ENGINEERING | AND | SCIENCE

February 1964

Published at the California Institute of Technology

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Westinghouse

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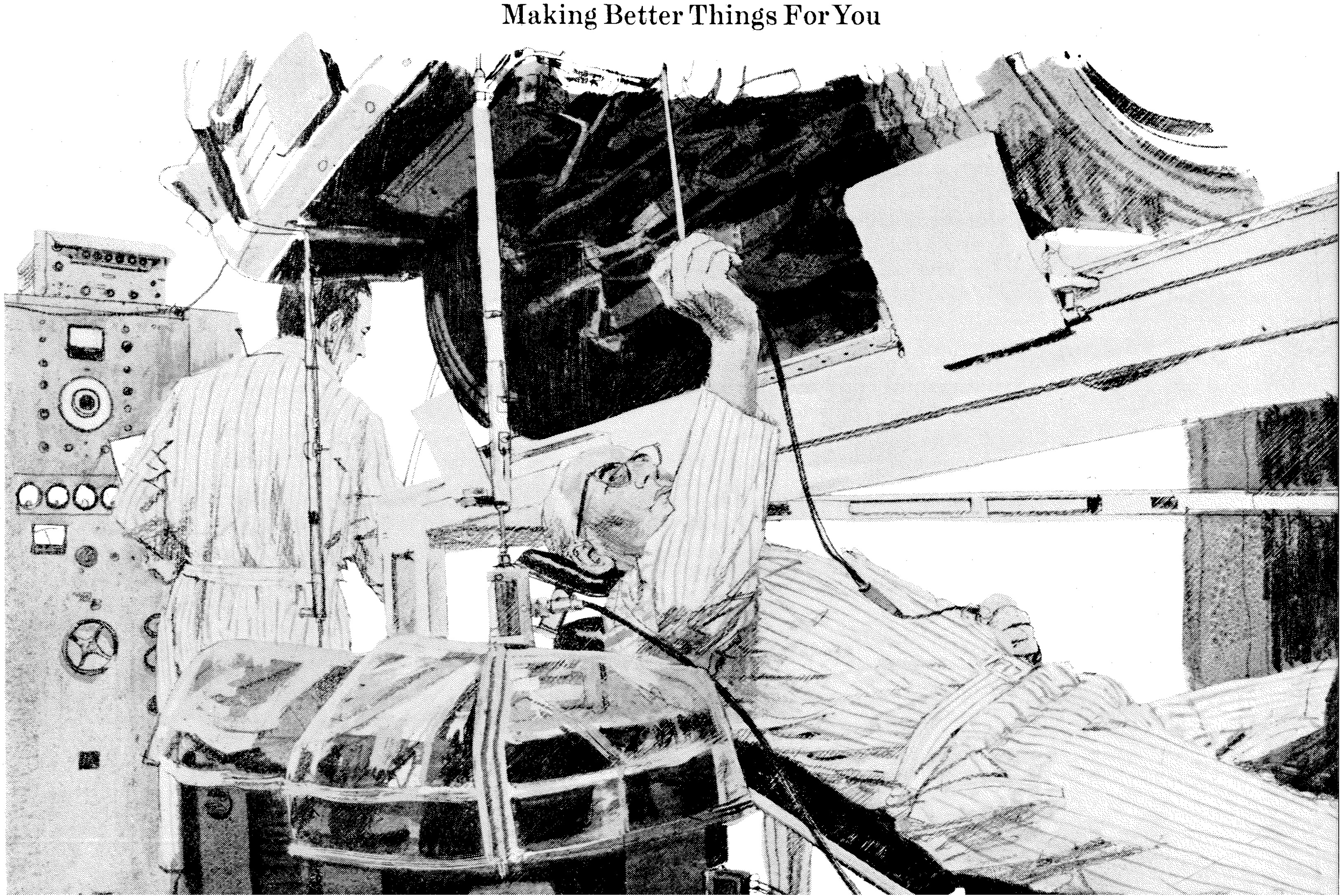

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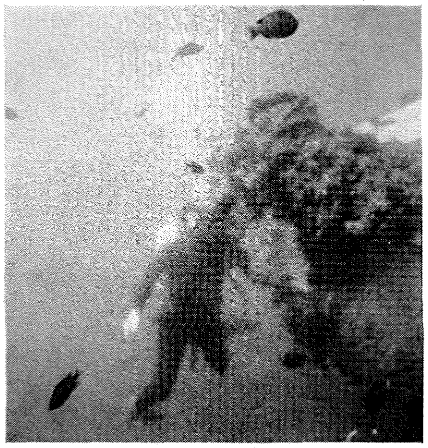

On Our Cover
a diver goes over the edge of a submarine canyon – one of the underwater environments described by Wheeler North in his article on page 7.

Dr. North received his BS in engineering in 1944 at Caltech, and after a tour of duty in World War II, came back to get a BS in biology in 1950. He earned his MS in oceanography and his PhD in biological oceanography from the Scripps Institution of Oceanography. In 1953 he went to Cambridge University as an NSF postdoctoral fellow. In 1956 he became assistant research biologist at the Institute of Marine Resources at the University of California, and in 1963 came to Caltech as associate professor of environmental health engineering.

Charles R. Cutler
graduated from Caltech in 1945 with a BS in EE, then, after a stint in the Navy and while teaching electronics in Washington, went to George Washington University Law School, where he received his law degree in 1949. He is now a member of the firm of Kirkland, Ellis, Hodson, Chaffetz & Masters in Washington, D.C.

Mr. Cutler's article on page 14 is based on notes made in his early days of law practice as a personal reaction to the evident misunderstanding which so many of his scientific friends had with respect to the legal profession. Says Mr. Cutler: "One former engineering classmate bluntly told me that the only reason legal documents aren't written in easy prose is that lawyers are afraid the public would be able to understand them, with the consequent elimination of the need for a legal profession. Just a few minutes later, he was delightedly showing me his latest purchase, a book on vector equations – which, of course, were almost entirely in Greek."

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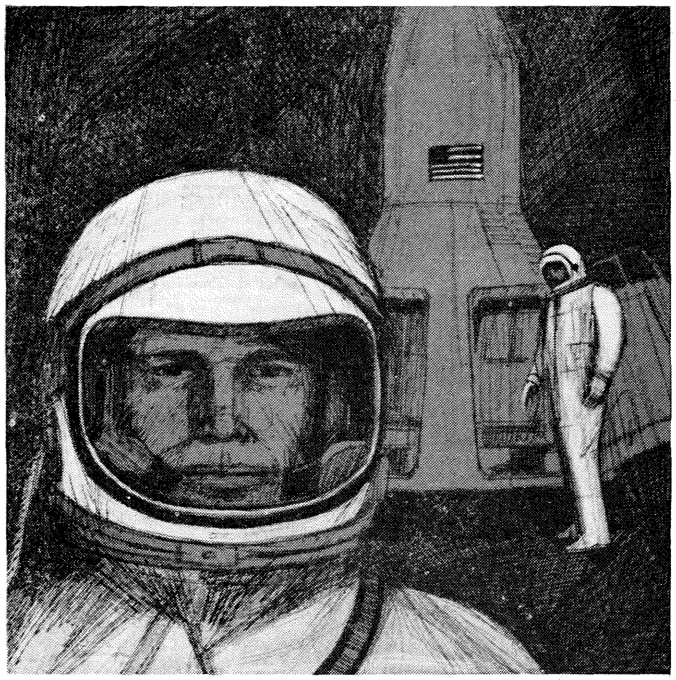

