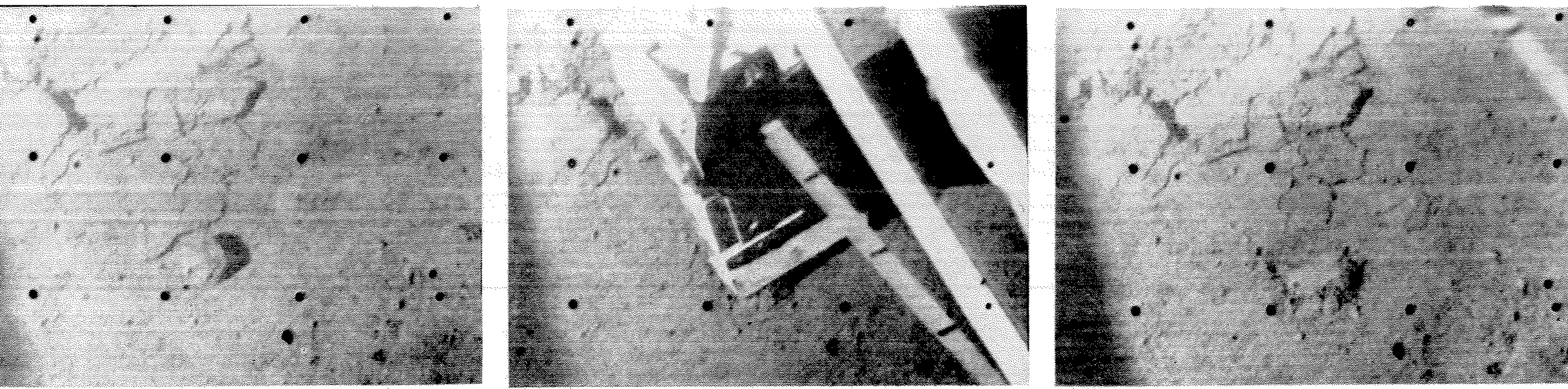
The commands to the sampler were followed by a command to the television camera to move, if necessary, in order to bring the sampler into its field of view and to take a picture. The picture which then appeared on our television monitor assisted us in deciding what move to make next. Thus the operation proceeded by a sequence of real-time pictures and decisions.

Several types of tests were carried out, since I was interested in a variety of material properties: (a) The mechanical strength of the lunar soil: this information is particularly important for use in the design of spacecraft for future manned and unmanned landings. (b) The density of the first few inches of lunar soil: it is of interest to compare this information with predictions about the density which have been made from earth-based radar and thermal measurements of the lunar surface. (c) The homogeneity of the lunar surface material. (d) The variation of the properties with depth. (e) An investigation of the nature of any accessible rocks. (Although many rocks are visible in photographs taken by Surveyor III, in its immediate vicinity only one or two small objects appeared as though they might be rock fragments.)

In the bearing tests, the sampler was driven downward until it was in contact with the lunar surface, and this position was identified. It was then driven further down by several successive 2.0-second commands until no further motion was observed. The motor was stalled. Narrow angle pictures were taken of the sampler scoop, both in the lunar soil and after the scoop was removed from the test point. From these pictures, the depth of penetration and the mechanism of deformation of the soil could be interpreted.

In the trenching operation, the scoop door was first opened and the surface sampler was commanded down into the lunar surface and then retracted back toward the spacecraft. The trench could be deepened, widened, or extended by successive passes through it.

During the formation of a trench, the lunar surface broke up into lumps and clods of material. These were believed to be either aggregates of finer-grained material or rock fragments. In order to determine just what their composition was, an attempt



The round object in the center foreground of the first picture is thought to be either a rock fragment or a soil clod. When the surface sampler is moved to bear down gently on the object, it disintegrates, indicating that it was a clod. A bearing test impression can be seen in the upper left corner of all three pictures.

was made to pick up one of the fragments which had been displaced during the trenching operations. However, when the scoop door was closed on it, the object was crushed. Apparently it was an aggregate of finer particles. A portion of the fragment which was still in the surface sampler bucket was taken to footpad two and dumped. An evaluation of its color characteristics was made by viewing the soil through the camera's color filters.

Other objects also appeared on the lunar surface which were brighter than the surface. One of these was picked up in the side of the surface sampler bucket and was brought closer to the television camera for viewing. When the bucket door was closed on the object (exerting a pressure of several hundred pounds per square inch) and it did not crush, it was assumed to be a rock fragment.

Later, when the surface sampler was moved in order to place this object on footpad two, the fragment was lost from the sampler. Apparently it was squirted from the spring-loaded door. When the loss was discovered, the sampler was lowered to the lunar surface, and the door was opened to see if the fragment had broken. No pieces were found inside the sampler bucket. It appeared that the fragment had been ejected intact.

The resistance of the soil to penetration by the sampler in an impact test arises from both the soil's static strength and its density. As the velocity of the impact increases, the part played by density becomes more important in comparison with the static strength of the material. Consequently, impact tests from different drop heights in which only the maximum penetration is measured can be used to evaluate this density approximately. The static strength is given by the bearing tests.

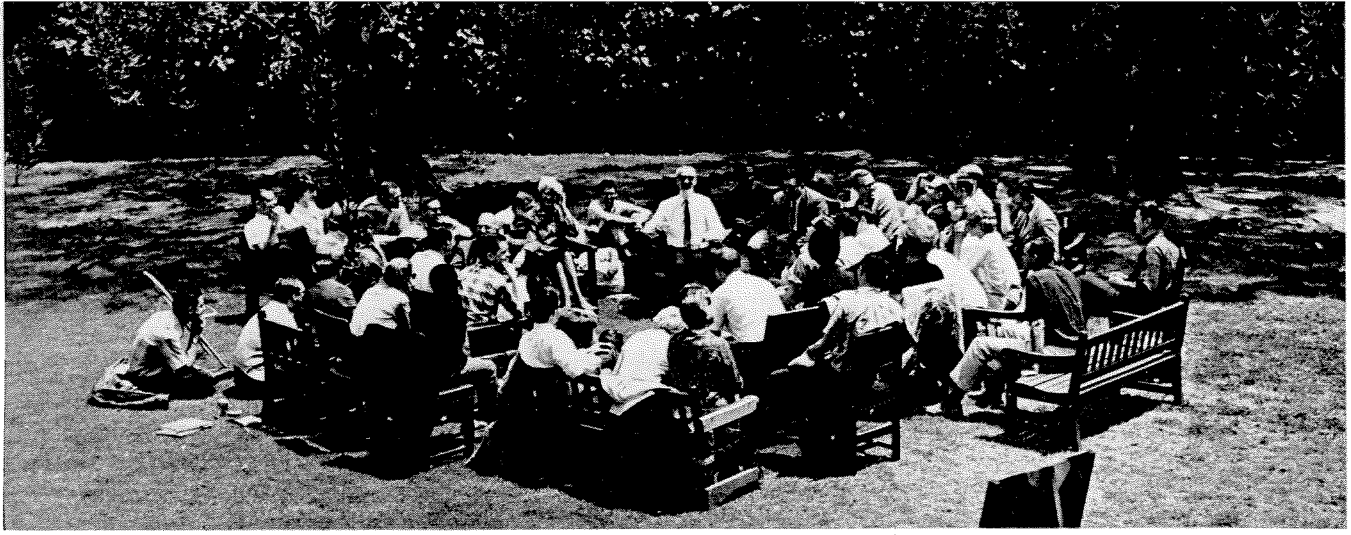
It appears from the surface sampler tests that the lunar soil is fine-grained material possessing a small amount of cohesion (in the order of a few hundredths of a pound per square inch) and an angle of internal friction of about 35 degrees, similar to that of a dry terrestrial sand. The impact and other test results appear to show that the material possesses an essentially normal terrestrial soil density of about 1.5 grams per cubic centimeter. When the sampler was pushed into the soil in the bearing test, the soil was displaced out of the way of the surface sampler, and it appeared that the material was very nearly incompressible.

