ENGINEERING | AND | SCIENCE

January 1963

Published at the California Institute of Technology

What's down under the sea? Hostile submarines? New food sources? Biological wonders like the archaic coelacanth fish? ¶ In many ways, we know more about the surface of the moon than we do about the sea around us. The sea guards its secrets in darkness, with pressures that crush steel like an eggshell. Radio waves that put us in touch with the stars can penetrate less than 100 feet of its depth. ¶ Westinghouse scientists are helping to unravel the sea's mysteries by perfecting new precision instruments for measuring salinity, acoustics, currents, pressures, sea floor contours. ¶ Westinghouse was the first to develop centralized engine room control for oceanographic ships, a development that will help make hydrographic and oceanographic surveying faster and more accurate than ever before. ¶ New undersea propulsion methods under investigation at Westinghouse involve fuel cells, thermo-electric generators, thermionic converters, cryogenic propellants. Strange words, strange world. ¶ For more information concerning a challenging career at Westinghouse, an equal opportunity employer, see our representative when he visits your campus, or write L. H. Noggle, Westinghouse Educational Center, Pittsburgh 21, Pennsylvania. You can be sure . . . if it's

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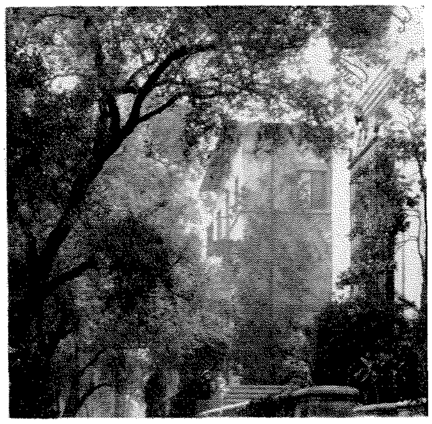
JANUARY 1963 *VOLUME XXVI* *NUMBER 4*



On Our Cover

is a new photograph of the Athenaeum, Caltech's faculty club, taken by the Institute's Graphic Arts Facility. On pages 14-20 of this issue, a sampling of some other striking pictures taken by Graphic Arts photographers, selected from the impressive exhibit of their work which went on display this month in the Winnett Student Center.

Albert T. Ellis,

associate professor of applied mechanics at Caltech, and Michael Fourney, graduate student, have incorporated a new scientific tool, the laser, in a high-speed camera which can film at a rate of over 500,000 frames a second, opening up an entirely new avenue of dynamic observation. On page 11, more information about Caltech's ingenious new high-speed laser camera.

Clarence R. Allen,

associate professor of geology, returned last summer from field trips to New Zealand, the Philippines, Formosa, and Chile, to study the dominant fault in each area.

These four faults, plus a big one in Alaska, and the San Andreas in California, are among the major fractures bordering the Pacific. In "Earthquakes and Mountains Around the Pacific," on page 24, Dr. Allen discusses the unique features of the Pacific earthquake rim.

Illustrations:

Cover, 14, 18, 19, 20–J. Douglas Stewart
15, 16–Robert M. Jeffrey
17–James McClanahan
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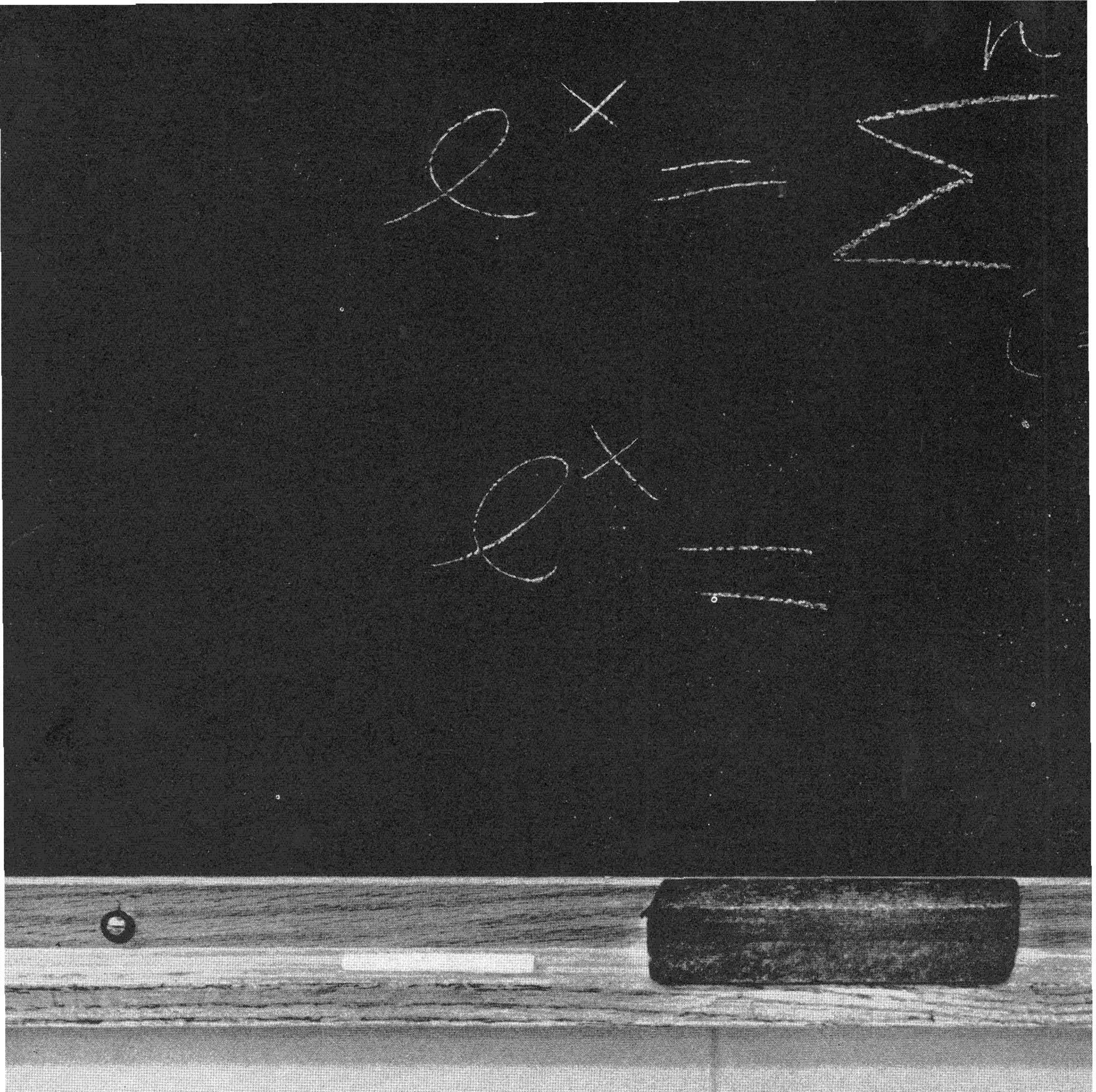

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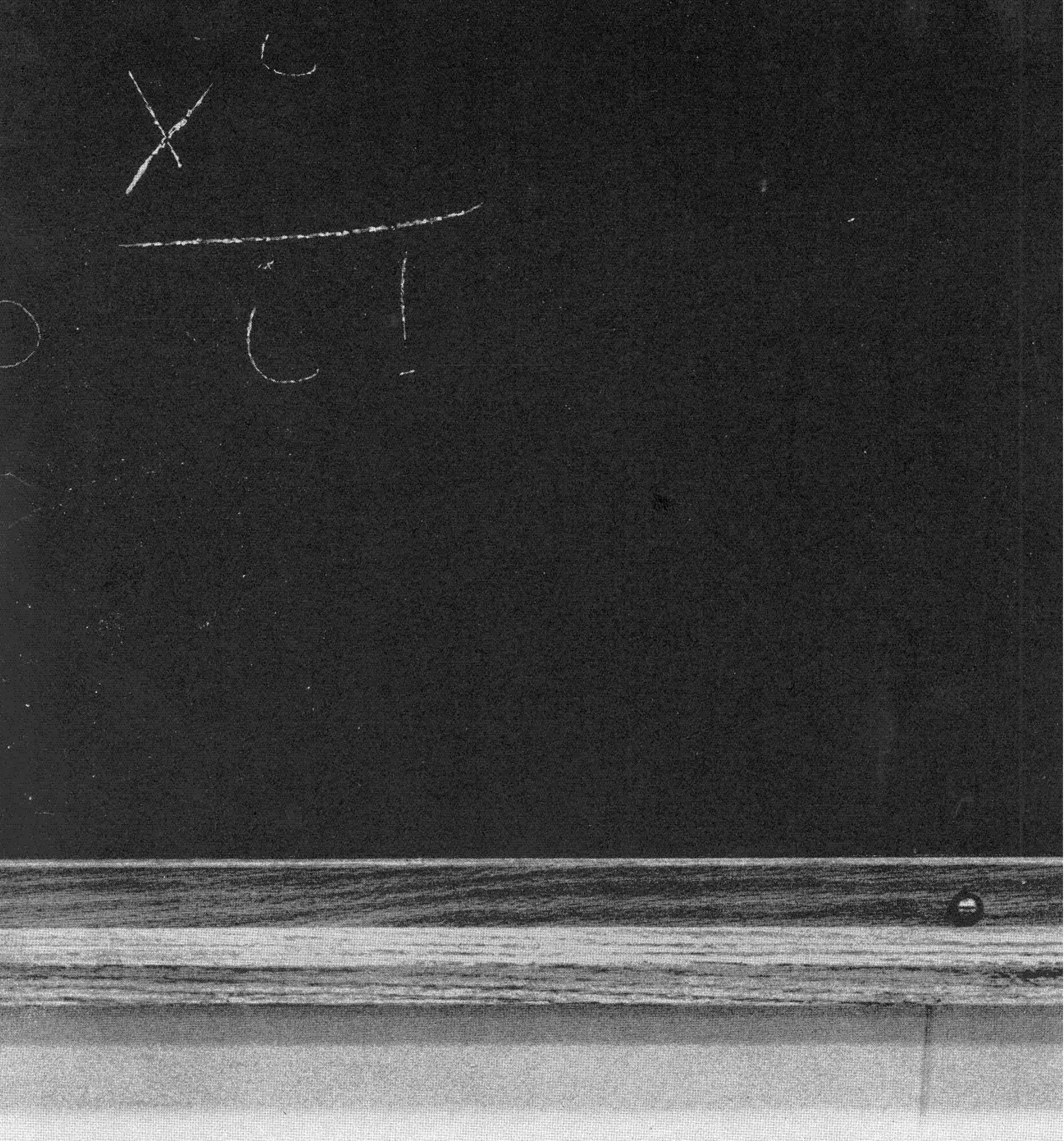


Books

ASTRONOMY
by Fred Hoyle
Doubleday *$12.95*

A lavish, oversized (8x11) pictorial history of astronomy by Fred Hoyle, the British astronomer who has served as part-time visiting professor at Caltech during the past five years. The illustrations are numerous and colorful; the text is lively, comprehensive, and understandable.

THE CHALLENGES OF SPACE
edited by Hugh Odishaw
University of Chicago Press *$6.95*

A collection of 22 essays on the scientific aspects of space exploration, covering everything from space research and technology to national space programs and international space cooperation. The authors, all experts in their fields, include such men as Joshua Lederberg, John R. Pierce, James A. Van Allen, Lyman Spitzer, Jr., and George P. Sutton. The material, which originally appeared in a special issue of the *Bulletin of the Atomic Scientists* (May-June 1961), has here been updated and expanded.

ILLUSTRATED GUIDE TO U. S. MISSILES AND ROCKETS
by Stanley M. Ulanoff
Doubleday *$3.95*

A new revised edition of this useful quick-reference book.

SCIENCE WRITER'S GUIDE
by John Foster, Jr.
Columbia University Press *$6.00*

This compact dictionary of scientific terms ought to prove useful not only to science writers but to readers of general scientific material as well. It may not have *every* scientific term in it, but it's a good start. Definitions are short and simple and they range all the way from abampere and ACTH to magnetohydrodynamics, Mendel's laws, penis envy, phonon, zooplankton, and zygote.

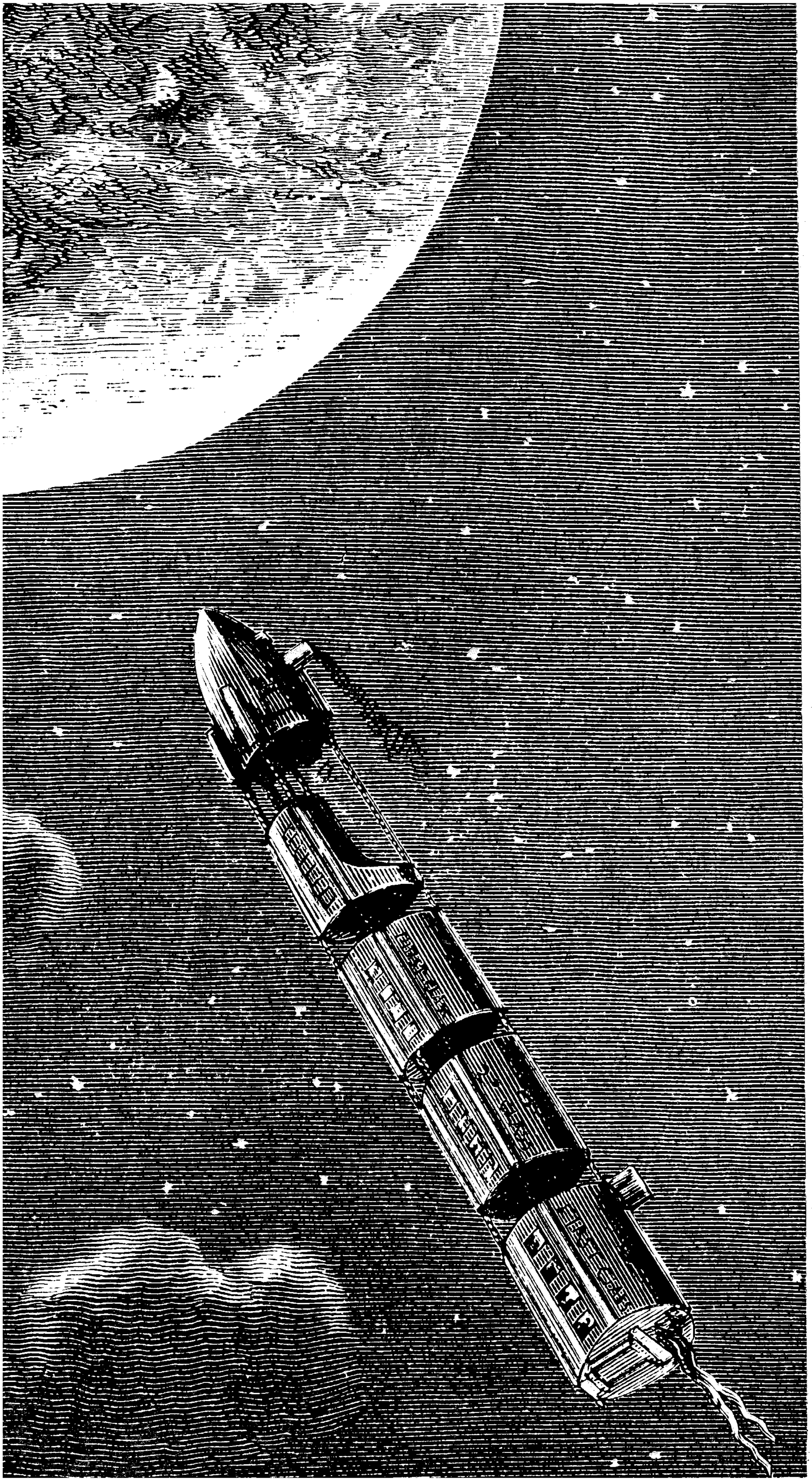
THE SPACE INDUSTRY: *America's Newest Giant*
by the Editors of Fortune
Prentice-Hall *$4.95*

A collection of tightly-written, informative articles from *Fortune* that touch on assorted aspects of space—technical, physiological, and commercial.