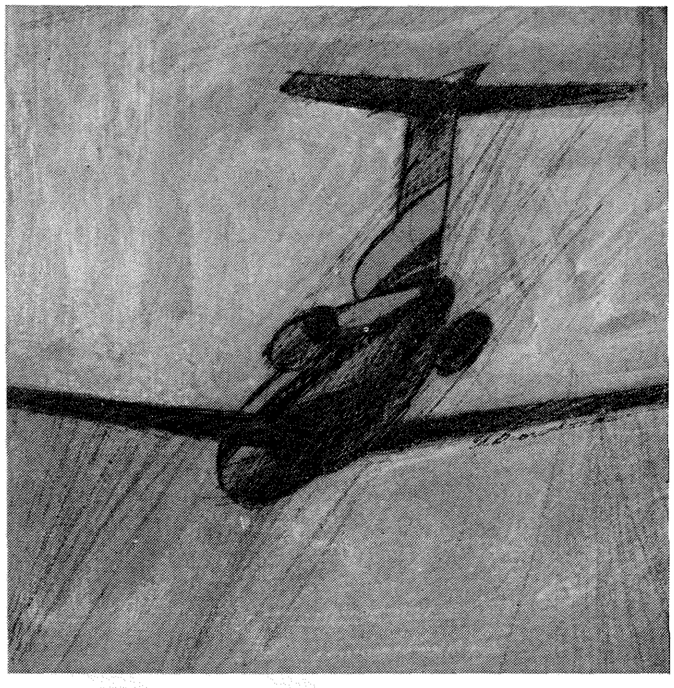

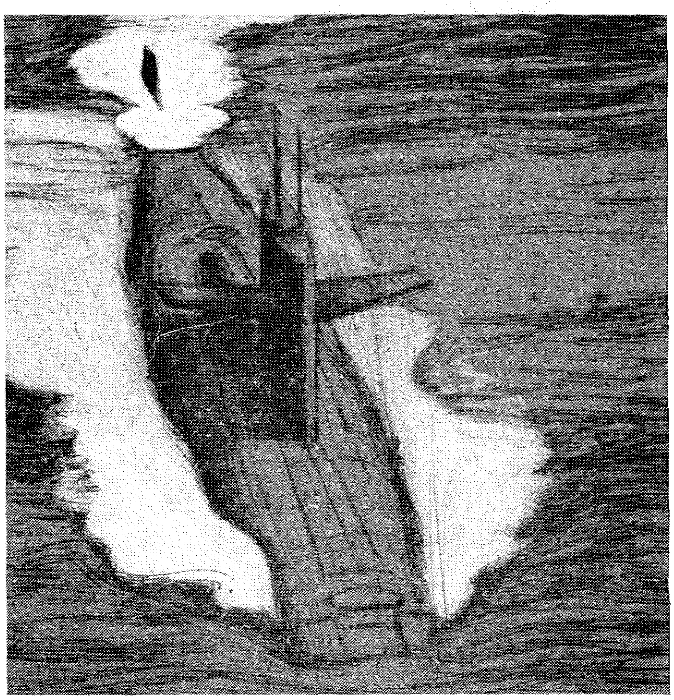

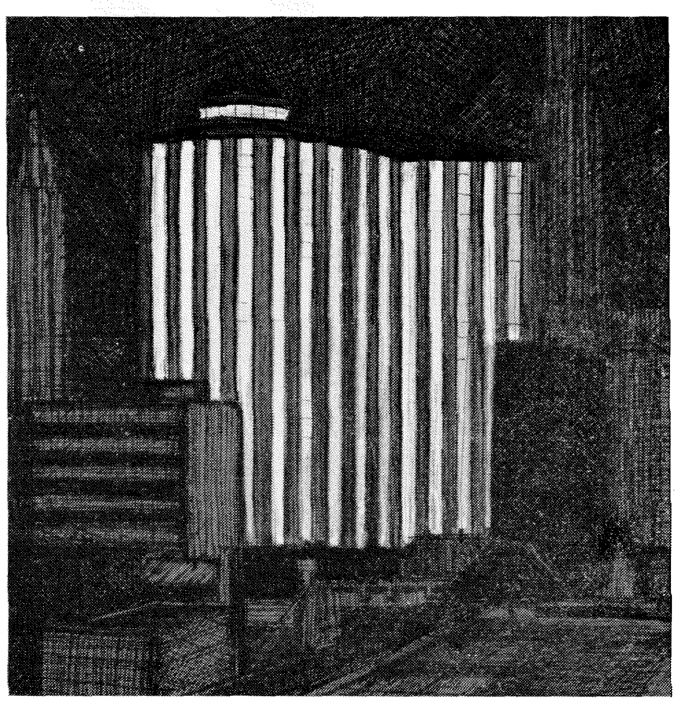

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THREE EXCITING UNDERWATER ENVIRONMENTS —

Coral Reefs, Submarine Canyons, and Kelp Beds

by Wheeler J. North

Though I have the title of environmental health engineer at Caltech, I am actually only an engineer second-hand, because first I'm an oceanographer. I received my training at the Scripps Institution of Oceanography in La Jolla, and I did a great deal of study in the ocean before I came here. I have become very interested in what man is doing to the sea in the way of discharging wastes into it; in what he does to the various populations of fishes, seaweeds, shellfish, and all the other things he takes out of it; and in the radioactive materials he puts into it. With the sea becoming more and more a part of our environment, I am truly an environmental health engineer in the study of what we are doing to the sea.

Perhaps I have lured you into this discussion under false pretenses with my title, "Three Exciting Underwater Environments . . ." The loaded word here is "exciting," because what the general public considers exciting and what I consider exciting don't always coincide – particularly that element of the general public which avidly watches underwater pictures on TV. When a shark starts nibbling on my swim fins, for example, I don't feel the urge to draw out my dagger and go to work on him. I'm a wet blanket. I go up and get out and climb into the boat. And if I'm diving, and killer whales enter the area, I go back to the beach. I get in my car and lock all the doors and roll up the windows.

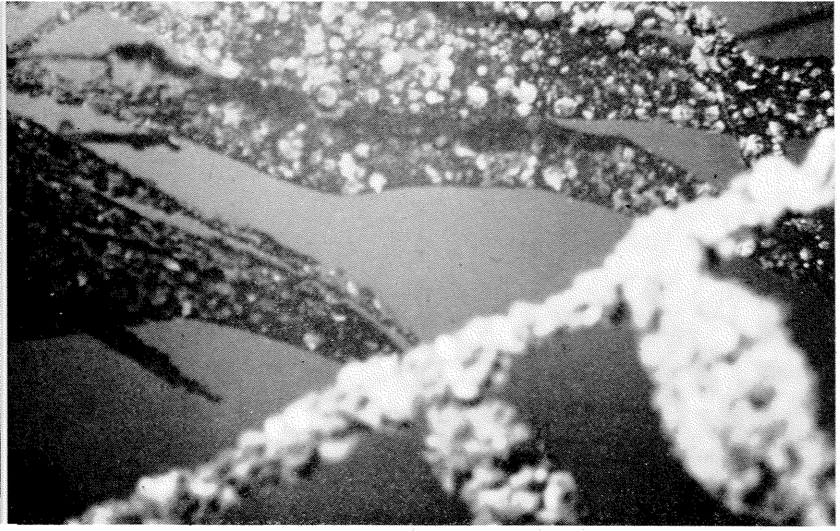
You may say that I lack a little bit of the spirit of adventure but I'm getting to be an old man and I doubt that I could change my ways. The question is, what do I mean by exciting? Well, I like a nice calm dive on a day when the ocean is nice and flat. I like to get down and see a beautiful underwater scene and enjoy it, examine it, and try to understand it. One of the things I am curious about is what makes the difference in some of these underwater environments. For instance, in certain parts of the sea it's just like landing on a desert as far as life is concerned; it's comparable to a barren pavement at 2 a.m., when there is absolutely no life at all. Other areas are teeming with creatures. Why is the ocean so rich in some areas and so impoverished in others?

I might say that this problem has great significance to man; roughly three-quarters of the population of the world is undernourished in one way or another, and if we are ever going to solve the problem of getting all the people of the world properly fed, we are going to have to turn to the sea sooner or later. This is because the area of the oceans – the land that's covered by the sea – is equivalent to 15 continents. By far the greater portion of our world lies underwater, so we must gain some kind of a comprehension of what goes on under the sea.

It has been said that in order for us to exploit the sea successfully we should stop being hunters and become farmers. But before you can farm a place you have to know what makes the soil rich, why plants grow, what plants are best to grow, and what are the most useful animals which can be handled by man in agricultural endeavors.

We know so little about the ocean that we can't hope to answer these questions all at once but we *can* begin by finding out what makes some areas rich and some areas underwater deserts. One can commence by studying the rich areas and I

"Three Exciting Underwater Environments" is a transcript of a Friday Evening Demonstration Lecture given by Dr. North, associate professor of environmental health engineering on Jan. 31.



Myriads of animals use the blades (leaves) and stipes (stems) of a giant kelp plant as a home. Sometimes the encrustations become so thick that the underlying plant is hidden. Occasionally the combined weight is so great that it causes the plant to sink to the bottom and deteriorate.

will limit myself here to three types — which could conveniently be called the swamp thicket, the garbage can, and the jagged wasteland, if we were to choose terrestrial counterparts. Under water these become the kelp beds, submarine canyons, and coral reefs and they are much more beautiful and exciting than their terrestrial stand-ins. The ocean transforms the uninteresting situations of dry land into fascinating environments through processes which we are just beginning to understand. Let's look first at the swamp thicket or kelp bed. Both are areas characterized by very dense vegetation.

KELP BEDS

Underwater vegetation is a good deal like terrestrial vegetation. If you watch a given piece of ocean bottom for a period of time, it may start out as a barren rock. Soon the rock is covered with a beginning vegetation. It is usually very short, comparable to grass on land. After this has grown a while it will gradually be replaced by larger plants, such as the long-bladed laminarians, which are comparable to small shrubs. These tend to shade the plants of shorter stature. Also, a different group of animals feeds on these larger plants. (Just as rabbits feed on grass and deer feed on shrubs, so the character of the vegetation in the ocean tends to determine what animals are present.)

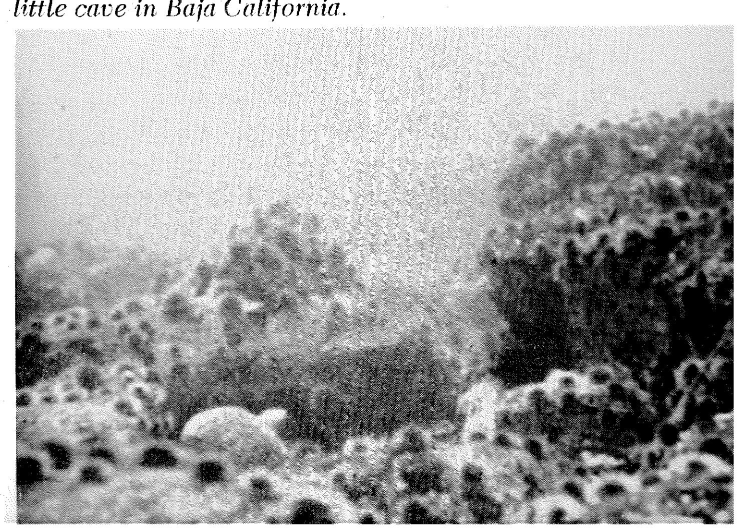
Then other plants tend to come in which are still larger — comparable to large shrubs or small trees — such as the palm kelp. When you start getting plants of this size they become quite attractive to fishes, just as the smaller size trees and the larger shrubs attract birds. Once again the character of the vegetation determines what animals are present.

Finally we get to the largest trees of the sea, which are the giant kelp plants. They grow all the way up to the surface. When they get to the surface they spread out and form a canopy which becomes so thick that sometimes light scarcely penetrates.

One of the important features of kelp is that it provides a surface for animals to roost on. Scallops and other creatures can encrust the blades of these plants to such an extent that sometimes you can't even see the kelp underneath. The ocean is very crowded with respect to available surface where animals can attach, and a kelp bed is like Manhattan Island, where you crowd a lot of people into a small space by building skyscrapers. There is roughly 10 to 20 square feet of surface provided by a kelp tree for every square foot of ocean bottom in a dense kelp bed. Certain animals love the shade provided by the kelp. Various anemones, crustaceans, molluscs, and echinoderms are shade-loving animals, as are some mid-water animals, and these creatures tend to gather in the kelp. The fishes love kelp too, and they come in and feed on all the little animals hiding in the cracks and crevasses, and roosting on the surfaces, so that the whole kelp complex forms a very rich area depending on this one plant, the giant kelp.