The physical parameters describing the lunar soil which appear from these simple surface sampler tests have a broader significance than only their engineering value for the design of future spacecraft. They make possible scientific interpretations of the physical state of the material.

These results indicate that the very high porosities and low densities which had sometimes been postulated as being lunar soil conditions do not, in fact, exist throughout the first few inches of lunar soil at the Surveyor III landing site. Ideas about lunar surface processes have had to be revised. It had been thought that in the very high vacuum at the lunar surface, meteorite bombardment would produce particles with extremely clean surfaces. The fragments would, therefore, adhere strongly to one another and possibly also to spacecraft components. The measured small amount of cohesion seems to indicate that the particles are not extremely "clean," that primary bonding forces are not acting between lunar soil particles, and that van der Waals forces are more probably present.

The lunar soil has shown a tendency to adhere inside the surface sampler bucket with a cohesion of the same order of magnitude as in the undisturbed soil. The area in which the surface sampler operated appears to be fairly homogeneous in its properties, but there are distinct indications in the trenches that the material is firmer or denser with depth within a few inches from the surface. The deepest trench was approximately seven inches, and the material at that depth was relatively firm compared to the surface.

At this time only the most preliminary evaluation of the tests and their results has been made. But the surface has been scratched, and our knowledge has been extended in a most direct way.



A PHILOSOPHER LOOKS AT CALTECH

ABRAHAM KAPLAN, professor of philosophy at the University of Michigan, visited Caltech this spring as a YMCA-sponsored Leader of America. During his four-day stay he met and talked with Caltech students (above) 14 hours a day. Before leaving campus he was interviewed by John Weir, associate professor of psychology at the Institute, regarding the impressions he gained here. This article contains excerpts of his comments.

John Weir: How would you characterize the general nature of the student body at Caltech?

Abraham Kaplan: They're the most intellectually mature undergraduates I've ever known. They are also by and large the brightest that I've known anywhere; but that's a different factor. What I mean by intellectually mature is: whereas I'm usually able to identify a student's class and even his semester fairly well, here I've constantly been off by several years and always with a systematic error in the same direction. Whenever I think someone is a senior, he's a freshman, and when I think he's a member of the faculty, he may be just a junior.

They are most decidedly not "hardnosed," if by that is meant what I call "scientistic"—wanting to count, weigh, and measure. In fact, my impression has been rather the contrary. I have a vision of an intense need for development of their human side. What is the opposite of hardnosed? William James speaks of hardheadedness and tenderheartedness. It is their tenderheartedness—a great desire to feed their appetites for human warmth, aspiration for literary and dramatic sensitivity, and that whole spectrum of interest. For instance, whenever our discussions have gone in the direction of the nature of science, there has not been a particular response. But the minute I bring in God, or morals, or art or beauty, there are 20 people who want to say something all at once.

Weir: You referred to this earlier as a hunger?

Kaplan: Yes, and I want to speak to that as one of the respects in which this campus is barren. I've been very struck by it in contrast to many other colleges that are not just inferior to Caltech but are so by several orders of magnitude. I have been on many such campuses and been aware that there is a showing of Laurence Olivier's "Hamlet"; that the local theater group is putting on a play of Ionesco's; there's a string quartet playing that evening; there's a retrospective show of the paintings of Lionel Feininger. Here I have not been aware, in a massive fashion, of the visual arts, of sculpture, of music, of theater, or poetry, or, for that matter, of even dance and beer parties. So it has been a sense of austerity.

There was also a hunger of another kind which is not especially characteristic of Caltech, but it surprised me because you have less reason for it than any other place—namely for a direct encounter with faculty. I have been told—and even those who didn't tell me conveyed it quite accurately—that they have never had a chance in all their time at Caltech to sit down side by side with a member of the faculty and just chat about something without a formal course context between them. This is almost universal in American higher education, but in a school as small as Caltech and with your enviable faculty-student ratio, it ought to provide for many such occasions.

Weir: But it is often said here that all the students have to do is to knock on any professor's door and he's quite willing—even eager—to see them.

Kaplan: But the fact is that they don't. As an educator I cannot rest content with saying, "Okay, now it's up to you. All you have to do is knock on the door." The fact is that if they don't knock on the door I want to find out why, and I want to maybe remove the door so that they don't have to knock.

Weir: Would you mention a few things that could be done to improve the situation?

Kaplan: I would want to organize an important part of the educational process to have its locus in the houses. The houses are now apparently a place where students eat and sleep and where they have their own lives, but not where they have a part of university life. I would like to see each member of the faculty take it for granted that he's going to spend six to eight hours a week in a house some way or other. And that he is going to be doing it not as something extracurricular and incidental but in very nearly the same spirit as in the classroom or in an office consultation—that is, continuing the process of intellectual growth and education.

I would also see that graduate students and undergraduates are thoroughly mixed in their housing. Students can learn at least as much, perhaps more, from one another as from faculty.

Weir: Do you think that our admissions or selection procedures could be improved?

Kaplan: Not for *you* they couldn't. You have so many students that are so fine, I don't think you can improve on what you have. But maybe it would serve the national interest better if you didn't have so many and let a few of the other places have a few. It would do *them* some good.

I find wholly admirable in every way that your students represent such a rich diversity of national and social background. I cannot overstate how significant a contribution that seems to me to be making to our life as a nation, as a society. The number of foreign students you have, the number of Americans of oriental descent, the Negroes, the number of Jewish students, the number of students that apparently come from lower economic strata—all of this creates an atmosphere in which certain basic values that are appropriate to a university are tacitly being reinforced every hour of the day. What is being said is that the one value that is being shared by everyone here is a dedication to the life of the mind, to the adventure of ideas, and that all these differentiations, which, alas, are so important elsewhere, have no place at Caltech.

Weir: What about our educational facilities?