ALUMNI BOOKS

ELECTRIC CIRCUIT ANALOGIES FOR ELASTIC STRUCTURES
by Richard H. MacNeal, MS '47, PhD '49
John Wiley & Sons, Inc. *$11.50*

DIGITAL PROCESSES FOR SAMPLED DATA SYSTEMS
by Alfred J. Monroe, MS '50
John Wiley & Sons, Inc. *$12.50*



ENGINEERING AND SCIENCE
January 1963, Volume XXVI, No. 4

HIGH-SPEED LASER CAMERA

By incorporating a laser in a high-speed camera, Caltech engineers have now made it possible to observe extremely rapid phenomena under high magnification. The high-speed laser camera not only greatly improves the quality of observations; it opens up an entirely new avenue of dynamic observation.

The laser (an acronym for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation) is an exciting new development being pursued by scientists in a variety of fields, from communications to medical instrumentation, welding, and weapons.

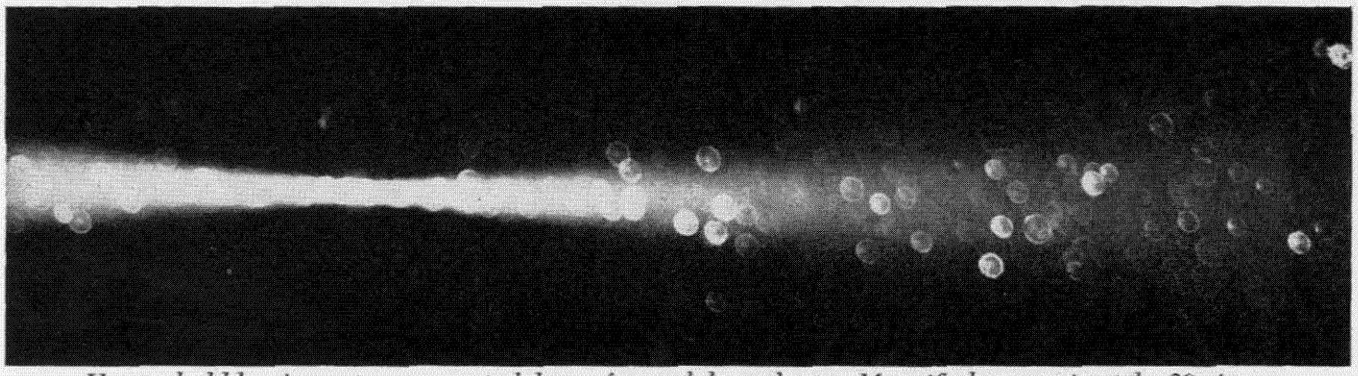
Basically, the laser is a device that converts ordinary light, which is of many wavelengths, into coherent light of one narrow wavelength moving in one direction. By means of optical pumping, the atoms in a synthetic ruby doped with chromium ions are caused to emit photons of light of one particular wavelength. Due to the crystalline structure of the ruby and the nature of stimulated radiation, the light which is emitted is coherent, monochromatic (one wavelength, or color), and linearly polarized. The intensity of this light is thousands of times greater than any previously obtainable light source.

The light in a ruby laser is ordinarily emitted in random, short-duration pulses of uneven intensity. Now, however, Dr. Albert T. Ellis, associate professor of applied mechanics at Caltech, and Michael E. Fourney, a graduate student, have converted the laser's random pulses into a series of pulses of uniform intensity up to repetition rates of over 500,000 pulses a second. The power in this laser beam is equivalent to more than 20,000 hundred-watt bulbs.

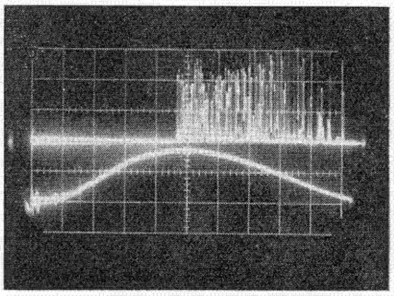
This provides enough light for the extremely short exposures necessary in taking motion pictures of very fast events. The instrument also enables researchers to use the laser pulses, in effect, as a camera shutter for filming at the rate of 500,000 frames a second. Exposure times as short as one billionth of a second are possible.

The primary objectives in the development of the laser camera are to study cavitation damage, to study dynamic phenomena in solids by means of photoelasticity, and to study fluid flow by means of scattered light from very small tracer particles as well as by standard Schlieren techniques.

Cavitation bubbles, generated by propeller blades, might typically grow to about 1/10 inch in diameter and live about a thousandth of a second. The impact of millions of these bubbles, collapsing with the pressure of 10,000 to perhaps

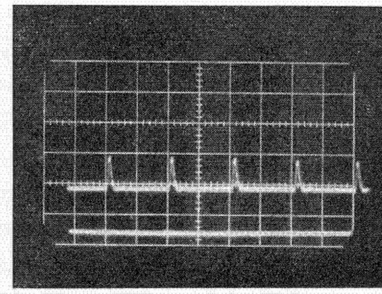


Vapor bubbles in water, generated by a focused laser beam. Magnified approximately 20 times.



Left: Traces from a dual-beam oscilloscope show (lower trace) the intensity of the light entering a ruby laser and (upper trace) the random pulse intensities and timing of the light emitted by the ruby.

Right: Photocell record of the light emitted by the ruby when pulsing is controlled by a Kerr cell at 500,000 per second.



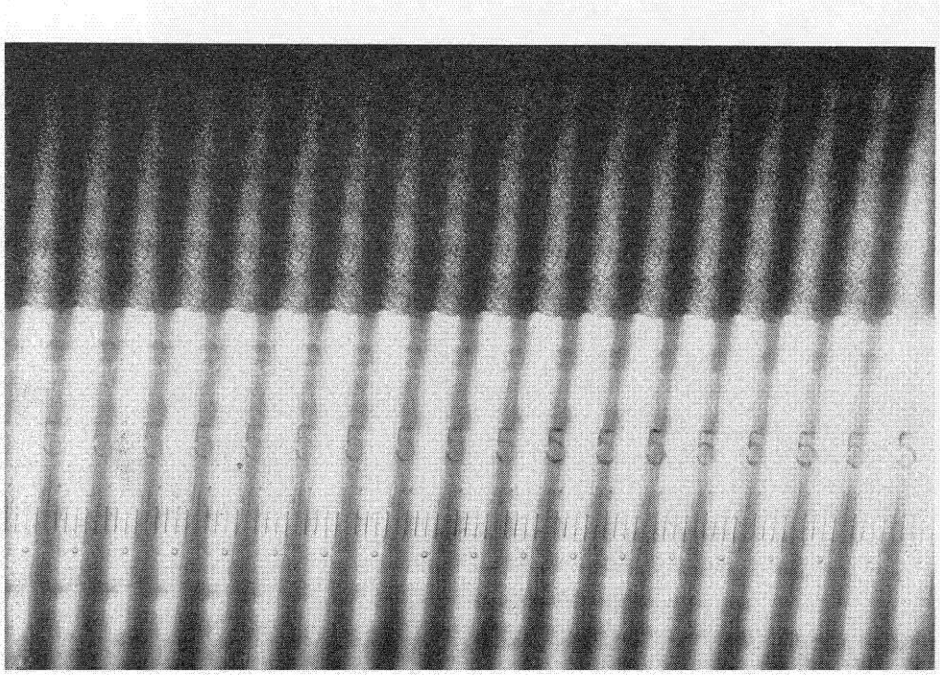
1,000,000 pounds per square inch, quickly eats away metal surfaces. Their damage to ship propellers and pumps has been a major problem for 100 years.

Dr. Ellis has been interested for some time in high-speed photography as a tool to study cavitation damage. With a multi-million-frame-per-second camera which he designed and built a decade ago, he has studied the history of a collapsing cavitation bubble. The newly developed laser camera makes a more detailed study of this possible. Also, now, the action of cavitation on a solid boundary may be observed by means of photoelastic techniques, a field in which Mr. Fourney has worked for the past few years.

The laser used in this camera consists of a ruby rod 3 inches long and ¼ inch in diameter enclosed in a cylindrical cavity of elliptical cross-section with highly polished surfaces. The ruby rod is located at one focus of the ellipse and a pumping light at the other; consequently, all of the pumping light is focused into the ruby rod. In the normal ruby laser, both ends of the cylindrical ruby rod are reflective so that light traveling along the axis of the rod will be reflected back into the rod. One end has a partially transmitting mirror so that a small portion of the light is allowed to escape on each pass. This light represents the output of the laser. As the light makes several passes through the ruby, the intensity is amplified by a cascading process as each photon of light, striking an atom in an excited state, causes it to fall to its ground state. This results in two photons of light of the same wavelength and phase relationship, traveling in the same direction as the incoming photon.

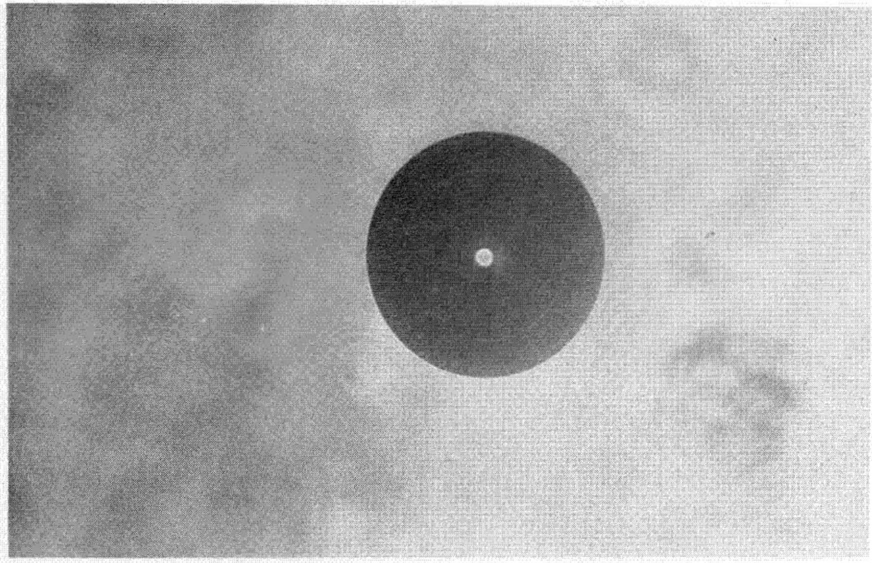
By introducing a Kerr cell in the light path between the active ruby material and the partially reflective mirror a shuttering effect is achieved. A Kerr cell is a small glass cell containing liquid nitrobenzene and two nickel electrodes. When no voltage is applied to the cell, the polarized light passes through without alteration. However, when a voltage is applied the nitrobenzene molecules are aligned in such a manner that the direction of polarization is rotated. Upon application of the proper voltage (10,000 volts for the cell used in the present experiment) the "lasing" action may be stopped. Thus, the lasing action may be controlled by regulating the voltage applied to the cell. The effect is similar to that of raising a dam so that more water (in this case, photons) is contained in the reservoir (crystal rod). When the dam (the Kerr cell shutter) is suddenly removed, a flood of photons is released through the partially reflecting mirror.

The Kerr cell as a shuttering device for a laser



In high-speed photography, light intensity requirements are much more severe at greater magnification. This test photograph of a ground-glass microscope scale, magnified 25 times, shows the sharpness that can be achieved with the laser camera operating at 200,000 frames a second. Division marks on the scale are 100 microns apart.