The kelp has enemies — particularly a destructive beast called the sea urchin. (It is eaten by Italians and Frenchmen and Portuguese, but Americans don't seem to like it, unfortunately — maybe because it looks like a pin cushion.) An army of urchins moving slowly along the ocean bottom is like a hoard of locusts. They clean everything in their path and remove all vegetation completely. These animals have little, flexible extensions called tube feet, with suckers on the end of them; if a kelp frond, waving back and forth in the currents, touches an urchin, the animal grasps it and slowly consumes it.

Swarms of sea urchins remove virtually all kelp and other vegetation from the rocks at the bottom of a little cave in Baja California.



The urchins never leave the bottom. In a few bites they can cut through the main stem of the kelp and sever the whole top of the plant so that maybe two or three hundred pounds of plant is lost to the kelp bed while only an ounce or so of plant tissue goes to feed the urchins.

After an army of urchins has finished removing all the vegetation, the grazers will move on or else they starve and die. Then the vegetation begins to come back. Fortunately, the vegetation often is restored rapidly because kelp is the fastest growing plant that has been found. Just within the last two years we have measured the growth rates and found that, at the maximum, plants grow 18 inches to 2 feet a day. The lifetime of a kelp "branch," or frond, is rather short – about six months. The base of the plant remains, however, after an old frond deteriorates and this lower part generates new young fronds from the growing tips located near the bottom of the sea. The plant thus may live for years, although the individual parts age rapidly.

The giant kelp may also be the longest plant in the world. Specimens of at least 200 feet in length have been seen locally, and kelp has been reported at tremendous lengths of 700 to 1200 feet, but these may be erroneous estimates made on drifting plants which appear to be anchored in deep water.

In no time at all a young plant can grow to the surface and, once it starts producing spores (which are the equivalent of a higher plant seed), it can seed an enormous area with new kelp. In fact, one adult plant can produce about 70 trillion spores a year.

Many of you know that kelp has been harvested off our coast for many years, but I doubt if you realize how useful are the products derived from this huge seaweed. You may have eaten kelp several times today already – in salad dressing, ice cream, beer, or other foods. You may have used it in toothpaste, pills, paint, ink, cardboard, or other forms. From man's point of view, it is a highly desirable plant.

So here, we think, is an excellent plant which man could use to cultivate the sea. It grows rapidly. It has a tremendous reproductive potential. It has been harvested as a wild crop for many years and proven useful. And many of the fishes and shellfish of the kelp beds are of economic importance. But now it is necessary for us to gain complete control of this aquatic plant, as the terrestrial farmer controls his crops. We must learn to grow it in quantity and transplant it to the sea.

Culturing and raising the tiny juveniles is quite

Wheeler North works with a kelp transplant.

easy, and several transplant experiments have been conducted successfully. In working with kelp transplants, we have anchored buoys to the bottom and then tied plants to them. In one instance I flew a plant 400 miles from where it was originally located in Baja California – a lovely little inlet called Turtle Bay – up to La Jolla, where I transplanted it.

It turned out that, for some reason, this species was much more attractive to grazing animals than the La Jolla species, and these creatures would come in and very quickly eat up the transplanted kelp. So we took a La Jolla plant and tied it on the same buoy with the Turtle Bay plant to get the two to mix in with each other. But the grazers were too smart for us; the fishes and crustaceans would come in and pick out the Turtle Bay plants and eat them down to nothing, while the La Jolla plant would be left quite intact and healthy – leaving also some frustrated oceanographers looking at it.

We were particularly interested in the Turtle Bay plant because, coming from so far south, it has somewhat different physiological characteristics. It can withstand warm water much better than our northern plants. In the summer we lose a great deal of our kelp beds because the water gets too warm, so we were trying to transplant the southern strain here to see if it would interbreed and produce plants that had a little better hardiness to temperature.

Another of our experiments consisted in clearing up an area near the entrance to San Diego Bay that was covered with sea urchins until, within a few weeks, we had a nice stand of young kelp plants developing. If all these plants grow to be adults they will be so big and so thick that no diver could possibly make his way through them. There are about 20 plants per square meter. (A good thick bed ordinarily has maybe one plant every 10 square meters, so this semi-artificial bed we created is roughly 200 times as thick as an ordinary bed.) We feel that this is very encouraging and that perhaps in the near future we will be taking our first real steps at culturing kelp in the open sea off La Jolla and Point Loma.

SUBMARINE CANYONS

In most parts of the world, as the dry land comes down to the ocean, usually at a gentle beach, there is a long, broad, rather shallow stretch of bottom that goes out about one or two miles (though sometimes as far out as a hundred miles) and then starts dropping off rather sharply down to the floor of the deep sea (which averages about 12,000 feet deep). The shallow, gently sloping portion is called the continental shelf. The outer edge of this shelf is from 300 to 600 feet deep. It extends all around the margins of most continents. Periodically in the shelves there are steep gorges, many of which come right up to the land. These submarine canyons are very rich areas indeed. When you dive in them you find great flocks of fishes. The rocks are swarming with animals so that sometimes the life encrusting these rocks is up to a foot thick, with animals just piled on animals. It is hard to see how any place can sustain so much life.

A rockfish glares from his crevice home in the wall of a submarine canyon, at the insolent human taking his picture. Note heavy growths of organisms attached to cliffs. These are all sedentary animals; the depth (170 feet) is too great to allow plant development because of the dim illumination at this level.

Why are these submarine canyons so rich? As yet, we can only speculate on this. My own theory is that they are the "garbage cans" of our coast. It may seem odd that such beautiful fish should congregate around "refuse" and "garbage," but very often the garbage they eat has been converted two or three times by smaller animals and more desirable worms and other things that fishes like. Where does all this garbage come from? Here, we will have to understand how the submarine canyons are created.

There is a broad river of sand that moves continuously along the continental shelves. This is the sand that is brought into the sea by the rivers and streams of the continent. Once in the ocean, it is continually being stirred up by the waves and gently moved along the coast by the currents, like a slow-moving river. On our southern California coast the prevailing current tends to go south, so this vast movement of sand – maybe two or three miles wide and greater than the Mississippi River in its volume – slowly and majestically moves along parallel to the shore until it hits one of the submarine canyons. As it moves along it carries with it all the seaweed and the dead animal bodies and everything else that settles on the bottom. When it arrives at a submarine canyon it goes over the edge and down the axis of the canyon, so that all this organic material is concentrated in the canyon and organisms which feed on dead material come in and live there. This is undoubtedly an important source of food that provides for the rich communities that dwell in submarine canyons. I should add that the material arriving from the shelf tends to accumulate in the upper portions of a submarine canyon for perhaps months until it suddenly becomes unstable and sweeps out down the canyon like a tremendous avalanche. Such processes are called turbidity currents and are considered important factors in eroding the canyons.

So, another way in which we could create our own rich areas would be to trap the sand, trapping the organic substances that flow in it, to provide our own "garbage dumps." Here the material could accumulate under controlled conditions and provide enrichment for forms like the larger fishes which man can use.

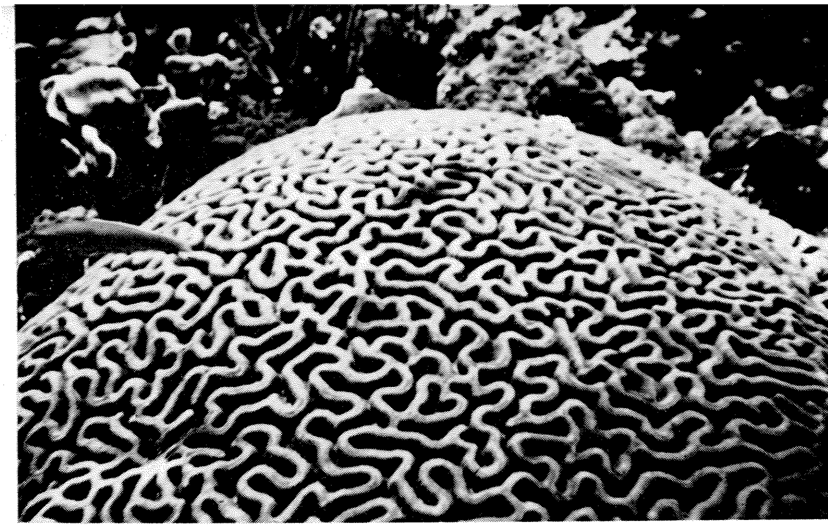
CORAL REEFS

Coral reefs, like submarine canyons, are some of the most fascinating places on earth. Sea fans, sponges, soft corals, hard corals, and molluscs form the base for a very complex community. The rich abundance of life here is reminiscent of the submarine canyons; animals live all piled up and encrusted on each other. Nonetheless, it is a jagged wasteland if you hunt for the plants which presumably are necessary to support this complex community. When you watch schools of fishes to see what they are eating you find they are feeding on little animals that live in the cracks and crevasses in the coral reefs. Some fishes actually bite the coral itself and chew off hunks of it. The coral reefs are filled with noises and crackling. For example, certain fishes are called grunts because they grunt, I guess, if you disturb them. (They are very common in the Florida Keys, and it is said that the early settlers there used to live on grits and grunts.)

All these smaller fishes are the intermediates in the food chains in the coral reefs. Some larger animals – such as the groupers, octopus, and sharks – are often very abundant in coral reefs. They feed on the smaller size fishes.

So we have these very elaborate communities. But there are very few plants in the area. This has caused people to puzzle for years about what was nourishing all this animal life. Animals depend basically on plants. The herbivores, or plant-eating animals, get their nourishment on the land, as in the sea, from plants. Plants get their nourishment from sunlight, of course. The carnivores eat the herbivores and the top carnivores, such as the shark, eat the lesser carnivores. But the puzzle remains: Where are the plants or other basic nourishment for this rich "jagged wasteland"?

Two brothers, Howard and Eugene Odum, started taking coral apart on a windward reef in Eniwetok Atoll recently and found that deep down inside the coral there were a variety of plants. They estimated the photosynthesis by this vegetation and concluded that it was an important source of the nutrition for the entire reef. Some of these little plants actually live right in the tissues of the coral, and it has been shown that these plants photosynthesize; they make chemicals that are extruded into the bodies of the corals and actually support the growth of the corals. The coral, in turn, provides protection for the plants.