Kaplan: I've had a little sense that books as a specific educational adjunct played rather less of a role here than they would even at quite inferior universities. But I hesitated to draw any conclusions, even if it is a fact, simply because the sciences play such a role here, and a laboratory is understandably more important than a library. Nevertheless, I would have thought that there would be two or three bookstores at which used books would be bought and sold. It isn't that I have any fault to find with your bookstore, which is as extensive as it should be, but I'm surprised that there isn't a great deal more. Around many universities there is to be found a little avant-garde bookshop where there are books that have nothing to do with classes—the kind of place where coffee is served, and once a week there's a poetry reading with guitar playing. Now it's easy for us to smile condescendingly, but I think they make an enormously important contribution. I'd also like to import a little bit of Berkeley or a little bit of Antioch College, or Reed.

Weir: A little offbeat?

Kaplan: Yes. College is the age for intellectual exploration and experimentation. That's what offbeat means. It's entirely right and proper for a kid to see what he would look like if he wore a beard or a mustache. It doesn't mean that this is what he is going to do the rest of his life. But now is the time for him to try it on, to try on various ideas and tastes in the arts and the like—at any rate, to be made aware of these larger horizons. There's a kind of a grimness here at Caltech. I would like to see more of joy, especially because these kids are so wonderful and capable of the joy of intellectual life. I feel as though I've come upon people who love to eat but who have never tried French cooking or Armenian cooking or Japanese cooking—only that wonderful rare roast beef.

Weir: Do you have any comments about the absence of girls on campus?

Kaplan: I think if girls were admitted at the undergraduate level in considerable numbers it would make an enormous difference to the quality of the place. I'm not just talking about heeding emotions. I'm also talking about a contribution to intellectual creativity, to excitement with ideas. It is not a recommendation where I say, "Why don't we have some good-looking girls around?" But I certainly think that it makes a considerable difference in the unfolding of the whole person and in making use of all the resources of the personality in an integrated fashion.

Weir: We are about to enter a period of expansion in the humanities and the social sciences. Could you suggest some direction we might take?

Kaplan: There are in the social sciences and the humanities two directions that can be distinguished, although the line between them is blurred. Let's call them hard and soft. In the hard social sciences there is much application of high-powered mathematical methods—decision theory, linear programming, game theory and the like. The idea that I would like to put forward is that that is decidedly *not* a direction to go. What I would like to see done at Caltech is to have the social sciences and humanities of the soft variety. I think it will contribute much more; it will be very much more of a ferment. If you do the other, then all you are doing is keeping everything here the same.

FROZEN FREE RADICALS IN INTERSTELLAR SPACE

by G. Wilse Robinson

The space between the stars is not an empty void but a region filled with dust and gas. To be sure, the number of atoms per unit volume is small—the average being only about 1,000 atoms per bucketfull of interstellar space. However, the concentration of atoms and dust tends to "bunch up" into clouds and is very uneven over space. Even in the clouds, however, the concentration of matter is not very high by ordinary standards. It is about 1/40th as dense as the best vacuums one can obtain in the laboratory by modern vacuum techniques, as can be seen by the comparisons below:

CONCENTRATION OF INTERSTELLAR ATOMS

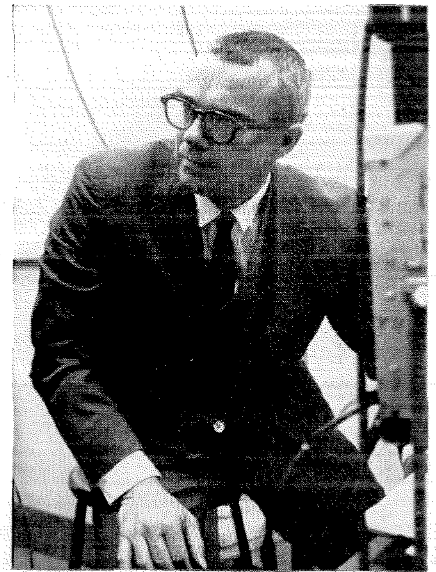
	atoms/liter
Average Value	100
Interstellar Clouds	100,000
Best Laboratory Vacuums	3,600,000

Even so, the space between the stars is so vast that the interstellar gas and dust comprise perhaps as much as 10 percent of the total amount of material in the galaxy.

Knowledge about the interstellar gas has been derived mostly from spectroscopic measurements. One finds that the white light from a very distant star, after passing through the immensity of space, has partially been absorbed because of the presence of the intervening gas. Each atom or molecule has a characteristic absorption color or wavelength which acts as a "fingerprint." In this manner, atoms and ions of the elements titanium, sodium, potassium, iron, and calcium have been found, as have the diatomic molecules CH, CH^+ (CH with one electron missing), and CN. Using radio frequency and microwave techniques, researchers have also detected hydrogen atoms and OH molecules. These atoms and molecular fragments are what I refer to as free radicals. (The use here of the term "free radical" to mean any atom or molecular fragment does not exactly coincide with the standard chemical definition.)

Many other kinds of whole molecules and molecular fragments, such as carbon atoms, hydrogen molecules, and water vapor, are believed to exist in interstellar space, but their absorptions are so weak at wavelengths of light presently possible for study that they have not yet been detected there. Rocket- and satellite-based spectroscopy has opened up new wavelength regions of the spectrum by eliminating atmospheric absorption, and, in the future, moon-based observatories will shed much more light on the problems of interstellar gas absorption.

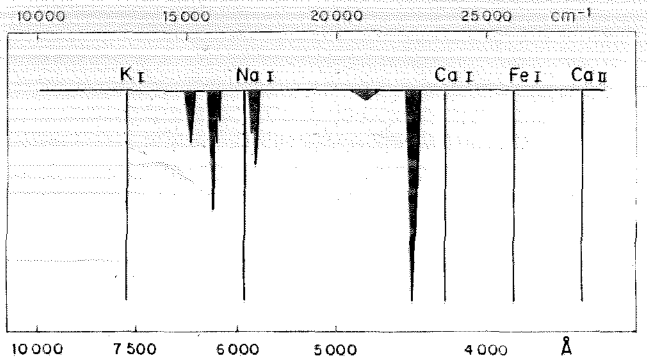
Our main concern here, however, is not with the individual atoms, molecules, and free radicals that form the interstellar gas, but rather with agglomerations of these—tiny, solid particles, many almost too



G. Wilse Robinson, professor of physical chemistry at Caltech, has been interested in "the space between the stars" for as long as he can remember. Only recently, however, has his work brought him very close to active participation in this field. While an assistant professor at Johns Hopkins University, Dr. Robinson discovered that atoms and small molecular fragments embedded in certain solids at very low temperatures absorb light in a manner resembling that by which light is absorbed by an isolated atom or molecule. However, differences in absorption between the isolated molecule and the "trapped" molecule cause difficulty in identification of such absorptions. Dr. Robinson reasoned that atoms and molecular fragments similarly frozen out in interstellar space could therefore be responsible for certain unidentified absorptions found there.