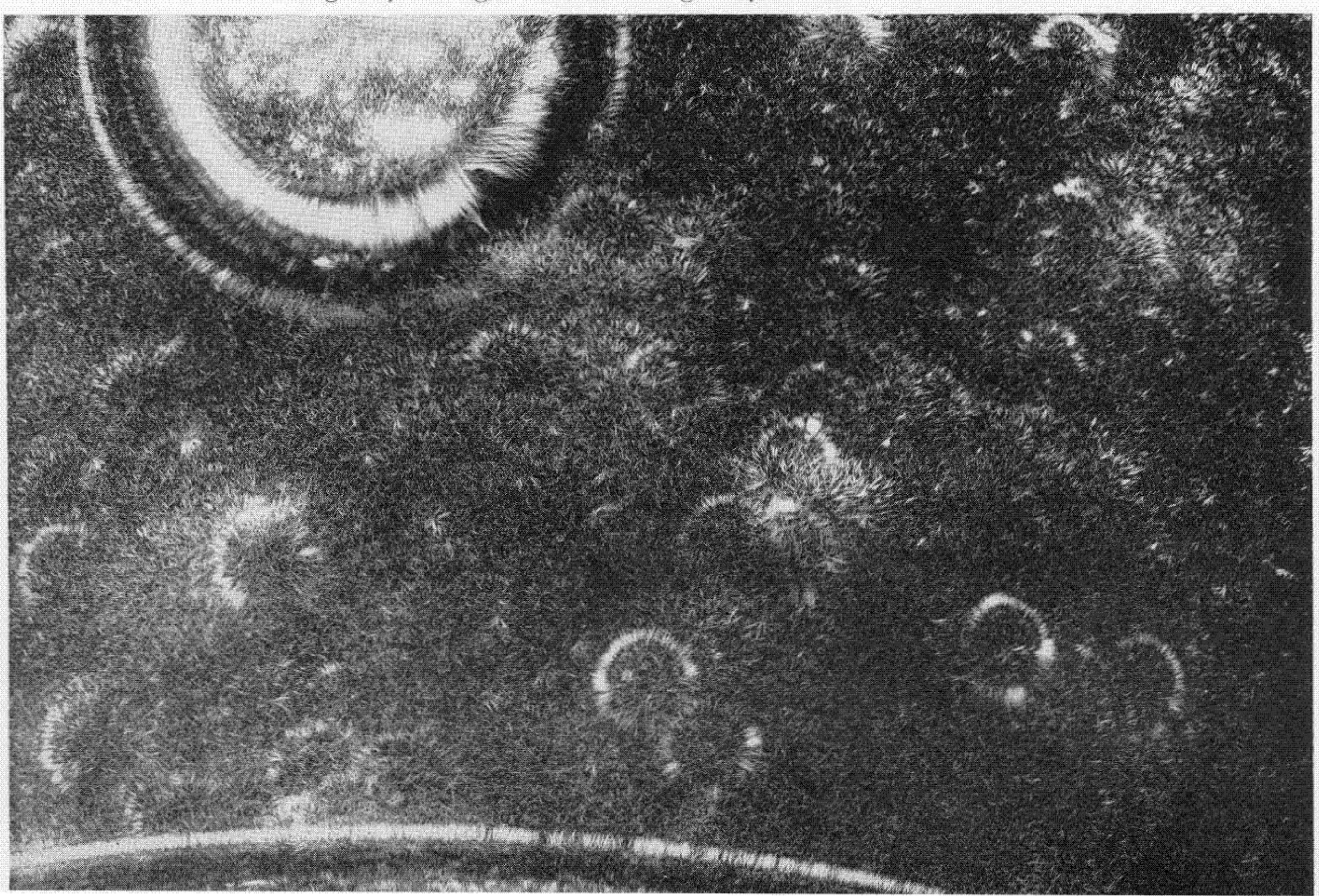
An air bubble, 0.13 centimeters in diameter, photographed in silhouette with light from a ruby laser. The bubble is held stationary by a sound field.



was first used by Robert W. Hellwarth and F. J. McClung at the Hughes Research Laboratories in Malibu, California. Dr. Hellwarth, a lecturer in physics at Caltech, and Dr. McClung produced a single pulse in which the amplitude was observed to be a thousand times greater than that of a normally operating laser. Dr. Ellis and Mr. Fourney have been able to produce multiple pulses in which the amplitude is also greatly increased. These light pulses are then used as a stroboscopic light source for the laser camera.

Dr. Ellis plans to use this newly developed laser camera in conjunction with a "blow-down" water tunnel for studying the collapse of cavitation bubbles in flowing water, the environment in which they are normally generated. Previously, in studying cavitation bubbles in still water, Dr. Ellis and his former student, Dr. Charl Naudé, had developed a theory that the damage is caused by a jet of water that pierces the bubble opposite to where it is in contact with a solid surface. With the assistance of another graduate student, Michael E. Slater, Dr. Ellis has developed the blow-down water tunnel, with velocities of up to 100 feet a second, in hopes of extending this theory to collapsing bubbles in flowing water. Assisting also on this project is Dr. J. S. Barnard, research fellow in hydrodynamics. This research, as well as the development of the laser camera, is supported by the Office of Naval Research.

Test photograph by scattered light of a concentrated solution of polystyrene spheres, .258 microns in diameter —smaller than the wavelength of the light used in taking the picture.



Spectators at a sportscar race, Zandvoort Track, Holland

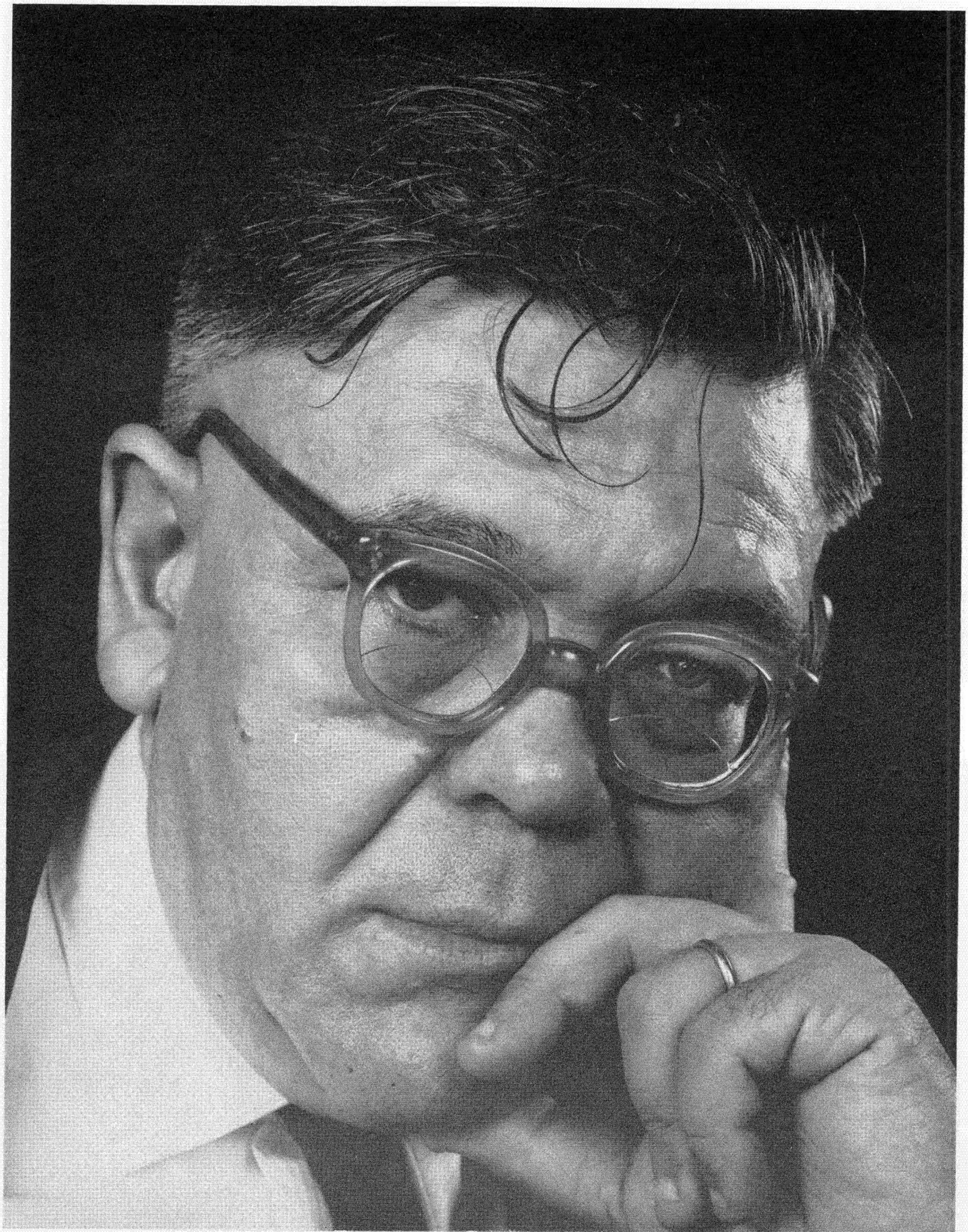
GRAPHIC ARTS SHOWCASE

A comprehensive exhibit of the work of Caltech's Graphic Arts Facilities went on display this month in the Winnett Student Center. The show featured the creative efforts of the department's printers, illustrators, and photographers. It included scientific, news, and experimental photography, examples of the National Geographic-Palomar Observatory Sky Survey, and printing and graphic reproductions made by various processes.

On the following pages, some examples of the varied photographic work of James W. McClanahan, photo department supervisor, and of Robert M. Jeffrey and J. Douglas Stewart, staff photographers.

Cross country meet.

Undergraduate discussion in the Y lounge.

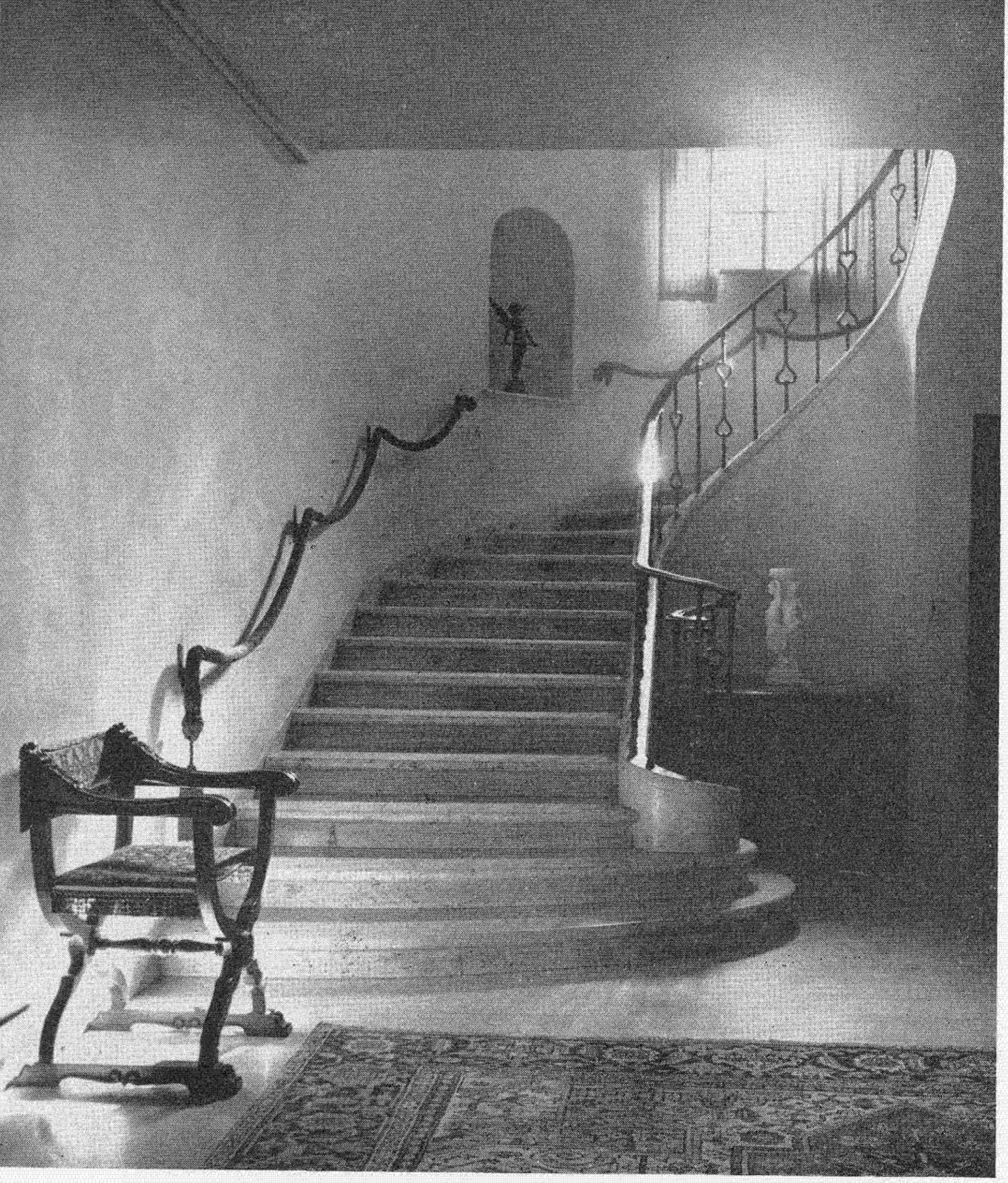


Emil R. Herzog, research assistant in astrophysics.

SOME CAMPUS PORTRAITS

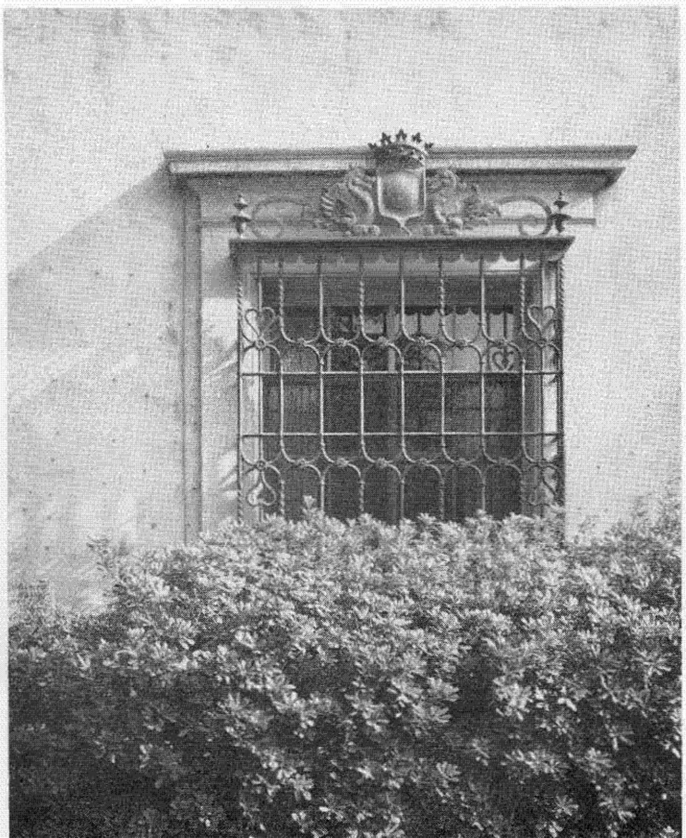
Usha Shah, graduate student in chemistry.