Large hemisphere formed by brain coral is one of the most massive components of the coral reef. This specimen, at Alligator Light in the Florida Keys, was about six feet in diameter.

Other plants live even deeper down in the skeleton of the coral and these account for a good deal of the basic nutrition of the coral reef, but they could not account for all of it. The answer comes when you examine the water itself. Scientists have found out that the ocean is like a dilute soup; the water contains much nutritious material, and forms of microscopic life are suspended in the water. Many coral reefs exist where swift currents flow by. These currents are constantly washing the reef with fresh nutrient soup and the tiny coral animals extrude their tentacles and filter the water as it flows by, thus deriving additional nourishment. This type of feeding is called filter feeding. We are not clever enough to be filter feeders ourselves yet – which perhaps is fortunate, because the microscopic life suspended in seawater tastes terrible.

These microscopic forms are called plankton and in coral reefs there exists this food chain of the tiny, floating, microscopic plants; then the somewhat larger corals which are feeding on the plants; then the small fishes which are feeding on the corals; and then the larger carnivores feeding on the small fishes. So we have three stages in our food chain.

There is one animal which telescopes the food chain – the whale. The whale is a huge animal which has learned how to feed on plankton; it carries a fine sieve in its mouth. If we could learn to telescope this food chain like the whale does, we could get out away from the continental shelves and the kelp beds and the submarine canyons and really get at the most abundant plants of the sea, the tiny plankton. These constitute the true pastures of the great and wide oceans.

The Month at Caltech

Steele Laboratories

A greatly expanded program of teaching and research in the electrical sciences at Caltech has been made possible by a gift from the Harry G. Steele Foundation of Pasadena which will finance most of the construction of a building to be devoted to the study of electrical phenomena. It will be named the Harry G. Steele Laboratories of Electrical Science, in honor of the late president of U.S. Electrical Motors, Inc.

The new building will be located on Chester Avenue just north of San Pasqual Street and adjacent to the Willis H. Booth Computing Center. It will have three stories above ground and two below, with a total floor space of 55,000 square feet. Together, these buildings quadruple the space heretofore available at Caltech for work in electrical engineering and related fields.

The cost of the new Steele Laboratories is estimated at $1,978,900, of which the Steele Foundation has given $1,136,900 and the National Science Foundation $842,000.

Harry G. Steele, who died in 1942, was a prominent figure in the cultural activities of Los Angeles and Pasadena and was keenly interested in Caltech's progress. He was a member of the Southern California Symphony Association, and was active in the affairs of the Los Angeles County Art Museum, the Southwest Museum, the Pasadena Art Museum, and the Pasadena Playhouse.

The Steele Laboratories will provide facilities for intensified work in two broad areas of the electrical sciences – physical research and systems research.

Physical research embraces solid state physics, plasma physics, and lasers – further developments in which could lead to new devices for energy conversion, power generation, and communication.

Systems research deals with the transmission and detection of signals, automatic control of devices or vehicles, and computers. Such studies have already revealed analogies between electronics and the mechanisms of the human brain and nervous system.

Arthur Amos Noyes Professor

George S. Hammond, professor of organic chemistry at Caltech since 1956, has now been appointed Arthur Amos Noyes Professor of Chemistry. The chair is named for the distinguished chemist who was one of the founders of Caltech and who at one time served as acting president of the Massachusetts Institute of Technology.

Dr. Hammond, a member of the National Academy of Sciences, is considered to be one of the world's leading investigators in physical organic chemistry. He is especially interested in the chemical changes that occur in some molecules as the result of energy being transferred to them by other molecules that have absorbed energy from light. His earlier work produced new insight into the action of oxidation inhibitors. At present, Dr. Hammond is active in the field of photochemistry, which he considers an enormously important means of harvesting, transferring, and storing energy, as well as a selective method of producing chemical transformations.

New Appointments

H. Frederic Bohnenblust, professor of mathematics and dean of graduate studies; and Jesse L. Greenstein, professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories, have been named as executive officers of the division of physics, mathematics and astronomy. They will help share administrative responsibilities of the division with its chairman, Carl D. Anderson. Professors Bohnenblust and Greenstein have been assisting Dr. Anderson for some time with administrative problems in the large and complex division, and the appointments formally recognize these efforts.

Harold Lurie, associate professor of engineering science, has been appointed assistant dean of graduate studies to help Dr. Bohnenblust. The work load of the graduate office has grown steadily along with the increasing number of graduate students – 687 this year, compared with 555 five years ago. The number of graduate students at the Institute now nearly equals the number of undergraduates — 697 in the current year.

Glee Club Spring Tour

The Caltech Glee Club will make its annual spring tour from March 16-20, opening its concert schedule in Evanston, Illinois, and continuing with engagements in Illinois and Wisconsin. This will be the first time the club has given concerts outside the state. The tour is being supported by the faculty, trustees, and student body. To date, concerts are scheduled for:

Monday, March 16	8:00 p.m.	National College of Education, Evanston, Illinois
Tuesday, March 17	8:00 p.m.	Beloit College Chapel Beloit, Wisconsin
Wednesday, March 18	1:00 p.m.	Rosary College River Forest, Illinois
	8:00 p.m.	Mount Morris Methodist Church Mount Morris, Illinois
Thursday, March 19	8:00 p.m.	Lawrenceville Township High School Lawrenceville, Illinois
Friday, March 20	8:00 p.m.	Carbondale Mormon Church Carbondale, Illinois

William N. Lacey Fund

A William N. Lacey Fund has been established at Caltech in honor of Dr. Lacey, professor of chemical engineering, emeritus. Dr. Albert Raymond, BS'21, MS'23, PhD'25, who is vice president and director of research and development at G. D. Searle & Company in Chicago, and a longtime friend of Dr. Lacey, suggested the fund in recognition of Lacey's many contributions to the Institute — and started it off with a generous amount.

The income from the fund will be available to the division of chemistry and chemical engineering for a variety of purposes — an honor award for notable achievement by a student, graduate or undergraduate; a scholarship or fellowship; a series of lectures by a distinguished visiting professor. The fund will be kept flexible to permit the income to be utilized most effectively at any given time.

Dr. Lacey had been a member of the Caltech faculty for 46 years, served as dean of graduate studies from 1946 to 1956, and was named dean of the faculty in 1962.

Dr. Lacey was married on July 15, 1963 to Madeline Hawley McClellan in Minden, Nevada. They now make their home in San Diego.

Honors and Awards

Robert F. Bacher, provost of the Institute, is the new president of the American Physical Society for 1964.

John R. Pierce, director of research in communications principles and systems at the Bell Telephone Laboratories, is one of five scientist-educators to receive the National Medal of Science from President Johnson. Dr. Pierce got his BS (1933), MS (1934) and PhD (1936) from Caltech.

Hallett D. Smith, professor of English and chairman of the division of humanities at Caltech, has been elected president of the board of trustees of the Polytechnic School in Pasadena.

Albert Tyler, professor of embryology at Caltech, has been elected president of the American Society of Naturalists.

Dean E. Wooldridge, research associate at Caltech, has received the $1000 magazine award in the 1963 AAAS-Westinghouse Science Writing Competition for his article in the June 1963 issue of *Harper's Magazine* on "Man's Mysterious Memory Machine."

EXPERTS IN RELEVANCE

Some observations on the training and practice of lawyers as compared to men of science— by a Caltech engineer turned lawyer

by Charles R. Cutler

The engineer who lets his colleagues know that he is considering the study and practice of law should prepare himself for all manner of jibes, jokes, and warnings — some seriously intended, some not. His brother engineers will shake their heads at the dismal prospect of memorizing Latin phrases, legal phraseology, and the struggle through dusty legal texts; all of which, it is claimed, will result in the production of a back-slapping rationalizer who will argue either side of a question, for a price.

The prospective law student himself has a somewhat brighter picture in mind or else he would not make the change, but he does brace himself for a plunge into the strange cold waters of an entirely different world, a world in which he expects his new education and training to bear no resemblance in method or content to his first love, the physical sciences. Once in law school, however, he is apt to be pleasantly surprised. Though the content of study is different, he will find a ready use for the analytical methods he developed at the "Institute."

Having gone through this experience, and having been initially dismayed by the lack of understanding between the professions of law and the physical sciences, I think some simple observations are in order concerning the education and practice of lawyers as compared to men of science, especially such applied scientists as engineers.

Stereotypically speaking, one can distinguish an engineering student from a law student at a distance of up to a city block. One carries a slide rule, the other a brief case. But, although the subjects studied by each could hardly seem more disparate, inside their respective classrooms an observer would find some things in common. It may surprise many to learn that the law student spends proportionately as much time in the study of "problems," as against the study of "laws," as does the student of engineering and science.

In most law schools nearly all of the texts are case books, which are a collection of court decisions in a given area of law rendered by courts throughout the country. Each decision is an opinion by a judge (or panel of judges) setting forth the pertinent facts of the case and applying the law to the facts, coming up at the end with a ruling.

Since the law may be different in various states and may be changed by the legislature at any time, the primary value of the case system is not in ascertaining what the "law" *is*. Indeed, it is not uncommon for adjacent pages in a case book to present two court decisions involving almost identical fact situations, but arising in different jurisdictions and with the courts arriving at opposite results.

Obviously, in such a course of study it is not *the law* which is being taught, but rather how to approach and solve a legal problem when one has a given set of facts. This emphasis on "approach" recognizes that a lawyer will seldom be fortunate enough in practice to encounter precisely the same legal-factual situations which he studies in law school. Therefore, the student must learn how to sift the facts of a given set of circumstances to come up with the *operative* facts under the law, as well as being able to "research" the law.

Engineering students also soon become aware that this sifting or setting-up process is one of the most important and difficult things to learn. How many times does an engineering student say, "I don't have any trouble with the equations once I get them set up"?