In 1959 Dr. Robinson came to Caltech as associate professor of chemistry. In recent years he has concentrated his work in the fields of vibrational and electronic spectroscopy of molecules, low temperature chemistry, and energy transfer phenomena in chemical and biological systems.

During the past year he has been advisor for the honors work of two Caltech undergraduate students, Jim Marable and Mike Ruth, who have been conducting experiments designed to identify the composition of "interstellar dust," which Dr. Robinson discusses in "Frozen Free Radicals and Interstellar Space." This article has been adapted from a lecture given by Dr. Robinson on May 15, the last of Caltech's 1967 Spring Lecture Series in Beckman Auditorium.



Broad interstellar absorptions with lines of potassium, sodium, calcium, and iron as reference.

small to be seen under a high-powered microscope. These interstellar grains, as they are called, may be ejected from the cooler regions of stellar atmospheres by radiation pressure, or they may freeze out from the interstellar gas in the very cold parts of interstellar space, which are around 20 degrees above the absolute zero. Or perhaps they arise from a combination of dust ejection followed by condensation of interstellar gas.

In any case, from a chemical point of view, the grains are expected to be very complicated. It makes a chemist's head swim to think of all the possibilities that can arise from a mixture of atomic carbon, oxygen, nitrogen, magnesium, silicon, and sulfur, plus a dash of atomic sodium, calcium, iron, and other less abundant elements, freezing out at low temperatures in the presence of constant bombardment by electrons, hydrogen atoms, and ionizing radiation.

Because much of the hydrogen may boil off, the grains, unlike the rest of interstellar space, need not have a high hydrogen content. Most of the hydrogen that sticks is probably chemically bound to the grain. Even if these particles were formed from "dirty graphite cores" (i.e. cores made up primarily but not entirely of carbon) ejected from stellar atmospheres, as some scientists think, the accumulation of complex chemical substances on their surfaces would seem to be inevitable. A typical-size grain contains roughly a billion atoms. Such a grain undergoes about a collision per minute with a hydrogen atom and about a collision per day with some chemically reactive heavy atom other than hydrogen. At this rate it takes only about a million years for such a grain to undergo collisions in space with a billion other atoms, not including hydrogen. So, the equilibrium composition of a grain may be pretty much at the mercy of its gaseous interstellar environment, rather than dependent on the mode of its initial formation.

Information about the grains is derived, just as for the interstellar gas, mostly from spectroscopic measurements. Absorption of light by grains, scattering of light by grains, and polarization of light by grains are examples of problems that have been studied. The diagram at the left shows, schematically, some of the more prominent, discrete absorption lines thought to be caused by the grains. The complexity of the spectrum is consistent with the expected complex chemical composition of the grains. It is to be emphasized that no definite identification of these features has yet been made, although many speculations have been advanced. Thus a major mystery exists. This is a pity since we are, therefore, ignorant of a measurable fraction of the composition of the universe.

In addition to these relatively discrete absorptions, there could be an underlying, general, continuous absorption caused by substances embedded in the grains. This aspect of the problem has never been considered by astrophysicists. The presence of a continuous absorption could spoil the interpretation of the light-scattering experiments on which much of our present knowledge of the grains rests.

The mystery of the grains is as much of a chemical problem as a physical one. Laboratory experiments, trying to duplicate the interstellar absorptions, should be performed by chemical spectroscopists who are familiar with complicated molecules adsorbed on or embedded in solids. Actually some work along these lines has been carried out. Atomic sodium and calcium can be frozen out under certain conditions resembling those in interstellar space. It is noteworthy that the absorption spectra of these frozen atoms are very close to the

RELATIVE STELLAR ABUNDANCES OF SOME ELEMENTS

Hydrogen	1,000,000	Magnesium	
Carbon	500	Silicon	25
Nitrogen	100	Sulfur	
Oxygen	1,000	Helium	150,000
Sodium			
Calcium	2		
Iron			

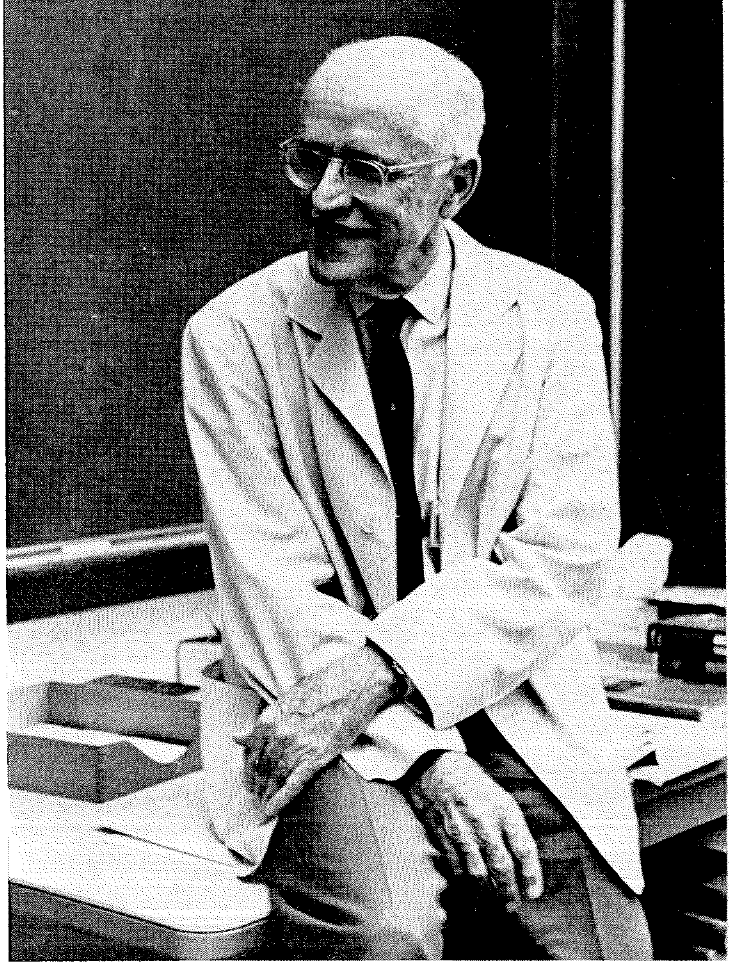
spectra observed for the grains. The concentration of sodium and calcium atoms in interstellar space is not high, as seen in the above table, but their absorption is very intense. Besides, in the grains, the atoms probably have a higher concentration than in the interstellar gas.

Further frozen free radical experiments are now being carried out at Caltech in a more directed effort to identify the grain material. Various mixtures of atomic carbon, oxygen, nitrogen, and hydrogen, together with the more prominent metal atoms, are allowed to impinge on a surface cooled to liquid helium temperature (4°K). The frozen material is then examined spectroscopically for the possible presence of the grain absorption lines.