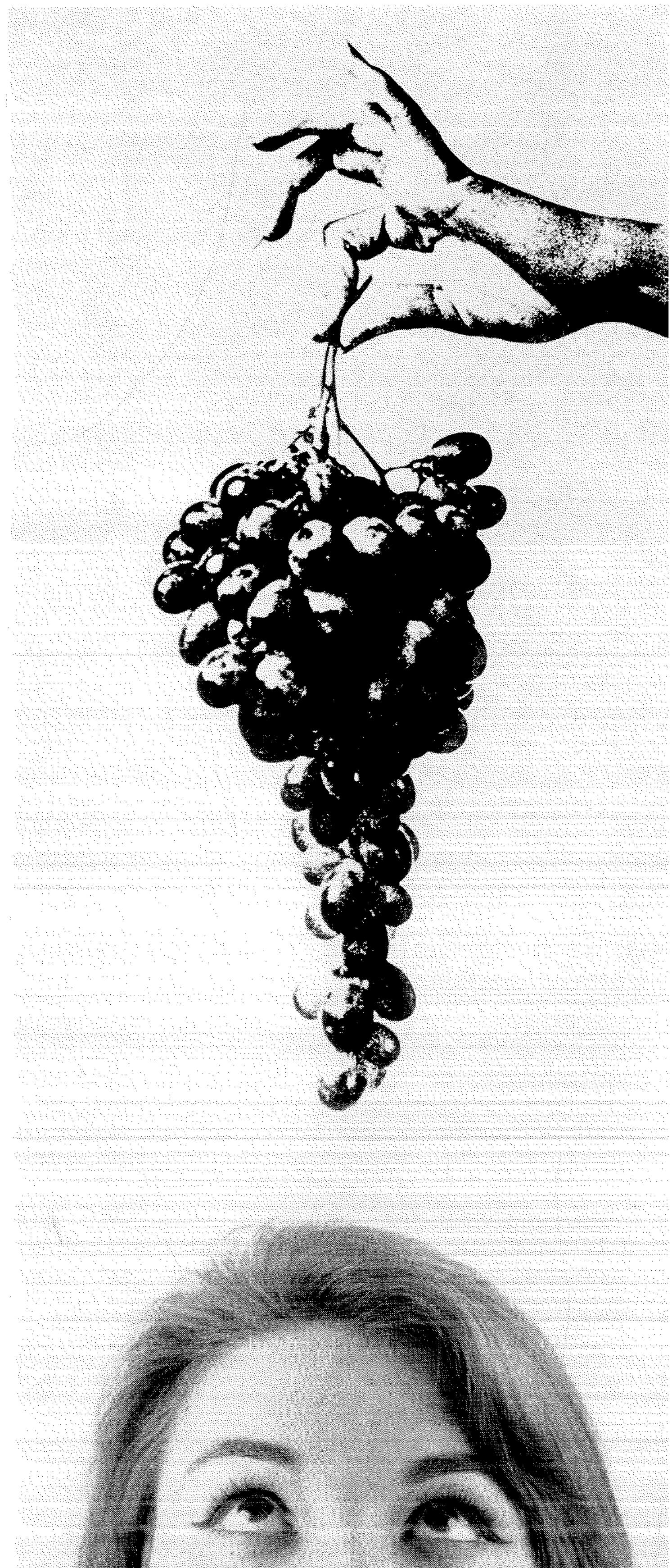
Dan H. Campbell, professor of immunochemistry.



THE ATHENAEUM

— A camera study of Caltech's faculty club





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Earthquakes and Mountains Around the Pacific

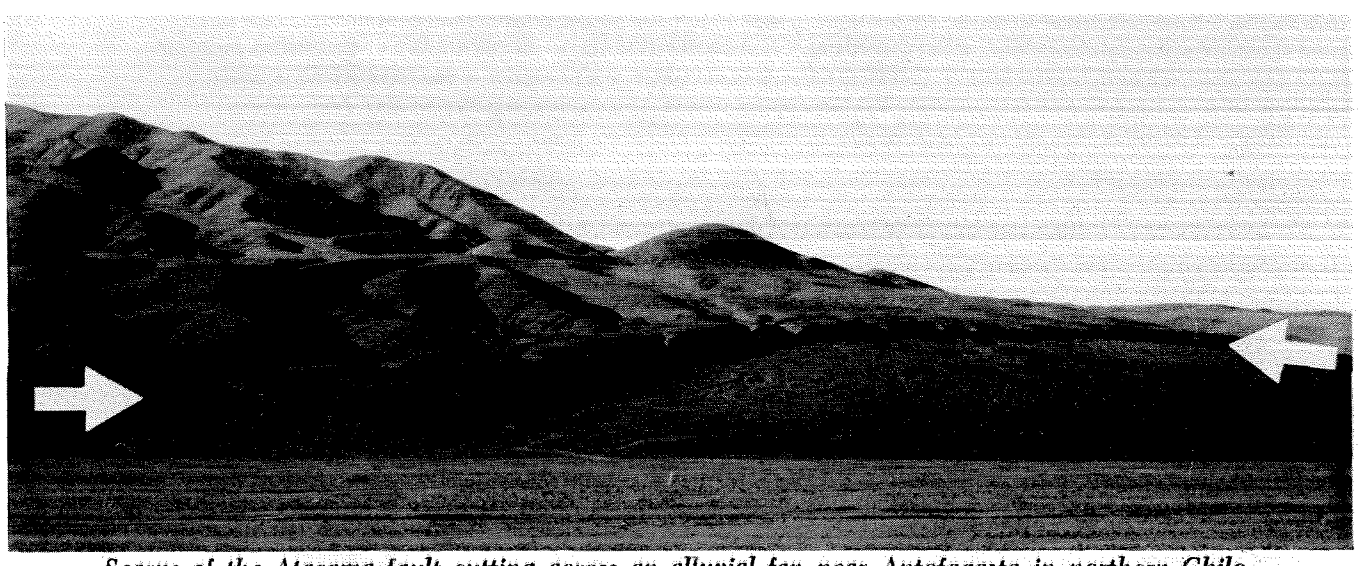
by Clarence R. Allen

Even after a century of intensive study, the problem of the origin of mountain systems remains as possibly the greatest enigma of the earth sciences. Specifically, what is the origin of mountain-building forces, and how are these forces manifested in the crustal rocks of the earth's surface?

Field geologists who have studied such classical mountain systems as the Alps and the Appalachians have always been impressed by the abundant evidence of uplift and compression shown by the highly deformed rocks in the cores of these ranges; consequently, most theories of mountain building have been intimately concerned with the mechanics of compression and vertical uplift. Contraction of the earth's crust (possibly due to cooling), and thermal convection currents in the earth's interior, are two of the theories most often discussed at present, although they are by no means the only ones.

Geological field studies of ancient mountain systems have told us much about the nature of the associated deformation, and have emphasized some of the conditions and constraints that must be satisfied by any valid theory. If such mountain-building processes are taking place anywhere in the world *today*, however, one might expect to observe them best in the regions bordering the Pacific Ocean, inasmuch as this circum-Pacific "ring of fire" can claim the great majority of the world's current earthquakes, most of its active volcanoes, and most of its very youthful mountain systems.

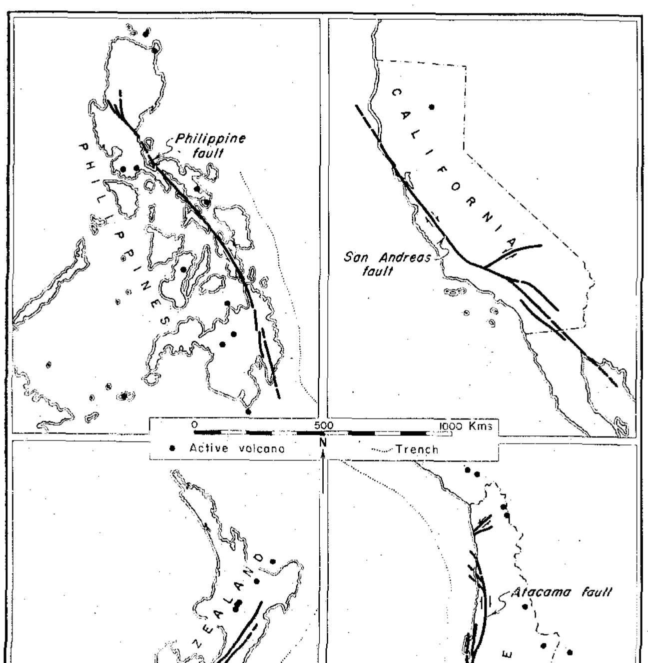
Great earthquakes certainly represent one of the most obvious manifestations of present-day mountain building, and the 1906 earthquake in San Francisco was one of the earliest circum-Pacific shocks studied in detail. The results were surprising to most geologists, because instead of the associated vertical uplift and evidence of great compression that might have been expected, the ground displacement along the San Andreas fault that caused this earthquake was almost entirely horizontal. During the earthquake, points



Scarps of the Atacama fault cutting across an alluvial fan near Antofagasta in northern Chile.

on the ground surface west of the fault slipped northward as much as six meters relative to points across the San Andreas fault to the east, with little or no vertical offset of the ground surface. Subsequent geological and seismological studies have shown that such horizontal (or "strike-slip") displacements characterize not only faults of the San Francisco area, but most of coastal California and northwestern Mexico as well – throughout the region dominated by the San Andreas fault system. And reconstruction of the geologic history indicates that strike-slip displacement of this type has been occurring intermittently along the San Andreas and associated faults for perhaps as long as 100 million years.

About 20 years ago a large fault system similar to the San Andreas was recognized in another circum-Pacific area – New Zealand. The Alpine fault of southern New Zealand is similar to the San Andreas not only in the dominance of horizontal over vertical displacements, but also in that the *sense* of displacement is the same. Both are so-called "right-handed" faults, so that as one faces the fault from either side, the opposite side appears to have moved to the right. Furthermore, the topography associated with the Alpine and San Andreas faults is remarkably similar. Both appear from the air as giant scars or rifts



Four of the major circum-Pacific faults.

Fault trench of Cucapa fault, a branch of the San Andreas, 25 kms south of Mexicali, Baja California.

cutting across the landscape, and rivers tend to erode along the faults with anomalously straight courses, owing to the wide zones of crushed and pulverized rocks within the faults.

The predominance of horizontal displacements in California and southern New Zealand did not fit well with existing theories of the mechanism of mountain building, so for many years it was suspected that these two areas were "peculiar" and not typical of the rest of the circum-Pacific belt. There were good independent reasons for this suspicion too. Neither California nor southern New Zealand have the active volcanoes, the deep offshore oceanic trench, or the earthquakes of unusually great focal depth that characterize the more typical circum-Pacific areas such as the Aleutians, Japan, or the west coast of South America; perhaps vertical displacements might still characterize these more typical areas. A few years ago even this idea came under doubt, however, when seismologists found that they could draw certain conclusions about the type of displacement that had caused a given earthquake by examining the seismograph records alone. This technique made it possible to infer the sense of displacement even if the surface effects at the epicenter were concealed by ocean waters or were otherwise unobservable.

The results of these so-called fault-plane solutions were a great surprise to geologists and seismologists alike, for they indicated that threequarters of the world's earthquakes were caused by predominantly horizontal fault displacements —not only in California and southern New Zealand, but in almost every other part of the world as well, including the entire circum-Pacific rim. In fact, these results were so startling that there is still spirited scientific debate among seismologists as to whether the method used in the fault-plane solutions is valid. One obvious geological check was to take a closer look at some of the other active circum-Pacific areas to see if faults similar to the San Andreas and Alpine faults might possibly have been overlooked up to this time. An added stimulus was given to this search by the interesting proposal that perhaps the entire Pacific basin was rotating in a counterclockwise direction. This hypothesis was supported by the right-handed displacements parallel to the Pacific margin that had been observed in California, New Zealand, and Alaska, as well as by some of the seismological results. If true, right-handed strike-slip movements should, of course, characterize *all* of the circum-Pacific rim.

Northern Chile is as typical a circum-Pacific area as one could hope to find. It has numerous active volcanoes, a deep offshore oceanic trench,

Wairau Valley, on the South Island of New Zealand, is a fault-controlled valley along the Alpine fault system. The arrows point to scarps of geologically recent breaks.

Left-handed stream offsets along the Camarones fault, northern Chile. Distance between arrows — 2½ kms.

and abundant seismic activity, including earthquakes of very deep focus. Little was known about possible active faulting in this area, and, in 1960, I had the opportunity of working here with Dr. Pierre St. Amand, a Caltech graduate, under the auspices of the Universidad de Chile and the Instituto de Investigaciones Geológicas de Chile. Because of the almost complete absence of rainfall, geological exposures in northern Chile are extraordinary, and our field studies indicated that a major fault zone similar to the San Andreas transects the Atacama Desert of northern Chile for a total distance of more than 1000 kilometers.

Like the San Andreas and Alpine faults, the Atacama fault is parallel to the Pacific rim and gives every indication of a history of horizontal displacement. The fracture is remarkably linear over distances of hundreds of kilometers, which would be most unlikely if the displacement were predominantly vertical; neither side is consistently higher than the other, yet the disparity in rock types across the fault indicates a significant total displacement; stream channels are offset horizontally where they cross the fault; and giant grooves or "slickensides" on the fracture surfaces are predominantly horizontal where they can be observed in the many mines along the fault. Offset stream patterns and other geologic evidence indicate that the sense of displacement along the Atacama zone has been right-handed. Subsidiary conjugate faults that trend 60° to 90° to the main fault — as in the Camarones fault shown above — are left-handed, as would be expected from mechanical considerations.

Thus the evidence from northern Chile supported not only the idea of worldwide dominance of strike-slip faulting, but was also consistent with the hypothesis of counterclockwise rotation of the Pacific basin. The great earthquake of May 1960 took place much farther south in Chile, and the associated faulting was evidently underwater offshore. However, everything that is known about this earthquake from seismograph records indicates that it, too, was consistent with the rotation hypothesis.

Despite the increasing evidence of strike-slip faulting along the borders of the eastern Pacific, little has been published on the character of possible faults along most of the western Pacific rim. The Philippines looked particularly promising in this regard, because earlier geological work there had indicated the possibility of a major fault zone extending the length of the archipelago from Luzon to Mindanao. Various authors had suggested every different type of displacement on this proposed fault, but had cited rather tenuous evidence. Through the cooperation of the Philippine Bureau of Mines, I had the opportunity to do field work in the Philippines in early 1962, and the Philippine fault turns out to be fully as spectacular in its gross physiographic expression as the San Andreas, Alpine, and Atacama faults, despite the tropical environment. The best exposures of the fault were found on the northern part of the island of Leyte, and the aerial photograph at the right shows some features of geologically recent displacements along the fault in this region. This is the area, incidentally, of perhaps the most intense fighting in the Philippine campaign of World War II. For almost four weeks the opposing armies literally fought for control of scarps of the Philippine fault near the village of Limon.