At exam time the law student might be asked to determine the legal rights and liabilities of a situation where a one-eyed illiterate runs a car into a rotten telephone pole on Sunday, disrupting a business telephone conversation and resulting in the loss of a $10,000 business contract. On the other hand, the engineering student could be asked to determine at what angle an inebriate (of given mass distribution) with rubber heels must lean in a decelerating streetcar going downhill in order to keep from falling into the lap of a schoolteacher. In each case a statement of applicable laws would not be so difficult; the problem is to discard the irrelevant facts, and to ascertain and arrange the important ones in such order that they may be utilized in a final solution.

Law students spend an immense amount of time learning how to analyze a given situation in order to determine what are the legal rights and liabilities arising from it. It is really the same logical process that must be utilized by an applied scientist who is seeking to apply physical and mathematical laws to a given problem.

It is also true that, just as there are "pure" science courses, there are courses in law school which approach the study of pure law. In some law courses which deal with federal law, such as taxation, the emphasis is on a study of statutes and regulations, since they are uniform for the whole country and a knowledge of the statutory structure will be useful to the student after he leaves law school. Even in these courses, though, attention must be given to factual examples and the case method is frequently used.

In addition there is a rough equivalent of engineering lab courses in law school; that is, moot court or mock court, in which the student tries a case before a jury of his peers (fellow classmates) or a law professor "judge". In such a course, he practices the techniques and procedures of litigation and learns how to conduct his own research. Science lab courses, as I recall, likewise have their chief value in teaching techniques and procedures and preparing the student for research.

It appears, then, that the time of both the law student and the student of the physical sciences may be classified as follows: (1) becoming acquainted with the laws or principles which are operative in the field; (2) analyzing and solving factual problems by ascertaining the relevant facts and correctly applying the proper laws or principles to them; (3) being trained in certain superficial though important procedures and techniques necessary to research and the expeditious solution of problems.

The ex-engineer law student finds that his time is not being spent in memorizing Latin phrases and legal phraseology; in fact, perhaps even less memory work is required than in engineering school. An analytical mind, one which can see through a maze of complex facts and arrive at the correct application of law, is the end sought by law school education. Justice Frankfurter once defined lawyers simply as "experts in relevance." It is not surprising that some law schools seek engineering graduates who have already had this very type of training in the physical sciences and who usually can easily turn their analytical powers on the legal problems which beset individuals and society.

Does the resemblance in methods of education of lawyers and engineers mean that similarities in the practice of the two professions exist after graduation? Despite many apparent and some genuine differences which are primarily the result of the manner in which they conduct their *business,* their work is surprisingly alike.

Consider an aspect of law practice which seems to have no counterpart in the physical sciences, such as that portion of an attorney's time spent in advocating a case before a court, jury, or other tribunal. Such advocacy, I am sure, consumes less than one percent of the time of the legal profession as a whole (though the figure is much higher for attorneys specializing in trial work), and I would guess the overall percent is continually decreasing. It is true that an attorney while arguing his case in court, especially in a jury trial, is essentially performing the art of persuasion. Nevertheless, while arguments to a jury frequently involve emotional overtones, a lawyer's oral argument before a judge or administrative tribunal would be much the same in logical nature as the oral attempt of a man of science to persuade a corporate or government body to adopt a certain course of action. In any event, regardless of the tribunal before whom the lawyer's argument is being made, most of the law has been practiced by midnight oil the night and weeks before. Behind every hour of public advocacy there lies in closet many hours of hard analytical work in preparation.

Aside from the art of advocacy, what is the great bulk of work for which a lawyer is trained and for which ability a client is willing to pay from five to a million dollars? It is the ability to analyze; to synthesize; to draw up and explain contracts,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deeds, wills, court briefs, and legislation (proposed, extant, and extinct); to solve factual and legal problems arising out of taxes, crimes, patents, radio stations, slander, negligence, insurance, ships at sea, domestic relations, trademarks; to administer under the law, trusts, estates, guardianships. This is the work of the lawyer; it is an applied science.

A lawyer's consideration of any case usually may be broken down into three basic concerns. First, he must determine exactly what his effort is expected to accomplish; second, he must ascertain every pertinent fact which might bear on this accomplishment; third, he must take into account all the applicable laws and legal principles. In some instances, ascertainment of the *facts* may be the most difficult problem, in others ascertaining the *law* (you may have to *predict* how a court would decide) would be the hardest. Both are essential.

As an illustration, a lawyer's preparation of a will provides an elementary example of legal science. A will is simple in principle and yet can present exceedingly complex problems in execution. If we follow a lawyer as he prepares a will, we will see that in a sense it is a "testamentary engine" which must be designed with the care and watchfulness of an engineer designing any complex device. The same mental processes are necessary in the preparation of any legal documents and, for that matter, in the administration of estates, or the preparation for litigation.

Take, as an example, the man who tells his attorney that upon his death he desires part of his estate to go directly to his wife, and the other portion to the children, but money is to be kept out of the children's hands during their immature years; and of course he wants to minimize death taxes. This is a very common type of will and could be written about as simply as just described. But a will so drawn, and without further inquiry, would be folly.

The next step to be taken by any competent designer, after learning what his product is supposed to do, is to ascertain every pertinent fact which might affect the operation of his product. In the case of the will, the full financial and family picture of the client should be presented to the attorney. Information on the emotional stability, business ability, and financial means of the wife is needed to determine what role the will should provide for her as a beneficiary and in administration of the estate. And, if the client holds a large amount of insurance payable to his wife, or owns considerable property or bank accounts jointly with his wife, or owns Texas oil property, his intent and the purpose of the will may be completely thwarted if their existence is not known to the attorney. All of these facts and many more must be learned by the legal draftsman, for the same reason that an engineer must know the physical conditions under which his machine will be expected to operate.

Next, the specific means or materials must be selected which are to be utilized in the end product. Knowing that a jet engine operates at high temperatures will lead an engineer to use only those metals which can withstand those temperatures. Likewise, upon being informed that the client's wife is a reliable businesswoman, the will draftsman may make her not only guardian of the person, but trustee of the property of the children. But if her abilities are not such, or if the assets are not subject of easy management, counsel will probably make other provisions to assure safe handling of the children's share of the estate, such as placing them in a trust managed by other capable trustees, either by will or a lifetime trust.

Of course, knowledge of just the *facts* is not enough; equally important is a knowledge of the laws involved. A will drawn without careful consideration of probate laws, and estate, income, and gift tax statutes is as inexcusable as the design of a high-powered automobile without consideration of Newton's laws of motion, or electronic components without consideration of relativity effects.

After the study of fact and law, and selection of the methods to be used, the personal experience and knowledge of the professional comes into play as he applies his personal skill to the problem. The artfully drawn will (or corporate profit-sharing plan) is just as much a thing of beauty to a lawyer as the neat solution of a problem by a mathematician or the clever design of an instrument by an engineer. Despite the cold analysis and calculation that goes into the work, the creative role of the individual craftsman is still felt.

The varying relationships between the legal profession and those they serve is an intriguing subject, deserving of extended discussion. But these broad brush strokes will be justified if it be known that a lawyer's training and practice, like that of an engineer, I believe, is directed primarily at making him an expert in relevance in his field.

Books

THE FEYNMAN LECTURES ON PHYSICS

by Richard P. Feynman, Robert B. Leighton and Matthew Sands

Addison-Wesley *$8.75*

Reviewed by Robert R. Blandford '59, graduate student in geophysics

There is little doubt in my mind that this collection of lectures given to Caltech freshmen by Prof. Feynman in 1961-1962 fully deserves to be reviewed in the standard book review journals, such as *The New York Times Book Review,* because it has great artistic and philosophic worth, besides being a textbook which probably should be owned by every scientist and engineer.

The fact that it almost certainly will not be reviewed in a journal of general interest is partly because of the split, such as it is, between scientists and humanists; and partly because the dispiritingly low level of life and comprehensibility in the typical text has prejudiced most editors to such a degree that they do not watch the non-popular publications in the hope that one may have general interest.

However, this book is for freshmen, and crackles with life. Those graduates of Caltech who have heard Prof. Feynman speak to small and large groups will remember his humor, his dramatic flair, and his interests in philosophy. All this is preserved wonderfully in this book, and for this we all owe thanks to the co-authors, Professors Leighton and Sands. The taped lectures have been transformed into a large, well-edited volume with wide margins which contain many clear, illustrative line drawings. Everyone connected with this volume is to be congratulated.

But, of course, Prof. Feynman assumes the major responsibility, and deserves the major credit. In the introduction he discusses how much credit he deserves, and, quite properly, evaluates this solely in terms of how much he succeeded in teaching his students.

Evidently, from test results and the volume of letters to the *California Tech,* some students were baffled by the multiplicity of subjects introduced, and by the speed and depth with which they were pursued. Prof. Feynman finds this discouraging, and around Caltech various ways of remedying and understanding the problem are being discussed. But I prefer to discuss the lectures from the point of view of a man who has had at least a liberal education in physics — mathematics through calculus, and an introductory physics course — who wants to understand the natural world about him, and who is prepared to give as much effort to Feynman's lectures as he gives to Joyce's *Ulysses.* The parallel between the two works is suggestive because both may be read for a greater understanding of the world, yet both abound in wit and humor and demand considerable concentration.

Prof. Feynman was evidently aware that some readers might take the wide range of topics and the casual tone to imply a shallow treatment characteristic of a survey course, because in the introduction he feels constrained to say that the lectures are meant to provide a thorough grounding in physics — which they do.

The philosophy contained in the book is mostly indirect and only rarely erupts into direct statement. When direct statements are made they make no pretense at rigor and either introduce or follow a long series of concrete scientific insights which serve as illustrations. To an unusual degree this book will imbue the careful reader with the author's specific brand of scientific spirit and philosophy.

The book opens with three chapters which prepare the philosophical ground and give a survey of all science. Prof. Feynman's casual yet powerful approach is immediately apparent. "If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the *atomic hypothesis* (or the atomic fact, or whatever you wish to call it) that *all things are made of atoms — little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.* In that one sentence, you will see there is an *enormous* amount of information about the world if just a little imagination and thinking are applied." Prof. Feynman then makes the necessary applications and discusses phenomena ranging from gases to human beings.