ERNEST H. SWIFT

professor of analytical chemistry

Dr. Swift will become professor emeritus this month when he retires after nearly 50 years at the Institute. He received his BS from the University of Virginia in 1918 and came to Caltech (then Throop College of Technology) the following year—the year Arthur Amos Noyes became director of chemical research. Dr. Swift received his MS from Caltech in 1920 and joined the faculty that same year as an instructor in chemistry. In 1924 he was awarded his PhD, in 1928 became assistant professor, in 1939 associate professor, and in 1943 professor of analytical chemistry. He served as interim chairman of the division of chemistry and chemical engineering from 1958 to 1963, and as chairman of the faculty from 1963 to 1965. During World War II, Dr. Swift was an official investigator for the office of scientific research and development, working on problems related to the identification of chemical warfare agents and their detection in the field. He was also a pioneer in the development of coulometric methods of analysis, in which an electric current is used to measure chemical elements. An avid tennis player, Dr. Swift will now have more time to pursue his favorite sport, although he plans to maintain an office on campus in order to continue work on the revision of his textbook on quantitative analysis.



RETIRING THIS YEAR

OLIVER R. WULF

research associate in physical chemistry

After 22 years at Caltech, Dr. Wulf retires this month as research associate emeritus. He is the first research associate of the Institute to be awarded this status. Dr. Wulf received his BS from Worcester Polytechnic Institute in Massachusetts and his MS from American University in Washington, D.C. After obtaining his PhD from Caltech in 1926, he spent 11 years with the U.S. Department of Agriculture, rising to the position of senior physicist in the Bureau of Chemistry and Soils. In 1939 he moved to the Weather Bureau as senior meteorologist, and, as a member of the Bureau, was a research associate at the Institute of Meteorology at the University of Chicago from 1941 to 1945. In 1945, still as a member of the Weather Bureau (and later under the Environmental Science Services Administration), he joined the Caltech staff as research associate in physical chemistry, where he has carried on an enthusiastic research program in solar-terrestrial relationships, geomagnetism, and large-scale circulation of the atmosphere. This work won him election to the National Academy of Sciences in 1949. In April of this year, Dr. Wulf retired from his government post after 41 years of service. He and his wife, Bea, who served as secretary of the division of chemistry and chemical engineering until last year, have left on an extended tour around the world by freighter. When they return, Dr. Wulf will resume his research at Caltech.

LIBRARY DEDICATION

JUNE 9, 1967

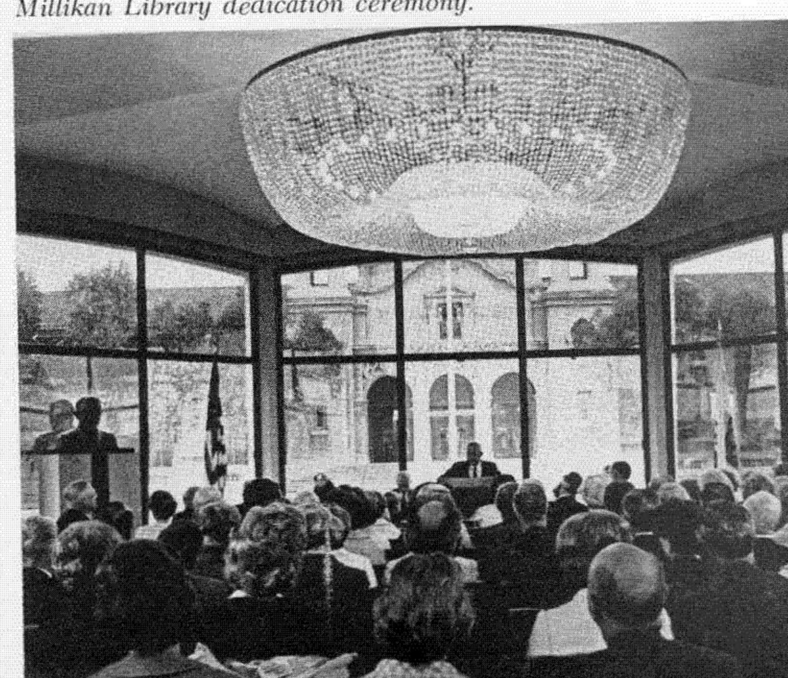
Caltech's Robert A. Millikan Memorial Library was dedicated in a short ceremony preceding the commencement exercises on Friday, June 9. Seeley G. Mudd, a member of the Caltech board of trustees, who donated the funds for the nine-story building, presented the key to the library to Arnold O. Beckman, chairman of the Institute board. The presentation took place in the octagonal-shaped, glass-walled room which adjoins the library on one side and projects into a reflecting pool on the other. The room will serve as conference quarters for the trustees.

Caltech President Lee A. DuBridge and Director of Libraries Harald Ostvold also took part in the program, which was attended by Caltech trustees and their wives, members of the faculty library committee, and friends and members of the Mudd and Millikan families.

The library is scheduled to open in the fall.

The new library in the final stage of construction.

President DuBridge (left) and Seeley Mudd.