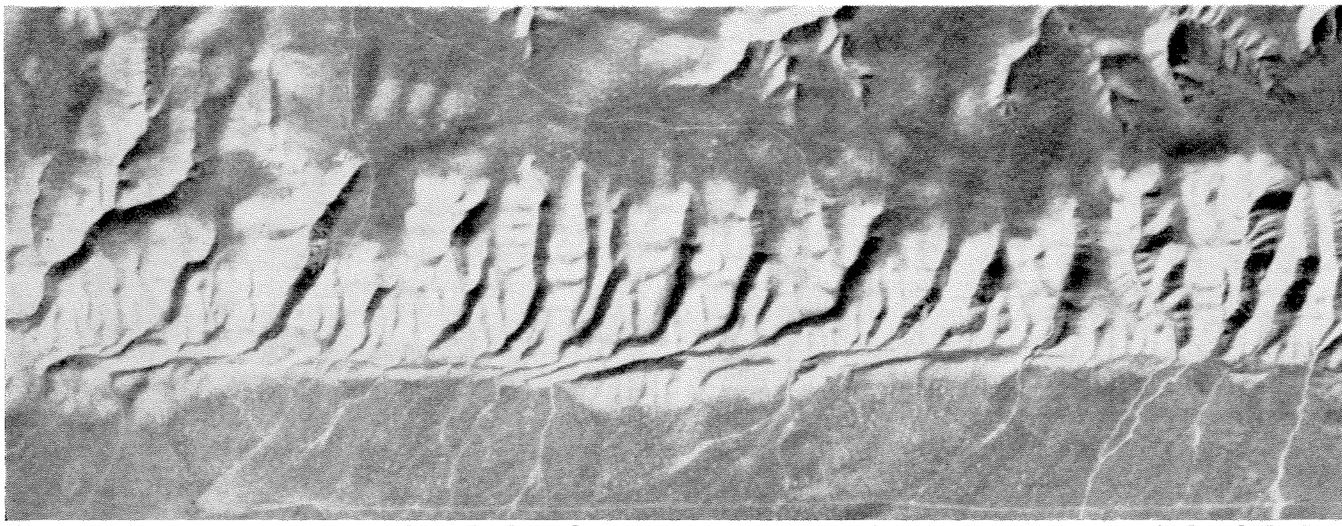
Determining the sense of displacement along the Philippine fault turned out to be somewhat more difficult than in desert areas such as northern Chile, because the dense jungle cover makes it difficult to identify – either in the field or on aerial photographs – many of the detailed topographic forms caused by recent displacements. However, clear-cut and consistent horizontal stream offsets have now been identified along the fault at numerous localities on the islands of Luzon, Masbate, and Leyte; these offsets are uniformly *left*-handed. Similarly, a great fault parallel to the Pacific margin near the east coast of Taiwan was found to have slipped during a series of major but little-publicized earthquakes in 1951, and in each instance the sense of displacement along the fault was predominantly horizontal and left-handed.

The exposed length of the Philippine fault– over 1200 kilometers – is about the same as that

Philippine fault zone in northern Leyte. The linear trench is due partly to erosion within the fault zone, partly to recent displacements of the ground surface.

of the San Andreas fault in California and Mexico, and its gently curved trace outlines the arcuate structure of the archipelago. If the Philippine Islands were slightly more submerged, the trace of the fault would be largely concealed beneath the sea, and it seems likely that similar throughgoing faults of strike-slip character underlie many of the other island-arc areas that are less well exposed. Likewise, the 150-kilometer length of fault exposed in eastern Taiwan presumably represents only a short segment of its total length; everything that is known about this fault suggests that it, too, is a master fault of regional tectonic importance.

Thus our field observations in a number of circum-Pacific areas tend to support the viewpoint that strike-slip faulting is indeed the predominant method of seismic strain release in the world today, and that California is not the unique or unusual area that we once thought it might be. But with regard to the question of possible counterclockwise rotation of the Pacific basin, it seems clear that the left-handed displacements that apparently typify the Philippines-



Aerial photograph of the San Andreas fault 75 kms west of Bakersfield, California. Consistent right-handed offsets of streams crossing the fault reflect horizontal displacements. Length of fault shown is 2.6 kms.

Taiwan region are not in harmony with the right-handed displacements that have been observed in Alaska, California, Chile, and New Zealand. The issue is not completely settled, however, because it might still be argued that the true edge of the rotating "disc" is not along the Ryukyu-Taiwan-Philippine lineament, but is instead along the parallel Bonin-Mariana-Palau arc system. I prefer to believe that the pattern of underlying currents is far more complicated than that of a single horizontally rotating disc beneath the entire Pacific, and that considerably more field work will be required before we understand even the basic pattern of deformation.

Where does this leave us with regard to the over-all question of the origin of mountain systems? Indeed, one might well ask: If fault displacements are predominantly horizontal, why should we have mountains at all? Several answers can be suggested:

(1) Certainly not all mountains are fault-bounded; many are associated with regional upwarping, folding, or volcanic activity. In studying faulting and earthquakes, we are obviously dealing with only one mechanism of strain release.

(2) If geologists are right in thinking that the total horizontal displacements on regional faults such as the San Andreas and Alpine may be as much as several hundred kilometers, and there seems to be increasing evidence of this, then a very small departure from purely horizontal movement in any one segment could eventually lead to very significant local vertical relief.

(3) We know very little about what happens at the ends of great strike-slip faults, but it is difficult to avoid the conclusion that considerable stretching and compression of rocks must take place in these areas, with associated vertical adjustments. Likewise, there must be considerable strain in regions where major strike-slip faults change trend, such as near the abrupt bend in the San Andreas fault at the south end of the San Joaquin Valley.

(4) Neither the fault-plane solutions nor field observations of historic earthquakes indicate that *all* earthquakes are caused by predominantly horizontal displacements.

However, the much more difficult question still remains: What is the *mechanism* of mountain building that would lead to predominantly horizontal displacements? It is hard to understand, for example, how this sort of phenomenon could be caused — except locally — by crustal contraction or by convection currents involving turnover of material due to thermal instability in the earth's interior. It would seem instead that we need either some sort of horizontally-moving sub-crustal currents or some mechanism whereby the crust should slip differentially over the underlying materials. One might ask if such displacements could not easily be explained by so-called continental drift, and it is indeed true that the documentation of abundant and large horizontal fault movements adds to the attractiveness of the continental drift hypothesis. But continental drift, even if true, is only a manifestation of more fundamental mountain-building forces and cannot be considered an ultimate cause in itself. So, as of today, the only honest answer we can give in response to the question of the origin of mountain systems is that we simply don't know. And, paradoxically, continuing geological field work, such as our studies of circum-Pacific faulting seems to be making the problem more difficult rather than simpler.

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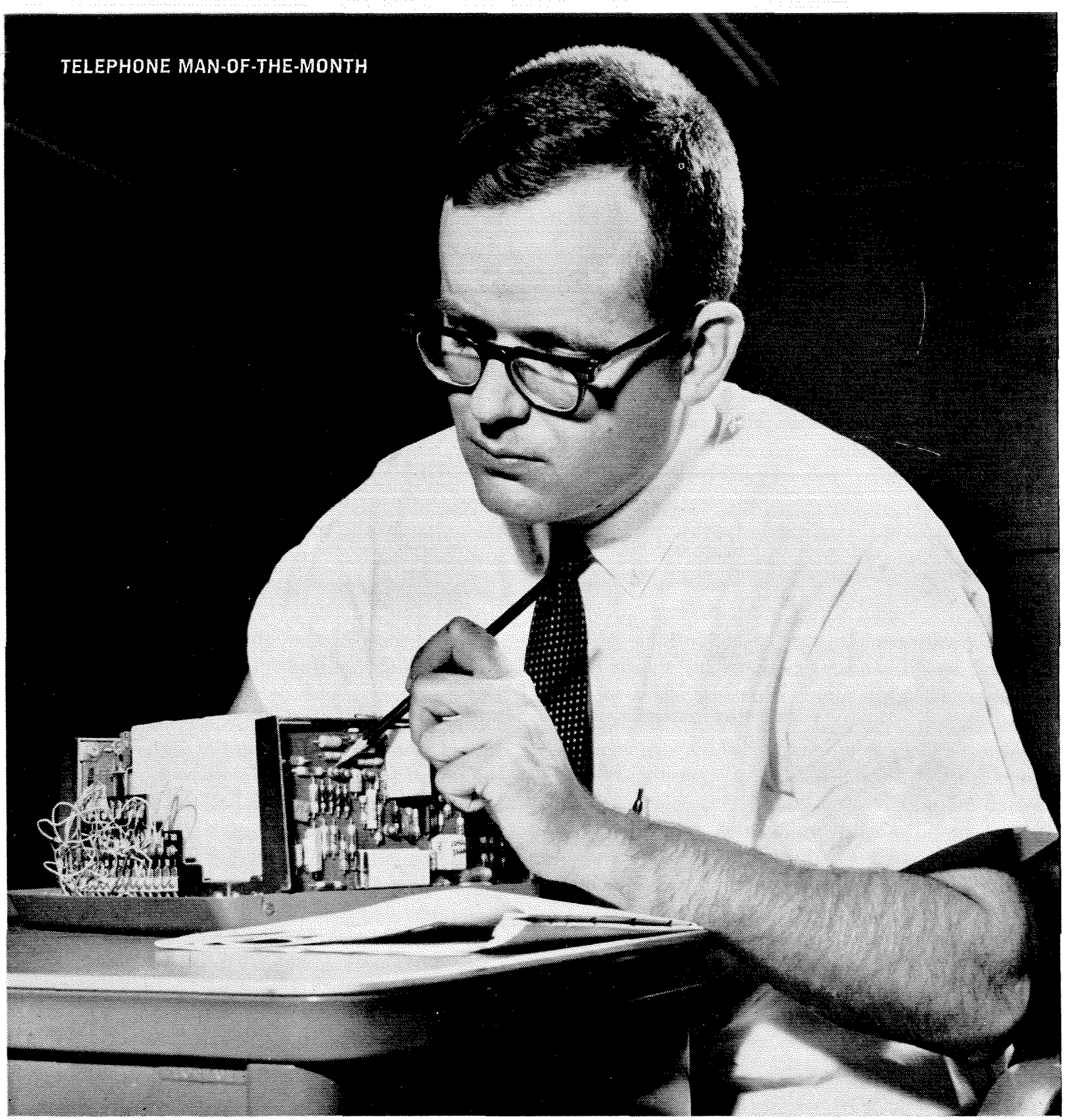


SCIENCE AND THE ENGINEER

Some reflections on the engineer's function in our increasingly complex technological culture

by M. A. Biot

It is a great honor to be associated with the name of Timoshenko, the teacher, the scholar, the great engineer and scientist. It is widely agreed that the high level of instruction and application of solid state mechanics in this country is due to his influence and his teaching.

However, to me the name symbolizes much more than the award and the honor.

It evokes a brilliant phase and tradition in the practice of science and engineering which unfortunately seems to be on the decline. This is the tradition of clarity, simplicity, intuitive understanding, unpretentious depth, and a shunning of the irrelevant.

There is, of course, no merit in sophistication for its own sake. In the understanding of the physical world, and particularly in the area of technological applications, it is important to perceive what is irrelevant. The level of irrelevance involves a value judgment which usually requires rather subtle habits of thought related to natural endowment and previous experience.

We should not overlook the importance of simplicity combined with depth of understanding —not only for its cultural value, but as a technological tool. It leads to quantitative predictions without laborious and costly calculations; it suggests new inventions and simple solutions of engineering problems. Aside from obvious economic advantages, it also provides an important quality in engineering design – namely reliability. In this respect one cannot help but reflect on our dismal record of staggering cost and repeated failures in the field of rocketry.

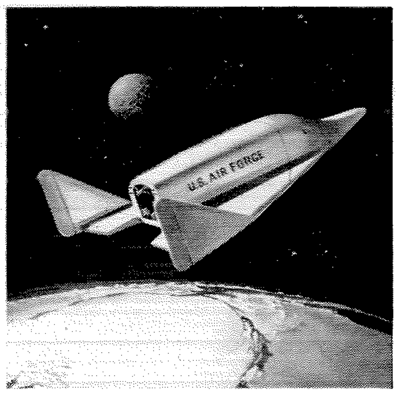
Deeper physical insight combined with theoretical simplicity provides the short-cut leading immediately to the core of extremely complex problems and to straightforward solutions. This cannot be achieved by methods which are sophisticated and ponderous even in simple cases.

The process of thought which is involved here may be described as "cutting through the scientific red tape" and bypassing the slow-grinding mills of formal scientific knowledge. Of course, formal knowledge is essential but, as for everything in life, the truth involves a matter of balance. The instinctive embodiment of this truth is to be found more often in the politician than in the scientist. However, it is essential to the make-up of a competent engineer.

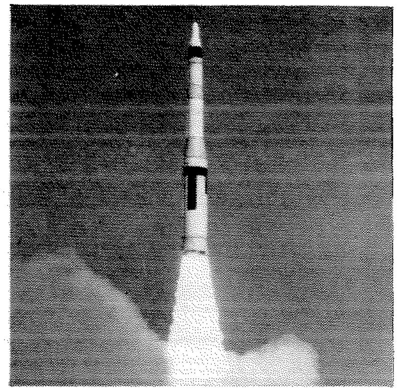
Doubt about the engineer's function in our increasingly complex technological culture has been expressed by the blunt question, "Is the engineer obsolete? Should he be replaced by the scientist?" Although such a question is the product of ignorance, the situation is such that, in this country at least, it finds a respectable echo.

continued on page 34

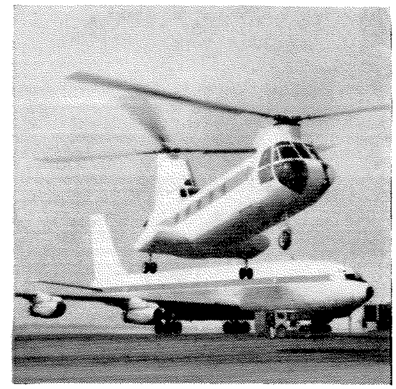
"Science and the Engineer" has been adapted from the acceptance speech given by Dr. Maurice Biot when he received the Timoshenko Medal from the American Society of Mechanical Engineers in New York on November 27, 1962. The medal, named in honor of S. Timoshenko, authority in the field of mechanics of materials, is given for "distinguished service or achievement in science or engineering." Dr. Biot, who received his PhD in aeronautics from Caltech in 1932, is a private consultant in physics, mathematics, and engineering in New York.