He then surveys the branches of physics — mechanics, electromagnetism, nuclear physics, and so on — and moves on to consider the relations of other sciences to physics. This chapter is opened with a warning to some perhaps naive freshmen: "We must, incidentally, make it clear from the beginning that if a thing is not a science, it is not necessarily bad. For example, love is not a science. So, if something is said not to be a science, it does not mean that there is something wrong with it; it just means that it is not a science."

In discussing the relation of astronomy to physics, he says: "One of the most impressive discoveries was the origin of the energy of the stars, that makes them continue to burn. One of the men who discovered this was out with his girl friend the night after he realized that *nuclear reactions* must be going on in the the stars in order to make them shine. She said, 'Look at how pretty the stars shine!' He said, 'Yes, and right now I am the only man in the world who knows *why* they shine!' She merely laughed at him. She was not impressed with being out with the only man who, at that moment, knew why stars shine. Well, it is sad to be alone, but that is the way it is in this world."

Among some younger physicists there is a tendency to dismiss as unworthy of consideration any branch of physics which can be treated classically. However, with his customary insight into what the problems of our understanding of the world are, Prof. Feynman devotes a paragraph to the importance of an analysis of turbulent flow.

Energy, velocity, acceleration

After this the successive chapters take up the detailed discussion of physics. The concepts of energy, velocity, and acceleration are introduced. Then Newton's law of gravitation enables a numerical calculation to be carried out in detail to give the shape of the path of a planet around the sun. By this numerical integration the mathematical problems are minimized and the points of physical interest are brought out clearly. This is an example of Prof. Feynman's consistent emphasis on physical insight, and his slight patience with mathematics for its own sake. After displaying the equations for N gravitationally interacting bodies, he writes: "So, as we said, we began this chapter not knowing how to calculate even the motion of a mass on a spring. Now, armed with the tremendous power of Newton's laws, we can not only calculate such simple motions, but also, given only a machine to handle the arithmetic, even the tremendous complex motions of the planets, to as high a degree of precision as we wish!"

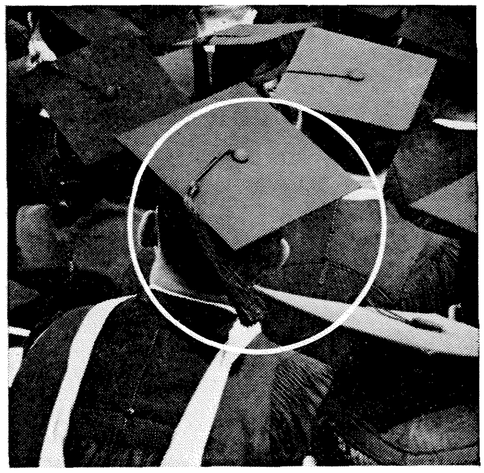
Then a careful discussion of the definitions of mass and momentum prepares the way for relativistic momentum. Relativity already makes its first appearance!

In the discussion of vectors, the modern concepts of symmetry are suggested immediately. A discussion of symmetry under translation leads to an amusing statement, perhaps bordering on the obvious, of the need for common sense in physics. "Suppose we build a complicated machine . . . (and another) exactly the same only displaced laterally by some distance . . . Will one machine behave exactly the same as the other? . . . Of course the answer may well be *no*, because if we choose the wrong place for our machine it might be inside a wall and interferences from the wall would make the machine not work. All of our ideas in physics require a certain amount of common sense in their application; they are not purely mathematical or abstract ideas."

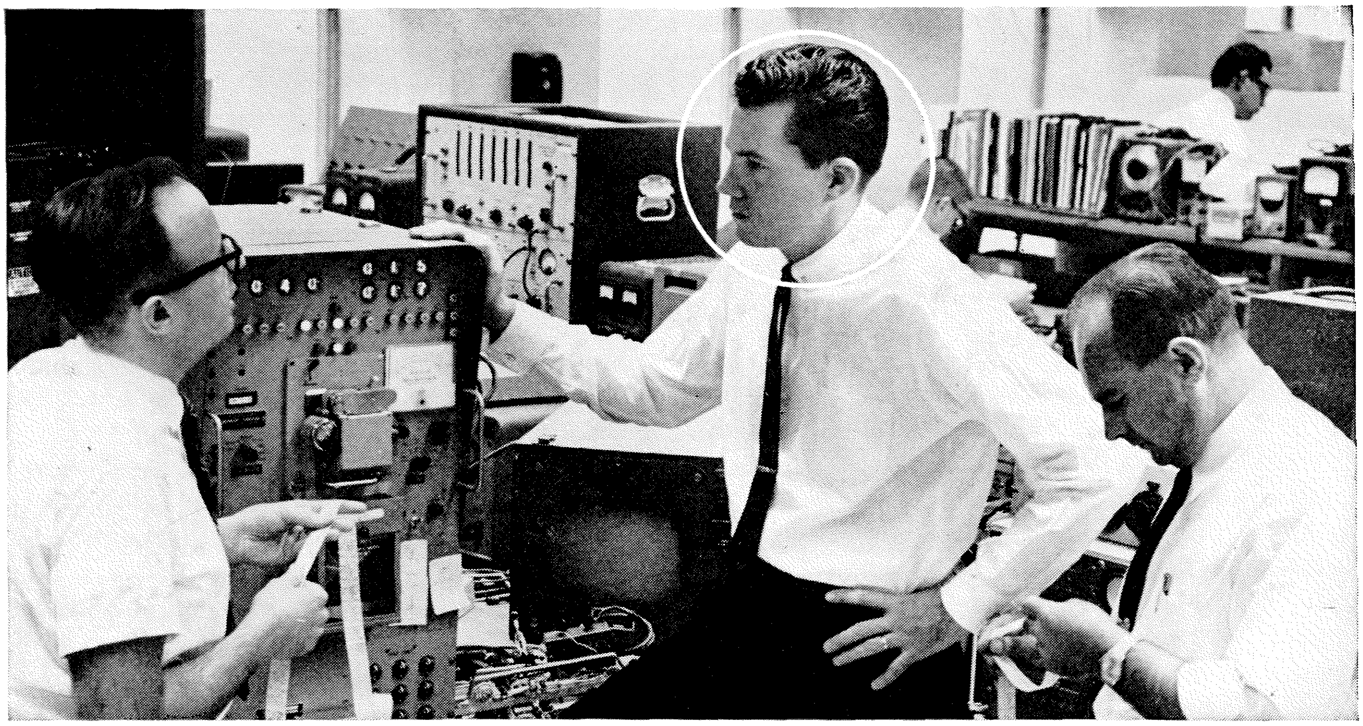
The concept of force

When the concept of force is given a detailed discussion, Prof. Feynman first mentions the definition of force as mass times acceleration. Then he says: "There must be something wrong with that, because it just is not saying anything new. If we have discovered a fundamental law, which asserts that the force is equal to the mass times the acceleration, and then *define* the force to be the mass times the acceleration, we have found out nothing . . . The real content of Newton's laws is this: that the force is supposed to have some *independent properties* . . . not completely specified by Newton or by anybody else, and therefore the physical law $F = ma$ is an incomplete law." The discussion goes on, but the characteristic revealed here for the first time is Prof. Feynman's willingness to attack head on, right from the start, all the paradoxes and "crazy" questions which students are wont to puzzle over.

He points out the fundamental distinction between empirical and fundamental laws, using as an example of the former the coefficient of friction. (Many of us have learned to solve problems using the coefficient of friction.) A more sophisticated example is the "law" that the drag on an airplane is proportional to the square of the velocity. Why does this law have a lower status than $F = ma$? "The reason is that . . . as we understand nature this law is the result of an enormous complexity of events and is not, fundamentally, a



John Lauritzen wanted further knowledge



He's finding it at Western Electric

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John attended one of Western Electric's three Graduate Engineering Training Centers and graduated with honors. Now, through the Company-paid Tuition Refund Plan, John is working toward his Master's in Industrial Management at Brooklyn Polytechnic Institute. He is currently a planning engineer developing test equipment for the Bell System's revolutionary, new electronic telephone switching system.

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The concept of conservative forces and work is next introduced in a conventional manner, and then two full chapters are devoted to the special theory of relativity including four-vector momentum. In this discussion Feynman's tendency to play with philosophy and to face squarely any interesting paradoxes is shown at its best. "When this idea (relativity) descended upon the world, it caused a great stir among philosophers, particularly the 'cocktail-party philosophers,' who say, 'Oh, it is very simple: Einstein's theory says all is relative' . . . In addition they say 'It has been demonstrated in physics that phenomena depend on your frame of reference.' We hear that a great deal, but it is difficult to find out what it means . . . That what one sees depends on his frame of reference is certainly known to anybody who walks around, because he sees an approaching pedestrian first from the front and then from the back; there is nothing deeper in most of the philosophy which is said to have come from the theory of relativity than the remark that 'A person looks different from the front than from the back.'

"There is another school of philosophers who say, 'It is obvious that one cannot measure his velocity without looking outside. It is self-evident that it is *meaningless* to talk about the velocity of a thing without looking outside; the physicists are rather stupid for having thought otherwise, but it has just dawned on them that this is the case. If only we philosophers had realized what the problems were that the physicists had, we could have decided immediately by brainwork that it is impossible to tell how fast one is moving without looking outside, and we could have made an enormous contribution to physics.' These philosophers are always with us, struggling in the periphery to try to tell us something, but they never really understand the subtleties and depths of the problem."

A direct attack

The next topics discussed include rotations, coriolis forces, and angular momentum. There is a humorous example of Feynman's direct attack on paradoxes in his discussion of the precession of a gyroscope. "It is very strange that when one suddenly lets go of a gyroscope it does not *fall* under the action of gravity but moves sideways instead! Why is it that the *downward* force of the gravity which we *know* and *feel*, makes it go *sidewise*? What really happens is . . . if we suddenly let go, there will instantaneously be a torque from gravity. Anyone in his right mind would think that the top would fall, and that is what it starts to do, as can be seen if the top is not spinning too fast. . . . When the motion settles down, the axis of the gyro is a little bit lower than it was at the start. Why? (These are the more complicated details, but we bring them in because we do not want the reader to get the idea that the gyroscope is an absolute miracle. It *is* a wonderful thing, but it is not a miracle.)"