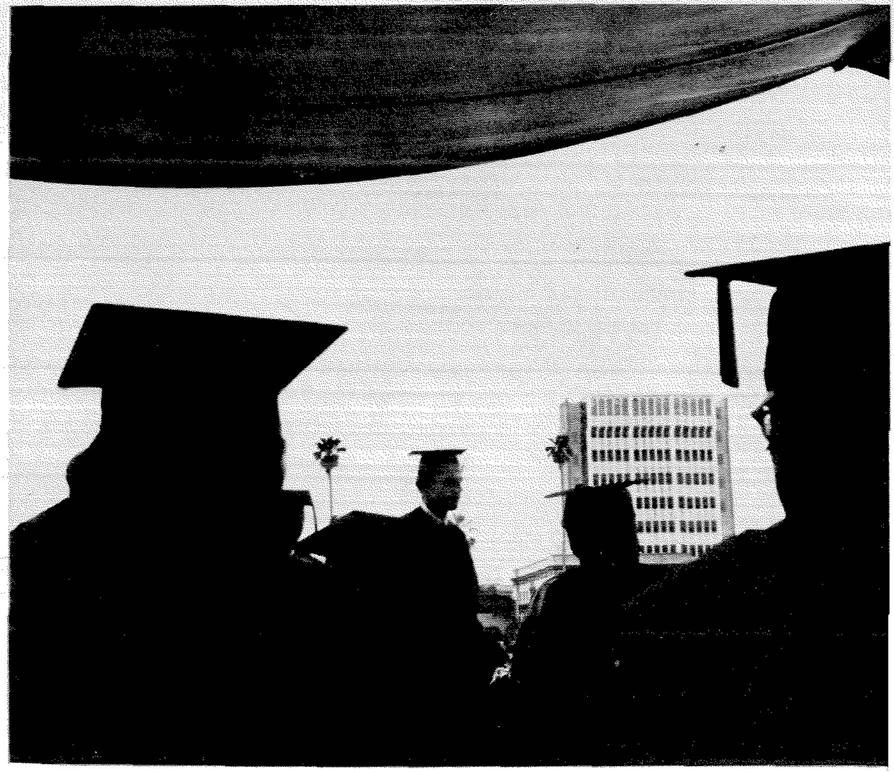


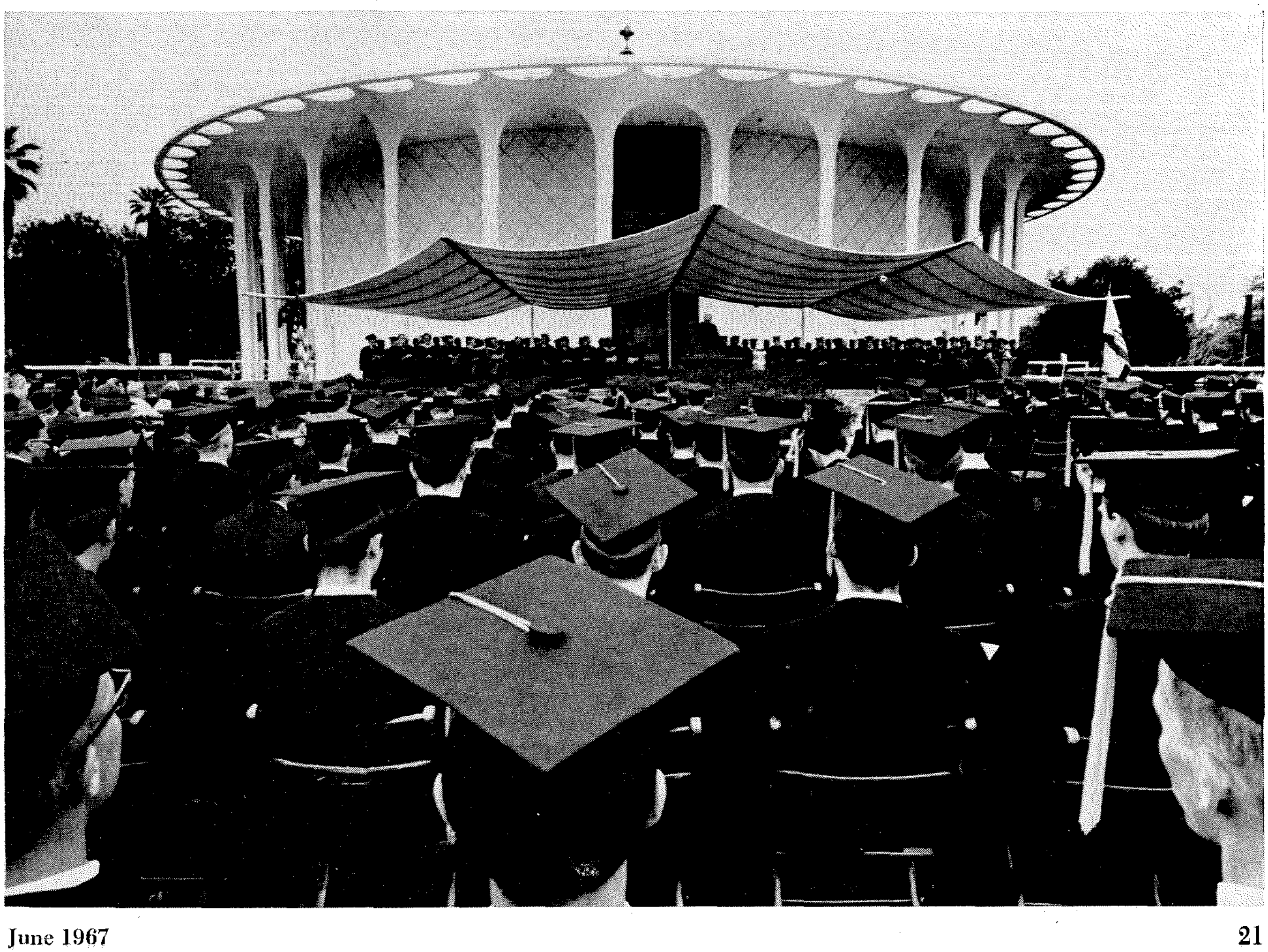
A chandelier of Bavarian crystal in the trustees conference room is lighted for the first time during the Millikan Library dedication ceremony.

COMMENCEMENT 1967

At Caltech's 73rd annual commencement on June 9, a total of 363 students received degrees —141 bachelors of science, 105 masters of science, 7 engineers, and 110 doctors of philosophy. Almost one-half of the seniors, who had maintained a B-plus average throughout their four years at Caltech, were graduated with honors.

President Lee A. DuBridge delivered the commencement address, "The Educational Process."





PERSONALS

1934

EDGAR L. KANOUSE, MS, has been appointed general manager and chief engineer of the Los Angeles Department of Water and Power. A veteran of 30 years with the department, Kanouse has been assistant general manager and chief engineer for the past year.

1937

DANIEL G. SCHUMAN, vice president-finance for Bausch & Lomb Incorporated in Rochester, N.Y., has been elected a director of the Financial Executives Institute, a national organization of financial executives from all fields of business, industry, and banking.

1939

ROBERT T. CARTER, MS '40, has been appointed assistant general manager of the petrochemical department of Texaco Inc., with headquarters in New York. He joined Texaco in 1940 as a chemical engineer in the refining department in Montana. After working on assignments in California, New York City, New Jersey, Illinois, and Cuba, in 1961 he joined the petrochemical department.

1943

TED L. CROSTHWAIT, MS, superintendent of the Bardstown, Ky., city schools, has received the first honorary degree conferred by Nazareth College of Kentucky. He was honored for his service to the youth of Nelson County and his cooperation in the student teaching program.

1946

FRANK LANNI, PhD, died on July 30, 1966, in Atlanta, Ga. He was professor of microbiology at Emory University.

DONALD J. O'MEARA, MS, AE '47, is technical director of the U.S. Navy Atlantic Undersea Test and Evaluation Center in Palm Beach, Fla.

1947

LOREN F. STRINGER, MS, manager of product development for the industrial systems division of Westinghouse Electric Corporation in Buffalo, N.Y., has been presented the "Order of Merit," the company's highest honor. The award is in recognition of his contributions to the development of industrial control systems and of static control and power conversion systems for heavy industry. Stringer joined Westinghouse in Pittsburgh in 1947 and was transferred to Buffalo as manager of product development in 1956.

1950

CRAIG MARKS, MS '51, PhD '55, has been appointed engineer-in-charge of the power development department for the engineering staff of the General Motors Corporation in Detroit. Marks joined General Motors in 1956 as a staff engineer in the automotive engines department.

GEORGE E. SOLOMON, MS, PhD '53, vice president of TRW Systems Group at TRW Inc., has been elected a member of the National Academy of Engineering. He was cited as one of the outstanding authorities in systems engineering due to his contributions in the design and development of space systems, weapons systems, and reentry vehicles.

1951

EDWIN A. MATZNER writes that he "lives in baronial splendor in the Paris of the Midwest—St. Louis. Far from Hogan's uneven stuccoes, Ed and his wife, Mary, a native Pasadenean, often think of the smog they have left behind as they gaze upon heptannuate offspring Cathy. Ed is one of the stoutest pillars supporting chemical research at Monsanto Co."