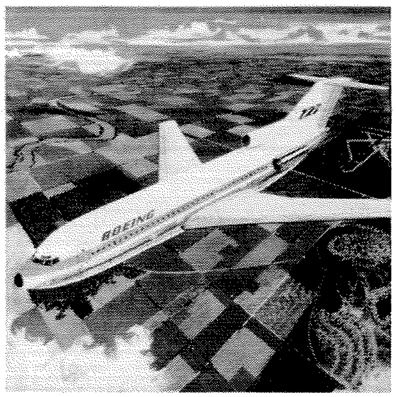
System contractor: DYNA-SOAR



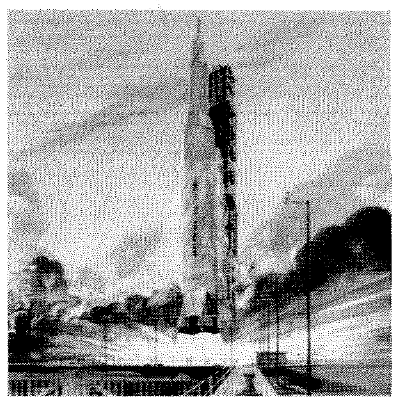
System integration: MINUTEMAN



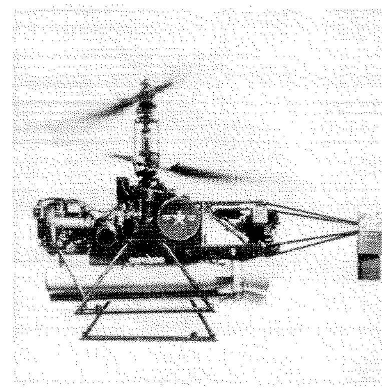
Boeing 707 with Boeing-Vertol 107



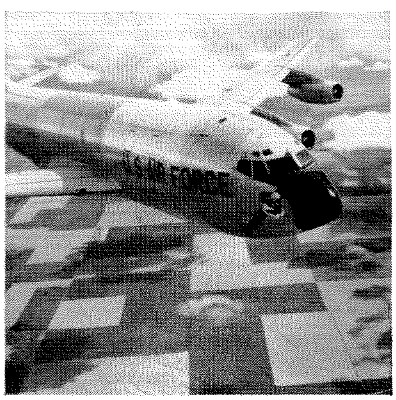
New Boeing 727 short-range jetliner



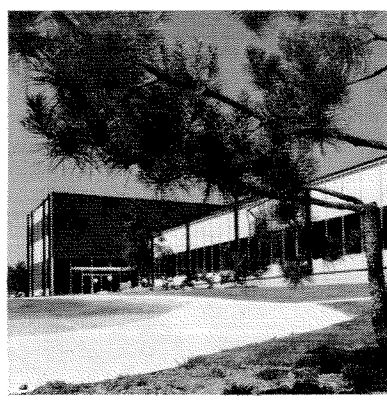
Space booster development: SATURN S-1C



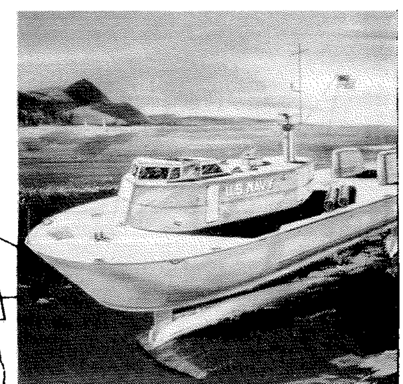
Boeing turbines power helicopters



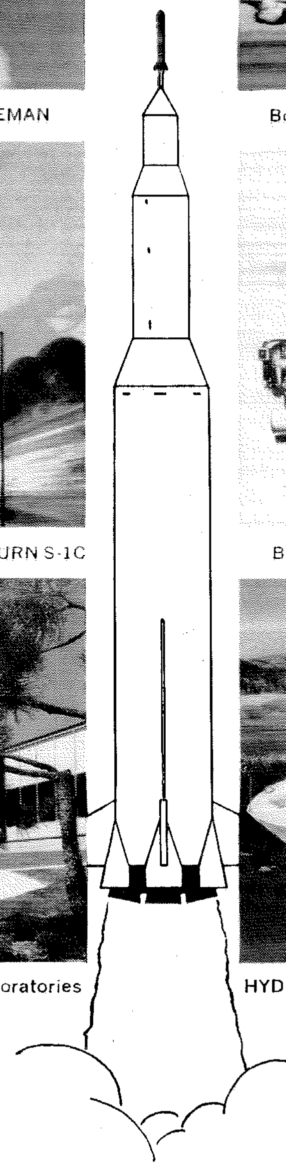
Boeing KC-135 jet tanker-transport



Boeing Scientific Research Laboratories



HYDROFOIL development, construction



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What about the physicist? Speaking in general, and with due respect for exceptional personalities endowed with outstanding natural ability, I think the physicist has turned away from his own tradition and has tended to become a victim of narrow specialization. Nuclear and particle physics, solid state, spectroscopy, plasma physics, all claim their victims. Many are almost totally ignorant of classical mechanics and are not able to understand the formulation of even a simple problem unless it can be reduced to the solution of a Schroedinger equation.

As for the mathematician, a situation has developed which is a complete reversal of what existed in the past. Many of the great names in the history of mathematics of the nineteenth century have been those of distinguished engineers. An outstanding example is Cauchy, who graduated as a civil engineer and was engaged in the practice of engineering for many years. These men were of a different breed. They had a deeper grasp of scientific knowledge, a much broader outlook than the professional mathematician of today.

Dehumanized mathematics

Whatever the cause of this reversal, we must face the fact that mathematical science has become dominated by abstract formalism. It is increasingly dehumanized and cut off from its roots in the rich and nourishing soil of physics and engineering, and the other natural sciences. What should be referred to as applied mathematics does not exist on its own, but describes essentially a function and a craft by which the science of mathematics finds its nourishment.

Much of the so-called applied mathematics which is practiced today is almost diametrically opposite to this function. It is permeated with legalistic hairsplitting, shrouded in pretentious language, as if the purpose were to obscure and surround with an aura of mystery and profundity what is very often a simple and even trivial subject.

This trend toward a formalism devoid of humanistic content, this emphasis on form at the expense of substance, is found not only in science. It also prevails in our contemporary art and literature and obviously results from deeper, and perhaps self-destructive, undercurrents in our culture.

It constitutes a retrogression toward the abuses of medieval scholasticism and away from that intimate union of craftsmanship and science so characteristic of the Renaissance period. In this connection I recall a quotation from Ortega y Gasset, in his book, *Man and Crisis:*

> "Life is not to be lived for the sake of intelligence, science, culture, but the reverse; intelligence, science, culture, have no other reality than that which accrues to them as tools for life. To believe the former is to fall into the intellectualistic folly which, several times in history, has brought about the downfall of intelligence."

Generally speaking, the professional mathematician has become a specialist in logical systems and rigor. His lack of flexibility makes him unable to exercise one of the very essential functions of mathematics in the natural sciences and engineering, which is to separate the relevant from the irrelevant, to simplify the formulation of complex phenomena, to synthetize and to unify the substance rather than the form.

There is no time here to dwell on the details. For contrast, let me cite only the brilliant treatment of the Navier-Stokes equations by Prandtl in his famous theory of the boundary layer.

There is, however, a more ominous aspect of this situation which brings up the matter of education of scientists and engineers.

We should remember that intuitive ability closely resembles artistic talent. It may be developed or it may be smothered, depending on the environment and the training. Rigor and abstract formalism are technical aspects of mathematics which may actually impede invention. They are for the specialist. The engineering student should be exposed to them only as an experience. They should not pervade his thinking nor exceed the point at which the intuitive faculties become inhibited.

Developing creativity

In many schools the hard core of mathematical and physical knowledge is submerged in a flood of special courses characterized by abstract-formalistic overtones. There is an emphasis on formal knowledge rather than understanding and the climate is not favorable to creative talent. It should be remembered that one of the important functions of a school is to discover, encourage, and develop talent and not only to transmit knowledge.

To make the situation worse, we are now witnessing the introduction of the abstract axiomatic

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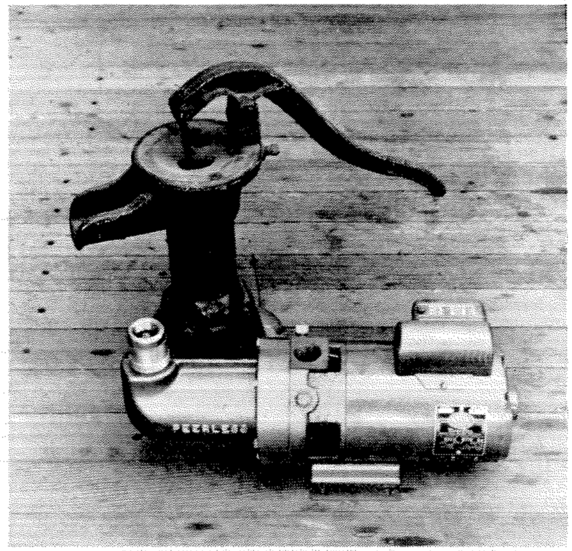

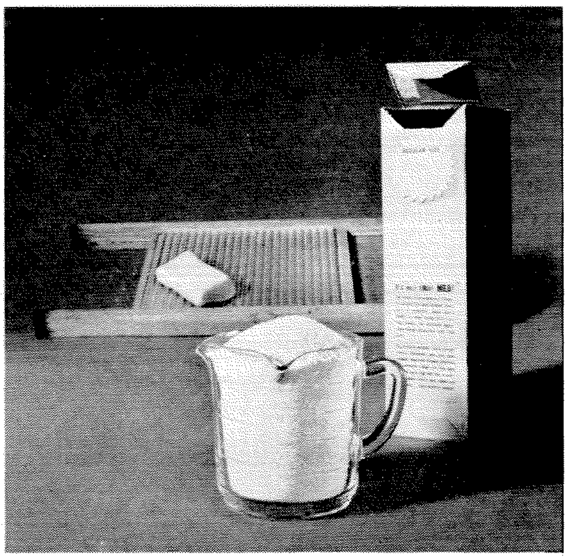

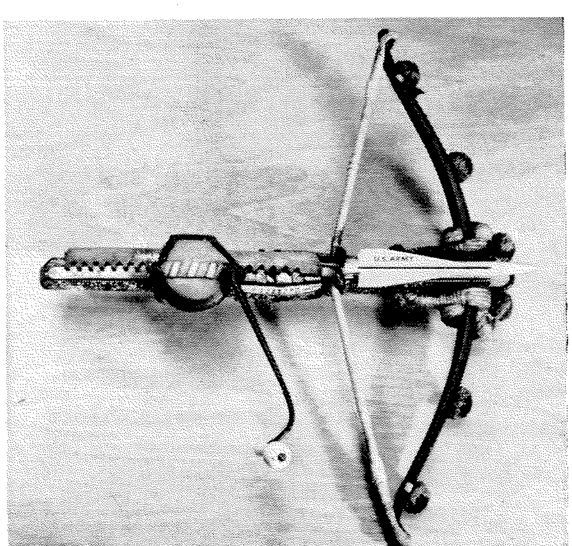

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Putting Ideas to Work in Machinery, Chemicals, Defense approach in high school mathematics. Such a development involves great dangers to our future scientific and technological standing. It has been said that "Learning is the kind of ignorance distinguishing the studious." I don't want to downgrade studiousness, but I don't think knowledge should be an obstacle to understanding.

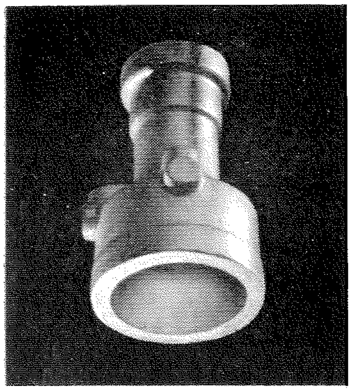
While I have dwelled on the more gloomy aspects of this situation, I would like to conclude with a more optimistic note.

Let us hope for a revival of humanism and a spirit of synthesis in science. Let us also put new emphasis on engineering as a professional craft, requiring high skill, natural talent, deserving social recognition, and distinctly different from the scientific professions as such. New stirrings are appearing in this direction. I am inclined to believe that engineers and engineering schools will play an important part in restoring the unity and central viewpoint in the natural sciences. This is because modern engineering, by its very nature, must be synthetic. Specialization carried to extremes is a form of death and decay.

One could formulate a principle of degradation of knowledge entirely analogous to the second principle of thermodynamics. It represents a powerful force which can be defeated only by a hard and difficult struggle. The burden of it must be carried, not by teams and organizations, but by a few individuals. In this connection there is much to be said for the smaller schools. They should provide a better environment for unhurried maturing of thought and for the nucleation process by a very small number of qualified people.

It has been customary for the recipient of an award to avail himself of the opportunity to reflect on current problems of professional interest. While I do not pretend to have brought to light any really new ideas, it seems to me that the occasion was most appropriate for their reemphasis in the framework of the Timoshenko tradition.

In this future synthesis and the revival of technological craftsmanship, I think we all agree that in the practice as well as in the teaching, engineers are called upon to play a very fruitful and essential part.



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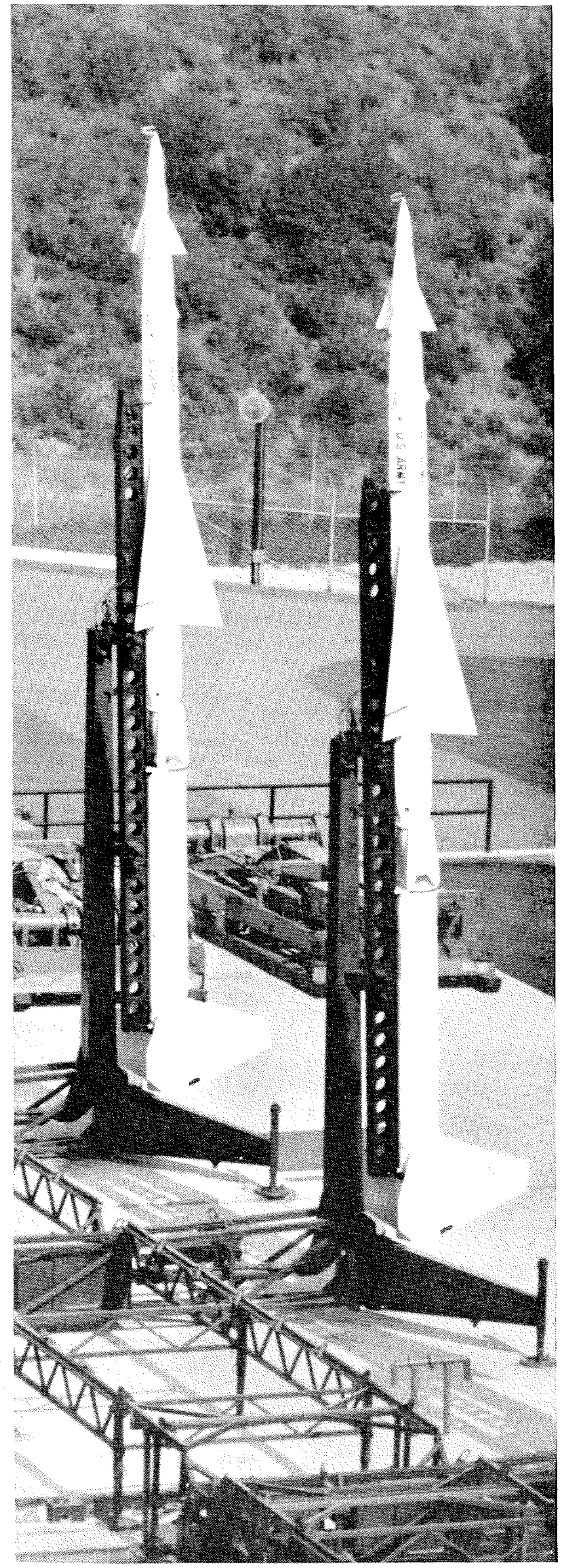

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Personals

1917

J. CALVIN BROWN, attorney and engineering consultant in Los Angeles, was chosen Engineer of the Month in November by *The Engineer of Southern California.* The selection was made by the Los Angeles Section of the American Society of Mechanical Engineers.