The discussion moves on to complex numbers and the harmonic oscillator. Illustrations of resonance are given from many fields, among them atmospheric tides and the Moessbauer effect.

Geometrical optics

In the discussion of geometrical optics, Prof. Feynman emphasizes how the best lenses are now designed with straightforward numerical computation. As usual, he places primary emphasis on physical understanding and, preparing the way for quantum mechanics, develops optics from Fermat's principle of least time. About this, he says:

"The following is another difficulty with the principle of least time, and one which people who do not like this kind of a theory could never stomach. With Snell's theory we can 'understand' light. Light goes along, it sees a surface, it bends because it does something at the surface. The idea of causality, that it goes from one point to another, and another, and so on, is easy to understand. But the principle of least time is a completely different philosophical principle about the way nature works. Instead of saying it is a causal thing, that when we do one thing, something else happens, and so on, it says this: we set up the situation and *light* decides which is the shortest time, or the extreme one, and chooses that path. But *what* does it do, *how* does it find out? Does it *smell* the nearby paths, and check them against each other? The answer is, yes, it does, in a way." And he goes on to explain.

One of the triumphs of this introductory course in physics, to my thinking, is its treatment of electromagnetism. The topics are discussed on a level of clarity and consistency usually not found until a graduate course. First, by means of an elegant, relativistically correct, formula for the field emitted by an accelerating charge, the far field of a

slowly oscillating dipole is deduced. Then the interference patterns of several dipoles are discussed and applications are made to radio transmission, diffraction gratings, radio astronomy antennas, colored films, crystals, and diffraction by opaque screens. All these applications are characterized by physical arguments of gratifying clarity.

The most advanced topic in the book is relativistic effects in radiation. The discussion is exceptionally clear and direct for such a difficult subject and considers, among other topics, synchrotron radiation and the ω, k four-vector.

Color vision

It will come as no surprise to anyone associated with Prof. Feynman's interests in common natural phenomena to find two full chapters devoted exclusively to color vision. The typical physics student elsewhere would go through an undergraduate *and* graduate school without hearing a single lecture on the subject, yet here it is given roughly the same amount of space as is devoted to such a fundamental topic as angular momentum. The vector theory of color vision is discussed, the chromaticity diagram is introduced, and the most recent experiments bearing on the mechanism of color vision and the physiology of vision are discussed in some detail. The only interjection of "standard" physics comes in the discussion of the resolving power of the eye of the bee.

Is this divergence from topics of more fundamental interest justifiable? On the one hand it certainly deprives some students of needed elaboration on more fundamental topics; but on the other hand, for the more creative student and for the general reader, it serves well as a window to the complex world outside the simplified house of physics, and illustrates a general method of approach to more complex phenomena.

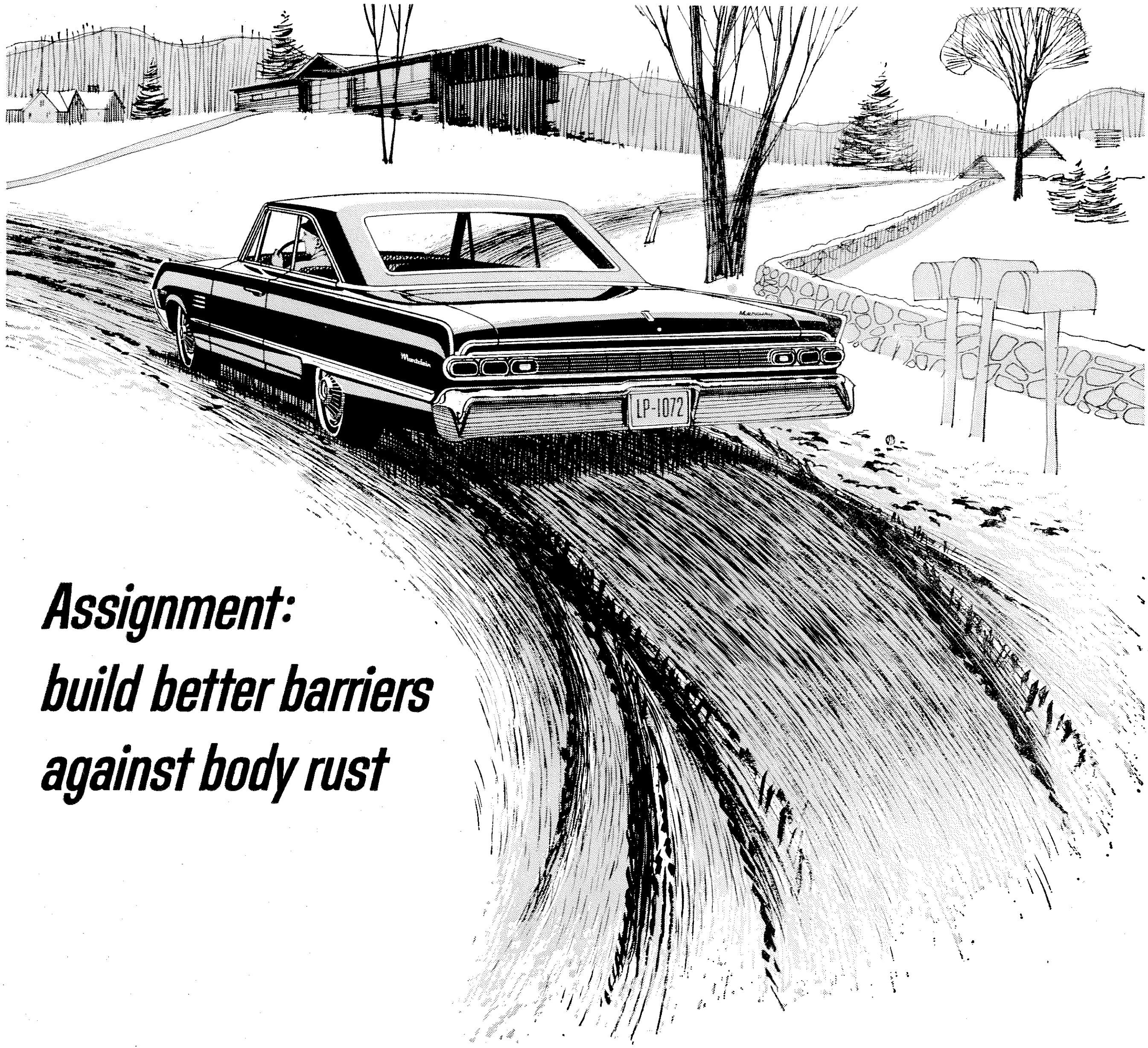
After the chapter on color vision come a number of chapters treating rather disconnected topics. There are two chapters giving a careful discussion of the experimental basis for the wave-particle duality in quantum mechanics, a chapter on the kinetic theory of gases in which the equipartition of energy is proved, and an introduction to statistical mechanics.

In five more chapters are found a startling diversity of topics seldom discussed in an introductory course, such as Johnson noise, Rayleigh's law for the thermal equilibrium of radiation, Planck's distribution, evaporation, thermionic emission, thermal ionization, chemical kinetics, induced emission, ionic conductivity, thermal conductivity of gases, the relation between mobility and molecular diffusion, reversible engines, and the Clausius-Clapeyron equation.

The third chapter of three on thermodynamics may be the most outstanding in the volume. It is titled "Ratchet and Pawl," and discusses the paradox that all our fundamental physical laws are reversible, yet the experience of life is that time's arrow exists. The discussion moves easily from the scale of a tiny ratchet and pawl machine lifting a flea, through the concept of entropy as disorder, to the observations of astronomers which indicate that the entire known universe is ordered. The chapter closes with the paragraph: "Another delight of our subject of physics is that even simple and idealized things, like the ratchet and pawl, work only because they are part of the universe. The ratchet and pawl works only in one direction because it has some ultimate contact with the rest of the universe. If the ratchet and pawl were in a box and isolated for some sufficient time, the wheel would be no more likely to go one way than the other. But because we pull up the shades and let the light out, because we cool off the earth and get heat from the sun, the ratchets and pawls that we make can turn one way. This one-wayness is interrelated with the fact that the ratchet is part of the universe. It is part of the universe not only in the sense that it obeys the physical laws of the universe, but its one-way behavior is tied to the one-way behavior of the entire universe. It cannot be completely understood until the mystery of the beginnings of the history of the universe are reduced still further from speculation to scientific understanding."

From sound to anti-matter

A chapter is devoted to the linearized sound equation in air, and the subjects of beats and modes of oscillation are introduced and discussed with the aid of Fourier analysis. A chapter is devoted to a qualitative discussion of waves in the earth and in water, and the volume closes with a chapter discussing symmetry in physical laws, of which the chief result is an understanding of the known facts about conservation of parity. Prof. Feynman points out that if instructions were given to an anti-matter world to make a replica of ourselves, then right and left would be confused: "So if our Martian is made of anti-matter and we give



Assignment: build better barriers against body rust

Result: More rust-resistant steel than ever before on 1964 Ford-built bodies!

Ford Motor Company, pioneer in the use of galvanized (zinc-clad) steel, long noted for its ability to fight off rust, is using increased amounts of this superior material in 1964 car models. This marks further progress in our continuing efforts to solve the problems of metal corrosion in car bodies.

Other Ford-developed rust fighters include special zinc-rich primers . . . aluminum and stainless steels in mufflers, moldings and body fasteners . . . quality baked-enamel finishes—all powerful barriers against rust in Ford-built cars and trucks.

A new process, now in limited test production, is the electrocoating of entire car bodies. This involves electrical attraction between positively charged metal surfaces and negatively charged paint particles. When the body is dipped in an aqueous solution containing the paint particles, a form of "electroplating" occurs, the paint seeking those areas with the least coverage, until a complete and uniform coating is deposited.

More examples of engineering leadership at Ford Motor Company bringing better products to the American Road.