GEORGE M. SAWYER and his wife, Ella, announce the birth of their third child, Michael David. Sawyer is employed by the AiResearch Manufacturing Company in Los Angeles.

ALEXANDER WYLLY, PhD, has been named vice president for eastern operations for the Planning Research Corporation, an international systems analysis and computer software firm. Wylly, who was formerly vice president for information systems in Los Angeles, will be in Washington, D.C.

1952

ROBERT S. DAVIS, MS '53, is president of Realtime Systems Inc. in New York City, a company he helped form in February 1966. The firm supplies computer hardware and software to industries.

GERALD D. FASMAN, PhD, has been promoted to professor of biochemistry at Brandeis University in Waltham, Mass. He is taking his sabbatical leave in 1967-68 at the Protein Institute, Osaka University, in Japan, and the Weizmann Institute of Science in Rehovoth, Israel.

1953

DAVID B. WITTRY, PhD '57, associate professor of electrical engineering and materials science at the University of Southern California, has received a Guggenheim fellowship to spend a year doing research in electron optics and microanalysis at the Cavendish laboratory at Cambridge University in England.

1954

ROBERT K. CAMPBELL is working for the Northrop Corporation in Ventura, Calif., as supervisor, technical contract administration. He is responsible for seeing that both the technical and business aspects of all contracts are fulfilled.

KENNETH D. JOHNSON, PhD, an environmental pollution control specialist, has joined the staff of the Manufacturing Chemists Association in Washington, D.C. Among Johnson's responsibilities will be service as a technical liaison with industry and government groups concerned with air pollution control. He was formerly chairman of the corporate environmental pollution control committee of the Atlantic Research Corporation in Alexandria, Va.

1955

JOHN J. DOMINGO, PhD '63, writes that he is working for the European Organization for Nuclear Research in Geneva, Switzerland.

1956

RALPH O. KEHLE, MS '57, is assistant division stratigrapher for the southeastern division of the Humble Oil and Refining Company in New Orleans. He was previously a research associate in charge of the rock mechanics and fracturing section of Esso Production Research in Houston.

1957

GEORGE HALL is construction supervisor, teacher, member of the board of trustees, and occasional bus driver at Pacific High School in Palo Alto, Calif. He is directing 50 students in the construction of this progressive school, which emphasizes the educative value of strong relationships between all members of the school community.

CAVOUR W. YEH, MS '58, PhD '62, has been promoted to associate professor of electrical engineering at the University of Southern California.

1959

DONALD M. KETTER, MS, is a contract engineer specializing in aeroelasticity with Beech Aircraft in Wichita, Kan. He was formerly an aeroelasticity engineer for Boeing Aircraft in Seattle, Wash.

MICHAEL W. PETERS writes that he is assistant professor of physics at the University of Hawaii in Honolulu, working on elementary particle research. He was formerly a project associate in physics at the University of Wisconsin in Madison.

BERNARD C. REARDON, MS, PhD '64, is lecturing in computer science at University College in Dublin, Ireland. He was formerly a professor at University College in Cork.

CLAYTON S. SMITH, MS, has been named a research chemical engineer for the Morton International Research Center, a division of Morton International, Inc., in Woodstock, Ill.

1960

JOHN N. COOPER, assistant professor of chemistry at Carleton College in Northfield, Minn., will become assistant professor of chemistry at Bucknell University in Lewisburg, Pa., in September.

FLETCHER I. GROSS, PhD '64, has been named associate professor of mathematics at the University of Utah in Salt Lake City. He will assume this position in July, when he completes two years of teaching at the University of Alberta in Canada.

WILLIAM MOHLENHOFF, AE, a commander in the U.S. Navy, is assistant project manager for F111B Aircraft at the Naval Air Systems Command in Washington, D.C. He was previously engineering director of the Navy plant office at McDonnell Aircraft Corp. in St. Louis.

1963

TERRY B. GALLOWAY, MS, PhD '67, has joined the Shell Development Company in Emeryville, Calif., as engineer in the chemical engineering department.

HARRIS GOLD, PhD, has been appointed manager of the aerophysics department, aero-plasma-physics laboratory of the Avco Space Systems Division in Wilmington, Mass.

ALAN LIPPERT, MS, was recently promoted to the position of systems analyst with the International Business Machines Corp. and transferred from Los Angeles to White Plains, N.Y. He is working on the application of graphic data processing to aerospace and manufacturing industries.

1964

WILLIAM BUSH, PhD, has been promoted from assistant to associate professor of aerospace engineering at the University of Southern California.

NOEL D. JONES, PhD, is a senior organic chemist with Eli Lilly and Company in Indianapolis.

1966

LARRY COOPER, MS, is working on propulsion advanced technology at the McDonnell Aircraft Corp. in St. Louis.

LETTERS

Pasadena, California

EDITOR,

I was very interested in Dr. Friedlander's article in your May issue, "Plastic Hearts, Membrane Lungs, and Artificial Kidneys—The Engineering of Vital Organs." Where can I find more material about this research?

JOE HELLER '62

For those wishing further information on this subject, Dr. Friedlander suggests the following references:

Connally, N. Thomas, Jr. (ed.), *"Proceedings of the Conference on Hemodialysis,"* PHS Publication 1349, U.S. Government Printing Office.

Calletti, Pierre M. and Brecher, Gerhard A., *"Heart-Lung Bypass,"* Grune and Stratton, New York, 1962.

Spaeth, E. E., *"Convective Diffusion of Oxygen, Carbon Dioxide and Inert Gas in Blood,"* PhD dissertation, Caltech, 1967.

Vurek, G. G. (ed.), *"Proceedings of the Annual Conference on Engineering in Medicine and Biology,"* Volume 8, 1966.

Books . . . *continued*

Gobble-Up Stories

by Oscar Mandel

Bruce Humphries Publishers $4.95

Reviewed by John Crawford, lecturer in English

Oscar Mandel, Caltech associate professor of English, again uses the form of the satiric fable in this, his fifth book. His dry, urbane, and gentle wit plays on themes of tradition, themes close to those of Aesop, and themes that simply remind us of ourselves in our own time.

It is this sense of relevancy that Mandel exploits best: A cow from Carinthia decides that her enriched diet indicates she is being fattened for the kill, laments this fate ("We moo in the void."), and directs her path to India, where cows are sacred. But in the town she comes to, cows are resented, poorly fed, and frequently beaten by the hungry men and boys. Our philsophical cow is left at the end of the tale a perplexed and bovine Sartre, unsure whether to return to Carinthia, where she would exist, "So fat, but oh so brief."

Death seems to be the ultimate foe in Mandel's satires. In "The Faithful Gardener," Death must wait while the old servant finishes smoothing his master's privet hedge. While Death waits, he muses over the stubborn desire of the gardener to complete his life's last task and over the fact that only man among created things is unresigned to Death. "The fire that goes out, the fern devoured, and the fawn torn by the lion understand me. Only man does not understand me."