1920

HORACE CRANE ANDREWS, building contractor and civic leader, died on September 26, 1962 in Los Angeles. He was 66. He leaves his widow, a son, Horace, and two grandchildren.

1922

DEWEY C. ROHLOFF died on November 26 of acute leukemia. He had been ill less than a week. After graduation he worked for the Richfield Oil Company until 1939, when he entered the poultry business in Tarzana. He retired in 1956. He leaves his widow, a daughter, Mrs. William Richtenburg, Jr., and two grandchildren.

1924

LOYS GRISWOLD, sales promotion representative for the General Electric Company in the Central States Region, retired on December 1 after 38 years with the company in Schenectady, Los Angeles, Phoenix, Hawaii, St. Louis, and Chicago.

1927

COL. VERNON P. JAEGER, chaplain in the U.S. Army, retired from active military duty on December 31, 1962. In March he will become director of evangelism and director of church development for the Oregon Baptist Convention.

1931

WILLIAM M. COGEN, MS '33, PhD '37, has retired from the Shell Oil Company, where he was a senior geologist, and has opened his own office as a petroleum geologist consultant in Houston. He had been with Shell since 1937, working in San Antonio, Corpus Christi, and Houston. The Cogens have two children – Lorna, 12, and Mary, 9.

JOHN L. BOVEE, JR., MS '32, died on October 21. He had been in a serious accident in July which confined him to bed with a cast on his leg to the hip. He was just getting around on crutches when he fell in the family pool and drowned. He was the owner of John L. Bovee Co., importers of pumps from Austria and Germany. He leaves his wife, a son, Robert, and daughter, Dorothy Steele.

1933

KENNETH S. FITCH, director of the engineering division of Direurmideast Docks, in London, England, died of a heart attack on November 2, 1962.

ROBERT D. FLETCHER, MS '34 ME, MS '35 MY, director of scientific services for the MATS Air Weather Service at Scott Air Force Base, Illinois, has received the Air Force Decoration for Exceptional Civilian Services. The award reads in part: "Dr. Fletcher has displayed the highest qualities of leadership in supervising the technical activities of the Air Weather Service and, through generous application of keen professional knowledge, has contributed greatly to the international advancement of meteorology and related geophysical sciences."

TRENT R. DAMES, MS '34, was chosen Engineer of the Month in *The Engineer of Southern California* for October

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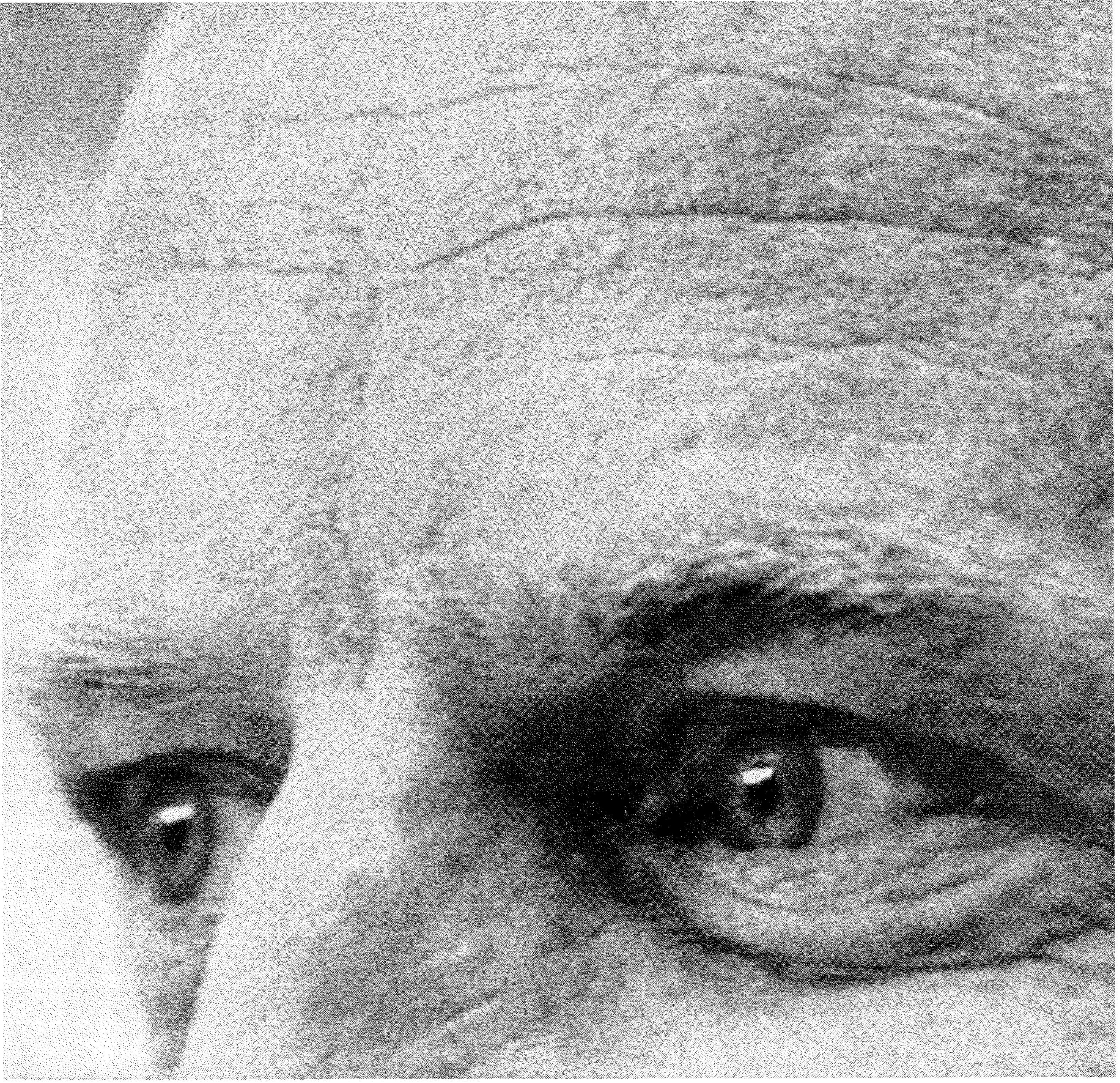

1962. He is executive partner in the engineering firm of Dames & Moore, founded in 1938, which now has ten offices, covering the country from New York to Honolulu and Seattle to Atlanta.

1937

LEVAN GRIFFIS, MS '38, PhD '41, now heads the Southwest Research Institute in Houston, a non-profit research company with headquarters in San Antonio. He was formerly dean of engineering and professor of mechanical engineering at Rice University. He has been named vice president of the new Houston institute.

HOWARD S. SEIFERT, PhD, director of advanced planning for research at the United Technology Corporation in Sunnyvale, and professor of aeronautics and astronautics at Stanford University, received the American Rocket Society's G. Edward Pendray Award for 1962, for his "outstanding contributions to astronautical literature." The Seiferts have three children: one daughter teaching, one in college, and a son who is a senior in high school.

1938

FRANK B. JEWETT, JR., president and chief executive officer of the Vitro Corporation of America in New York City, has received a 1962 Sports Illustrated Silver Anniversary All-America Career Award. This is an annual award by the sports magazine given to 25 men on the basis of their career success and community service in the intervening years since their senior football season at college. Nomination for the honor is made by each candidate's alma mater and election is by a panel of eminent judges.

Frank Jewett was active in athletics throughout his four years of undergraduate life at Caltech. He not only participated in football, but also in rugby, track, swimming, and yachting. He was on the U.S. Olympic Yachting Team in 1936 (monotype), was the National Junior Sailing Champion (Sears Cup) for two years, and held the Prince of Wales Cup for one year.

He was vice president of the student body, president of the Beavers Club, secretary of his house, and president of the senior class.

In a note to Hal Musselman, Caltech director of athletics, Frank said: "An incident occurred at the award of my goal posts that I think might amuse you. In alphabetical order each of the awardees went individually to the rostrum in the ballroom at the Waldorf in New York, where with great ceremony and popping of flash bulbs, the master of ceremonies read the recipient's name, the name of his alma mater, and his present position. In my case this solemn pronouncement was followed by a second-take blurt which blared over the public address system, 'My God, I didn't know they played football at Caltech!'

"It brought down the house and shocked me to the extent that I forgot to punch him in the nose."

Jewett lives in New Canaan, Conn., with his wife and four children, who are 10, 13, 16, and 18.

1948

CONWAY SNYDER, PhD, is now staff scientist in the physics section of the space sciences division at JPL. ROBERT MEGHREBLIAN, MS '50, PhD '53, is chief of the division. R. J. MACKIN, JR., MS '51, PhD '53, is chief of the physics section. RAYMOND HEACOCK, BS '52, MS '53, is chief of the space instruments development section.

1950

RICHARD D. DeLAUER, AE, PhD '53, has been elected a vice president of Space Technology Laboratories, in Redondo Beach, Calif. He is associate director of the ballistic missile program management, and director of STL's Titan Weapon Program office in San Bernardino. He has been with the company since 1958. GEORGE E. SOLOMON, MS, PhD '53, director of STL's systems research and analysis division, has also been named a vice president of the company. He was a consultant to the Ramo-Wooldridge Corporation on re-entry design problems for the intercontinental ballastic missile program prior to joining the firm in 1954.

DR. PETER T. KNOEPFLER, is now university psychiatrist at the University of Utah, and is also in private practice in Salt Lake City. He was married in 1960 and has a year-old son, David.

1952

JOHN C. PORTER, JR., MS '58, is now head of JPL's office for the California Universities Council on Space Sciences. He was formerly chief of the research analysis section at JPL. His new duties will include providing technical and administrative assistance to various California universities conducting space programs, and promoting mutual support between them and NASA. He is married and has three children.

1954

WILLIAM A. NEVILL, PhD, professor of chemistry at Grinnell College in Iowa, shares a special cancer research

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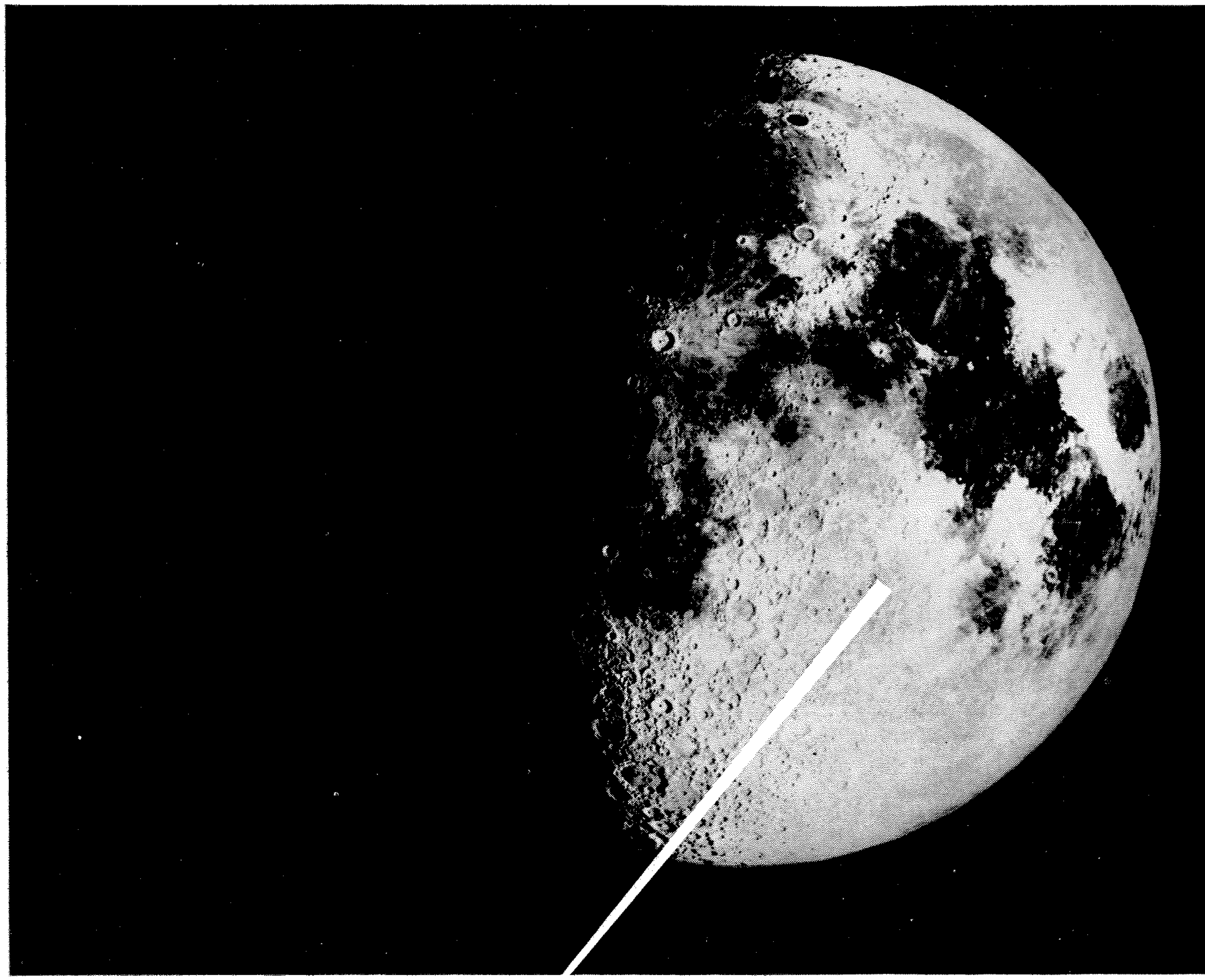


Personals . . . *continued*

grant by the U.S. Public Health Service. The initial grant is for nearly $40,000, with future support of over $20,000 more in the next two years, for research on "Nuclear Magnetic Resonance of Metal Complexes of Possible Anti-Cancer Compounds." The grant also provides for the purchase of a Varian A-60 Spectrometer, an instrument capable of measuring the exact environment of atoms in chemical molecules.

EDWARD J. GAUSS, assistant professor of electrical engineering at the University of Alaska, who is also doing research in the Geophysical Institute at the University, writes that "George was born on December 14, 1962, in Fairbanks while his father was demonstrating the University's 60-foot radio telescope to an engineering class. When he got to the hospital he met CARL BENSON, PhD '60, and his wife arriving for a similar activity. His son, Carl, was born a few hours later. Carl is a glaciologist at the Geophysical Institute.

"Our daughter, Christy Ann, now 3½, was born in Los Angeles while wisps of smog seeped through the window. In Alaska, things were a bit different. The night before our son was born wisps of multicolored aurora danced in the clear arctic sky. I passed out chunks of dried moose to celebrate the arrival."

1957

ITIEL I. HAISSMAN, MS '58, spent two and a half years as a lieutenant in the Navy of Israel and then spent a year in France studying literature and philosophy. He writes that he is now "traveling far and wide over Europe, dividing my time between skiing, literature and women — all delightfully integrated in my recent book, *A Guide to European Girls*, soon to be published in the U.S."

THOMAS C. HAYS, MS '58, is one of 16 Baker Scholars at the Harvard Business School. These Scholars represent the academic top five percent of the class of 1963 in the Business School. Tom is married to the former Mary Ann Jergens of Beverly Hills.

1958

DONALD REITERMAN is now a research and design engineer at Arrowhead Products in Los Alamitos, working mainly on space suits.

LAURENCE E. BERRY is an engineer in the soap equipment department of Proctor and Gamble in Cincinnati. He was formerly a project engineer in the liquid propellant branch at Edwards AFB. The Berrys now have two sons, Douglas, who will be two in March, and Kenneth, born last April.

CHAIRMAN OF THE BOARD

"Yeah, it's me again, Miss Johnson . . . Do ya have Sternmeyer for me? . . . He's on another line? . . . Well, I'll just wait a minute . . .

One of these days I'll *be important. People will be waitin' on* me . . . *I'll call the trick then . . . I can see it all now . . .*

All right, gentlemen, the 14th Annual Directors Meeting of Western Atomic Raisin & Tortilla, Inc. will commence. Some of you gentlemen know me. Some of you don't. But just to clear the air I'll tell you this; I bought *this company last night.*

Now all you need to know about me is that I'm your new Chairman of the Board.

Credentials? I'm a Caltech man. Need I say more?

One more thing – tica-ta-tica-ta-tica-ta – *Excuse me, gentlemen, my two-way wrist ticker-tape is ticking. Goodness, gentlemen. Our WART common has gained 8 points. That means I've just made $780,411.13. I believe I'll just give it to Dear Old Tech; it will help the ol' 'lumni Fund go over the top.*

Well, gentlemen, enough of this trivia. I run a tight ship and –

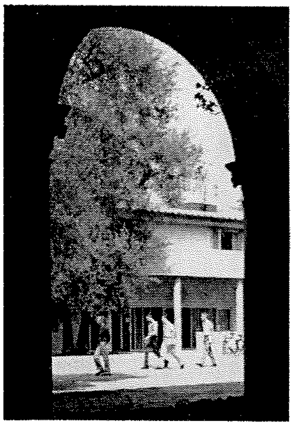
"What? Oh. George! Sure I heard ya, what didj'a say? Oh. Well, I called to tell ya I'd like to hold off on this year's 'lumni Fund gift for a while 'cause I'm – well, I'm a little short this month . . .

"I know, George, I know . . . I've heard the whole story an' I'm *tired of it* . . . No, George. I said I, ah, I'm *mired in debt.*

"Ya know, George, the way you pressure me for money all the time you'd think I was rich or somethin. I'm just an *engineer* ya know. I'm not a Chairman of the *Board.*"

YOUR ALUMNI FUND COUNCIL WILL WELCOME
YOUR GIFT REGARDLESS OF WHAT YOU ARE.

CALTECH CALENDAR



ATHLETIC SCHEDULE

Basketball

January 29
Occidental at Caltech
February 2
Whittier at Caltech
February 5
Occidental at Occidental
February 8
Redlands at Redlands

Tennis

January 29
Pasadena College at Caltech
January 31
Pasadena College at Caltech
February 2
All-Stars at Caltech
February 5
PCC at Caltech

FRIDAY EVENING DEMONSTRATION LECTURES

Lecture Hall, 201 Bridge, 7:30 p.m.

February 1
Rapid Solidification of Liquid Alloys
—Pol Duwez
February 8
Processes and Machinery in Making Proteins
—Paul T'so
February 15
What Minerals are Deposited by Marine Life
—Heinz A. Lowenstam
February 22
Large-Scale Motions in the Earth's Interior
—Leon Knopoff

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William L. Holladay, '24

SECRETARY
Donald S. Clark, '29

VICE-PRESIDENT
Peter V. H. Serrell, '36

TREASURER
John R. Fee, '51

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Patrick J. Fazio, '53
G. Russell Nance, '38
Richard W. Powell, '40
William H. Saylor, '32
William H. Simons, '49
Charles P. Strickland, '43

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342 Madison Ave., New York 17, N.Y.
Vice-President — Bruno H. Pilorz, '44
75 Echo Lane, Larchmont, N.Y.
Secretary-Treasurer — Harry J. Moore, '48
590 Madison Avenue, New York 22, N.Y.

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2727 29th St., N.W., Washington 8, D. C.
Secretary — Cmdr. Joseph B. Deodati, '46
7933 Deepwell Dr., Bethesda, Maryland

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Spectromagnetic Industries
521 Lebanon St., Hayward, California
Vice-President — Edwin P. Schlinger, '52
Scott-Buttner Electric Co., Inc., Mountain View, Calif.
Secretary-Treasurer — Dallas L. Peck, '51
U. S. Geological Survey, Menlo Park, Calif.
Meetings: 13th Floor, Engineers Club, 206 Sansome St., San Francisco
Informal luncheons every Thursday at 11:45 A.M.
Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

CHICAGO CHAPTER
President — Laurence H. Nobles, '49
Department of Geology, Northwestern University
Evanston, Illinois
Vice-President — Philip E. Smith, '39
Eastman Kodak Company
1712 Prairie Ave.
Chicago, Illinois

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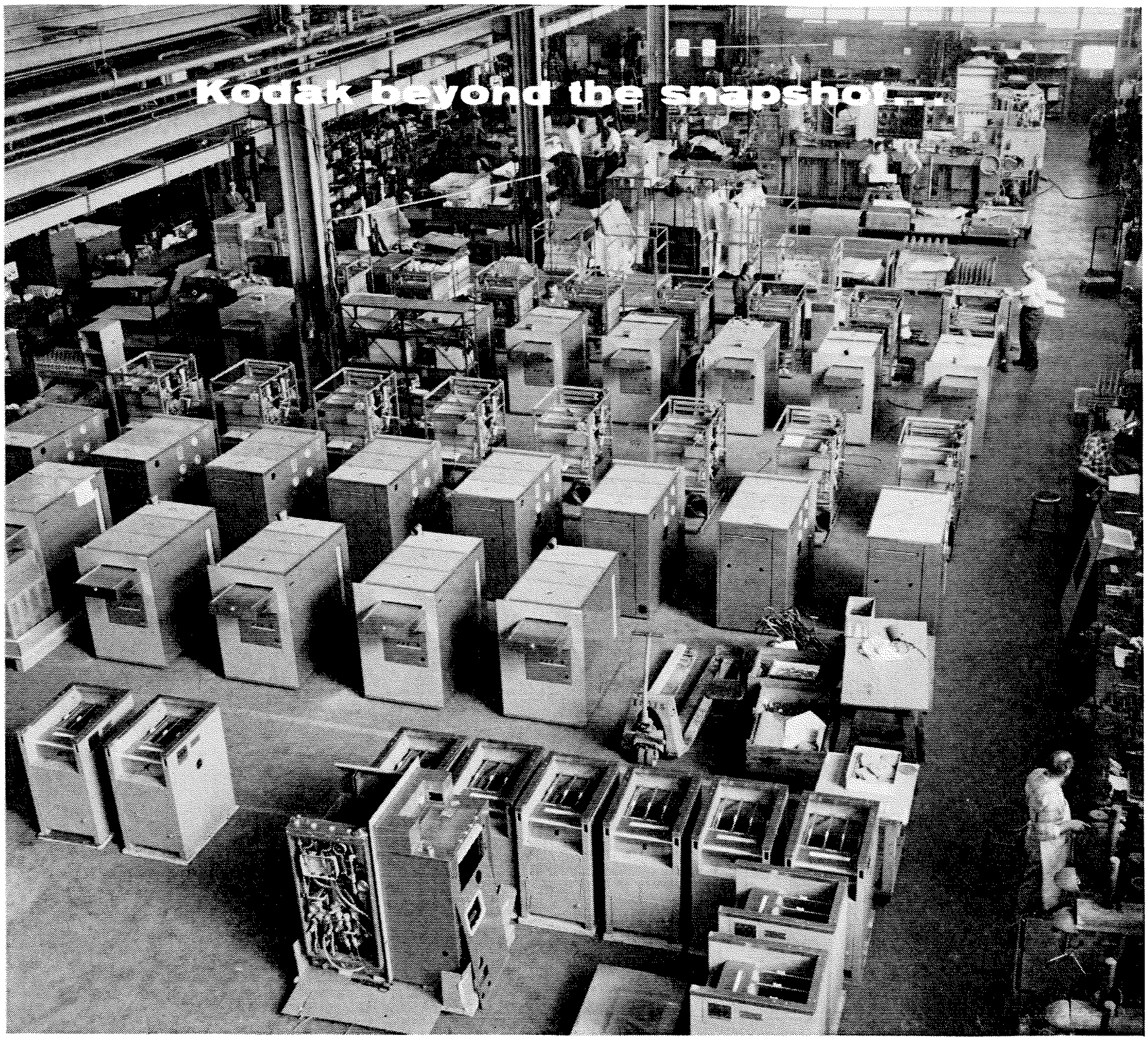
President — G. Donald Meixner, Jr., '46
4416 Hazelwood Ave., Sacramento, Calif.
Vice-President — Robert K. Breece, '47
4812 "I" St., Sacramento 19, Calif.
Secretary-Treasurer — Dudley E. Bennett, '47
4535 Marble Way, Carmichael, Calif.
Meetings: University Club, 1319 "K" Street
Luncheon first Friday of each month
Visiting alumni cordially invited—no reservation

SAN DIEGO CHAPTER
Chairman — Maurice B. Ross, '24
3040 Udal Street
Secretary — Frank J. Dore, '45
Astronautics Div., Convair
Program Chairman — Herman S. Englander, '39
U. S. Navy Electronics Laboratory



We make machines, but Wall Street calls us a chemical company.

People who know nothing about Wall Street associate us with simple little cameras.

Photography involves cameras, and it also involves chemicals. A great deal of our chemical activity, however, does not involve photography. On the other hand, the chemistry of photography now hides inside machines like the ones above, so that photography doesn't seem to involve chemistry any more. "Involved" is certainly the word for the situation.

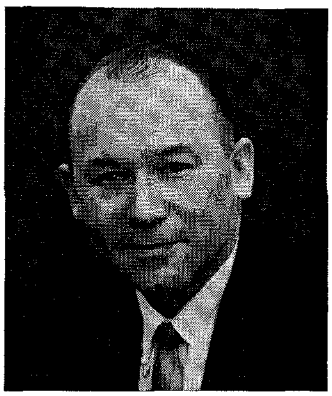
It is an involved situation but it is also a very healthy one.

So healthy is the demand for electromechanical machines of all kinds and sizes to perform the chemical operations of photography that our sizable body of electromechanical engineers keeps very pleasantly occupied. Possibly you will write to us, and possibly we shall strike up a correspondence, and possibly you too will come to work for us as an electromechanical engineer, and possibly you will be running a vitamin factory for us on the day we pin the 25-year medal on you. That's the beauty of diversification.

EASTMAN KODAK COMPANY, Rochester 4, N.Y.

Manufacturing Careers Offer Diversity, Challenge and Opportunity

An Interview with G.E.'s H. B. Miller, Vice President, Manufacturing Services



Halbert B. Miller has managerial responsibility for General Electric's Manufacturing Services. This responsibility includes performing services work for the Company in the areas of manufacturing engineering; manufacturing operations and organization; quality control; personnel development; education, training and communications; materials management; purchasing and systems as well as the Real Estate and Construction Operation. Mr. Miller holds a degree in mechanical engineering and began his General Electric career as a student engineer on the Company's Test Course

For complete information about General Electric's Manufacturing Training Program and for a copy of G.E.'s Annual Report, write to: Personalized Career Planning, General Electric Company, Section 699-06, Schenectady 5, New York.

Q. Mr. Miller, what do engineers do in manufacturing?

A. Engineers design, build, equip, and operate our General Electric plants throughout the world. In General Electric, this is manufacturing work, and it sub-divides into categories, such as quality control engineering, materials management, shop management, manufacturing engineering, and plant engineering. All of these jobs require technical men for many reasons. First, the complexity of our products is on the increase. Today's devices—involving mechanical, electrical, hydraulic, electronic, chemical, and even atomic components—call for a high degree of technical knowhow. Then there's the progressive trend toward mechanization and automation that demands engineering skills. And finally, the rapid development of new tools and techniques has opened new doors of technical opportunity—electronic data processing, computers, numerically programmed machine tools, automatic processing, feedback control, and a host of others. In short, the requirements of complex products of more exacting quality, of advanced processes and techniques of manufacture, and of industry's need for higher productivity add up to an opportunity and a challenge in which the role of engineers is vital.

Q. How do opportunities for technical graduates in manufacturing stack up with other areas?

A. Manufacturing holds great promise for the creative technical man with leadership ability. Over 60 percent of the 250,000 men and women in General Electric are in manufacturing. You, as an engineer, will become part of the small technical core that leads this large force, and your opportunity for growth, therefore, is unexcelled. Technical graduates in manufacturing are teamed with those in marketing who assess customer needs; those in research and development who conceive new products; and those in engineering who create new product designs. I sincerely believe that the role of technical graduates of high competence in the manufacturing function is one of the major opportunities for progress in industry.

Q. What technical disciplines are best suited to a career in manufacturing?

A. We need men with Doctor's, Master's, and Bachelor's degrees in *all* the technical disciplines, including engineering, mathematics, chemistry and physics. We need M.B.A.'s also. General Electric's broad diversification plus the demands of modern manufacturing call for a wide range of first-class technical talent. For one example: outside of the Federal Government, we're the largest user of computers in the United States. Just think of the challenge to mathematicians and business-systems men.

Q. My school work has emphasized fundamentals. Will General Electric train me in the specifics I need to be effective?

A. Yes, the Manufacturing Training Program is designed to do just that. Seminars which cover the sub-functions of manufacturing will expose you to both the theoretical and practical approaches to operating problems. Each of the succeeding jobs you have will train you further in the important work areas of manufacturing.

Q. After the Program—what?

A. From that point, your ability and initiative will determine your direction. Graduates of the Manufacturing Training Program have Company-wide opportunities and they continue to advance to positions of greater responsibility.

Progress Is Our Most Important Product

GENERAL ELECTRIC