The brevity of these fables makes them unpretentious. But within their briefness a point is both made and won; and physicists, executives, and libertines do not escape Mandel's quick rapier-thrusts.

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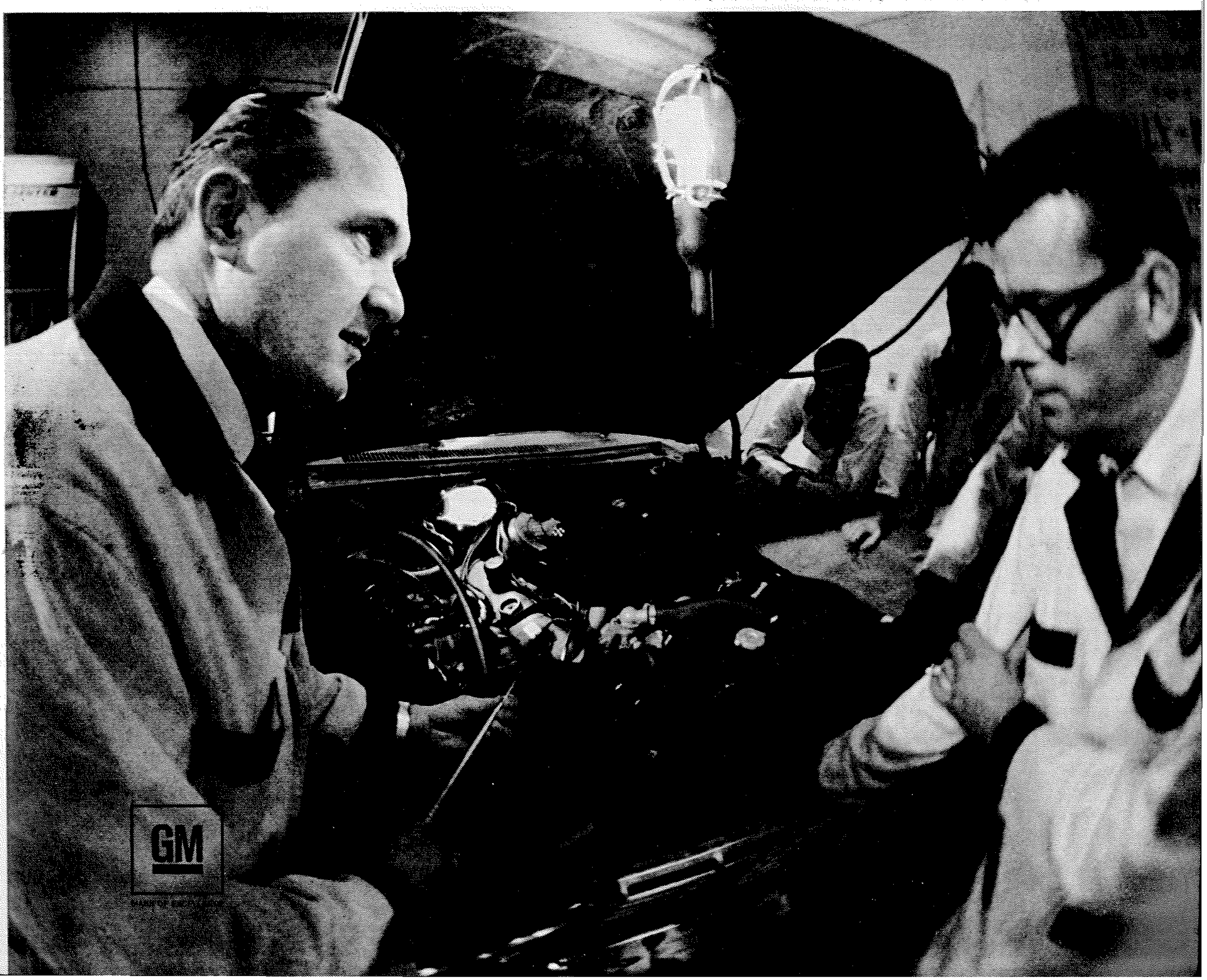
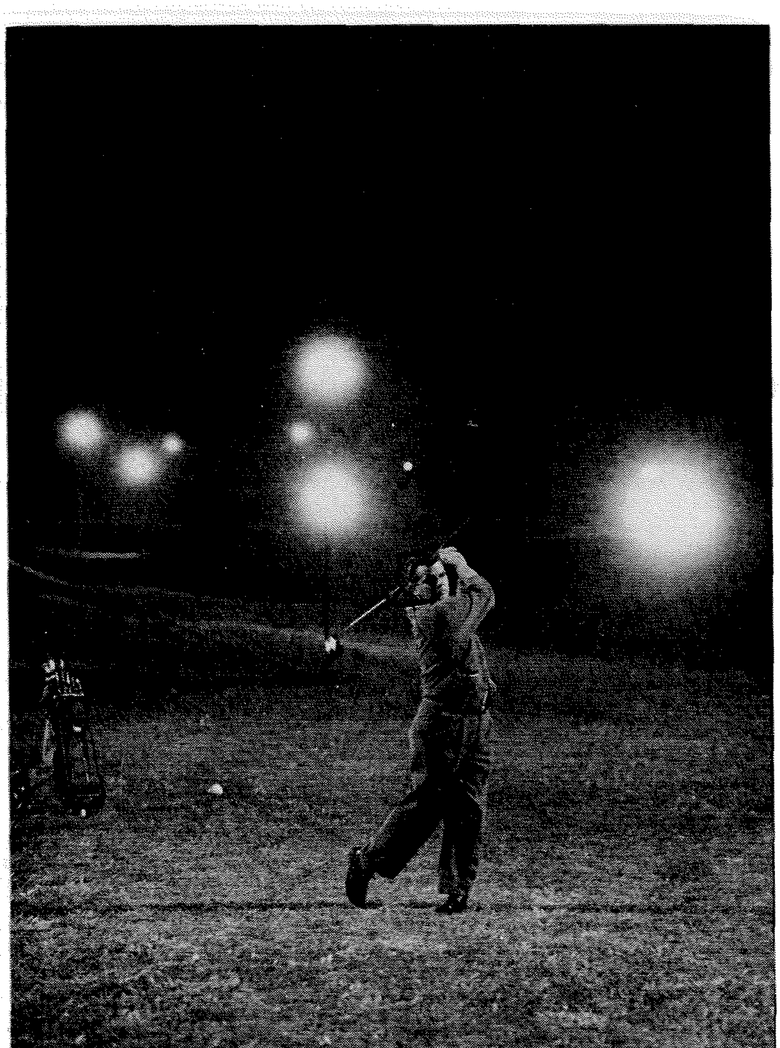
Paul Meyers, instructor, GM Training Center, Warren, Michigan



General Electric engineers and scientists are satisfying the needs of society . . .

like longer days



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