Ford

MOTOR COMPANY

The American Road, Dearborn, Michigan

WHERE ENGINEERING LEADERSHIP BRINGS YOU BETTER-BUILT CARS

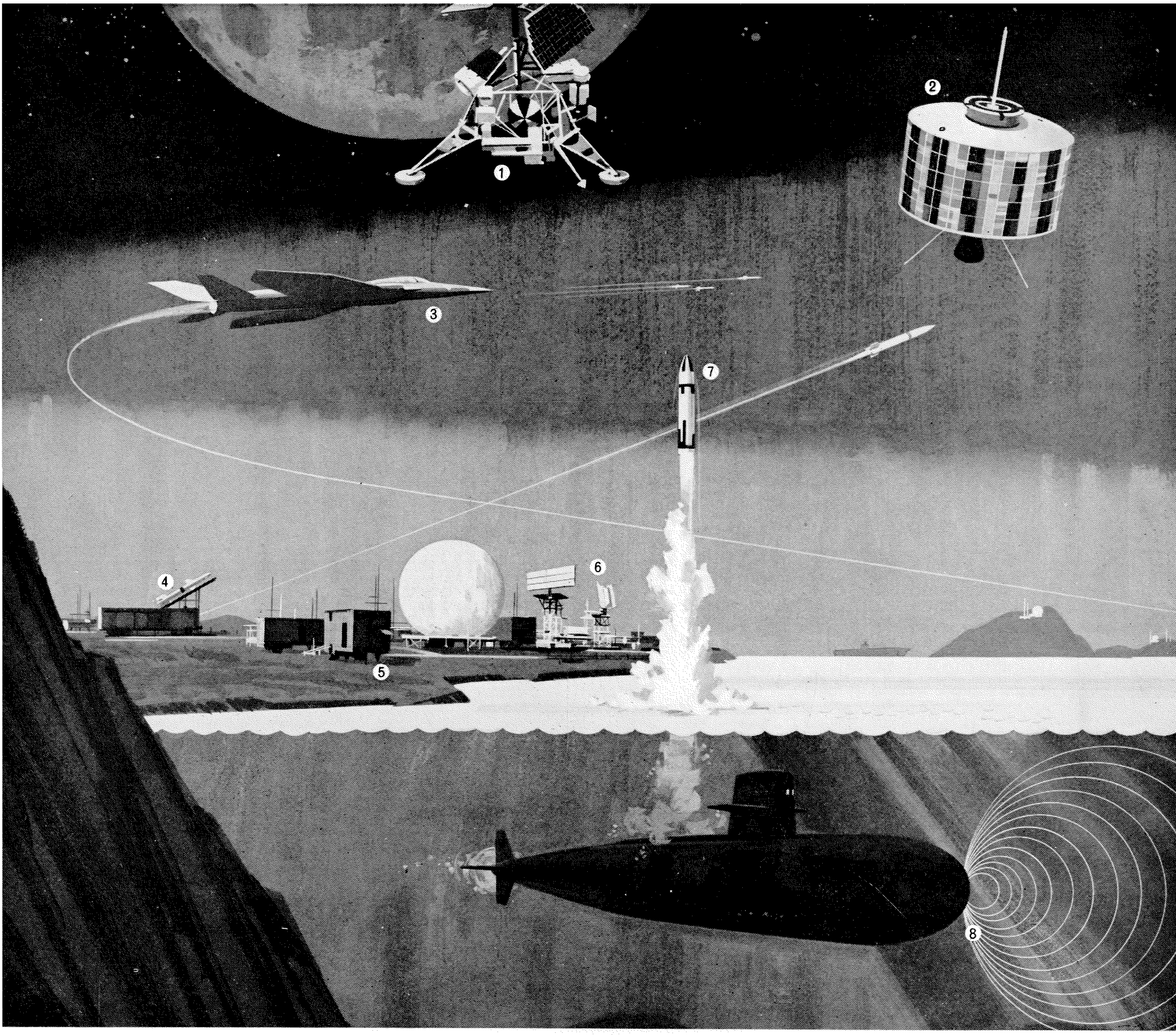
him instructions to make this 'right' handed model like us, it will, of course, come out the other way around. What would happen when, after much conversation back and forth, we have each taught the other to make spaceships and we meet halfway in empty space? We have instructed each other on our traditions, and so forth, and the two of us come rushing out to shake hands. Well, if he puts out his left hand, watch out!"

This book seems to me to demand criticism on other than its purely scientific and pedagogical merit (although the scientific merit is beyond dispute, and those students who have understood the material may have a start which will make them great scientists of the future). I have quoted and detailed the contents extensively because it seems to me that we have before us a work of art, capable of standing by itself and of contributing substantially to a complex world view.

One of the characteristics of many great novels is that between the great spiritual flights the reader is deluged by great volumes of "the real" which the author has gathered in his notebooks. The effect is to expand the reader's world, and to set off the peaks of spiritual achievement.

Throughout Prof. Feynman's lectures much of the same pattern may be seen. The complex data of the physical world is presented in wide-ranging yet penetrating detail. The leaven to the loaf is his constant good humor, found more in the tone than in jokes. And then, occasionally, while one is held on this high plateau of excitement and interest, a philosophical summation is given which, if not rigorous, is alive and convincing.

As does the novelist, Prof. Feynman portrays the observed world and points beyond it. I am reminded of the close to *The Origin of the Species*: "There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, while this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and wonderful have been, and are being evolved." Darwin was devoted to clarity, honesty, and graciousness. In our times one such man speaks with a Brooklyn accent. The times have changed but the men are still with us.



Opportunities at Hughes for EE's—Physicists—Scientists:

from the ocean floor to the moon...and beyond

Hughes sphere of activity extends from the far reaches of outer space to the bottom of the sea . . . includes advanced studies, research, design, development and production on projects such as: ① **SURVEYOR**—unmanned, soft-landing lunar spacecraft for chemical and visual analysis of the moon's surface; ② **SYNCOM** (Synchronous-orbit Communications Satellite)—provides world-wide communications with only three satellites; ③ **F-111B PHOENIX** Missile System—an advanced weapon system designed to radically extend the defensive strike capability of supersonic aircraft; ④ **Anti-ICBM Defense Systems**—designed to locate, intercept and destroy attacking enemy ballistic missiles in flight; ⑤ **Air Defense Control Systems**— border-to-border control of air defenses from a single command center— combines 3D radar, real-time computer technology and display systems within a flexible communications network; ⑥ **3D Radar**—ground and ship-based systems give simultaneous height, range and bearing data—now in service on the nuclear-powered U.S.S. Enterprise; ⑦ **POLARIS** Guidance System — guidance components for the long-range POLARIS missile; ⑧ **Hydrospace** — advanced sonar and other anti-submarine warfare systems.

Other responsible assignments include: *TOW* wire-guided anti-tank missile, *VATE* automatic check-out equipment, Hard Point defense systems. . . . R & D work on *ion* engines, advanced *infrared* systems, associative computers, *lasers, plasma* physics, *nuclear* electronics, *communications* systems, microwave tubes, parametric *amplifiers, solid state* materials and devices . . . *and many others.*

B.S., M.S. and Ph.D. Candidates
Members of our staff will conduct

CAMPUS INTERVIEWS

February 20 & 21, 1964

Learn more about opportunities at Hughes, our educational programs, and the extra benefits Southern California living offers. **For interview appointment and literature, consult your College Placement Director.** ***Or write: College Placement Office, Hughes Aircraft Company, P. O. Box 90515, Los Angeles 9, California.***

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HUGHES

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Alumni Speak Out...IV

In the more than 5,000 Alumni Survey questionnaires that have been returned to the Institute to date, responses to the back-page invitation for "comments" have been gratifyingly numerous. Although there is no such thing as a typical comment, these are some representative ones.

Students entering C.I.T. are presumably selected not only for high intelligence but for superior accomplishment in competition with others. No doubt this process selects people capable of very high technical and scientific achievement. But do you also have in this group the future professor who is unavailable to his students, the department head or group leader who pushes his assistants around without regard for their personal needs, and the highway engineer who can design a superb freeway but is unresponsive to suggestions that it violates scenic values or displaces too many people? Broadly speaking, are we selecting future leaders who will lead us into a "Progress-at-any-Price" type of society?

I worked so hard to keep from getting "booted out" of graduate school at Caltech that when I have a "night-mare," I dream I am back at work in Gates.

I, and most of the alumni I currently know as friends or business associates, are disappointed and alarmed at the "liberal" leanings of the present student body. At worst, this is due to "pinks" in the humanities staff; at best, Caltech is doing an inadequate job of teaching the merits of free enterprise, incentive systems, and individual freedoms versus the proven inadequacy of Communism, Socialist bureaucracies, and other State Monopoly systems. (Why is this pro-slavery, anti-freedom movement called "liberal"?)

Present entrance requirements make it extremely doubtful if such as I will ever again qualify for your school. You will be the loser, I think.

My own psychological maturity had not developed enough for me to be as effective as might have been possible years later. Maybe this could have been helped by some really skillful direction from a psychologist-counselor related to CIT. The competitive pressures combined with the school's always-excessive demands allow only the super-geniuses and super-grinds to survive.

In spite of Cal Tech's past success, or perhaps because of it, the time for a more radical educational plan is probably here.

The quality of the education I received at Cal. Tech. was very poor. This is because the faculty is or was chosen mainly for their research ability rather than their teaching ability. This means that the students who graduate from Cal. Tech. not only have learned the subject material but, due to the inadequacies of the instruction, have been forced to learn how to study on their own.

When I first graduated from Cal. Tech., I was dissatisfied and disappointed in the quality of the teaching. Now, by comparison with the education of colleagues from different universities, the Cal. Tech. education seems very good.

Contrary to the prevailing attitude in undergraduate Caltech, Caltech is not the technical center of the world. A substantial effort should be expended in showing the students that, after graduation, they do not always have to be right (and others wrong).

This is the finest school of its kind in the country.

I have never been as happy before or since I was at Caltech. The attitudes of the teachers (faculty) and administration are unique and correct.

Caltech helped to mold my personality and make me a better person, aware of my responsibility to my fellow man.

I only wish that my basic nationalism which led me to join the service for about 3 years had not prevented me from attending graduate school—for I was fortunate and accepted. It was foolish of me not to attend.

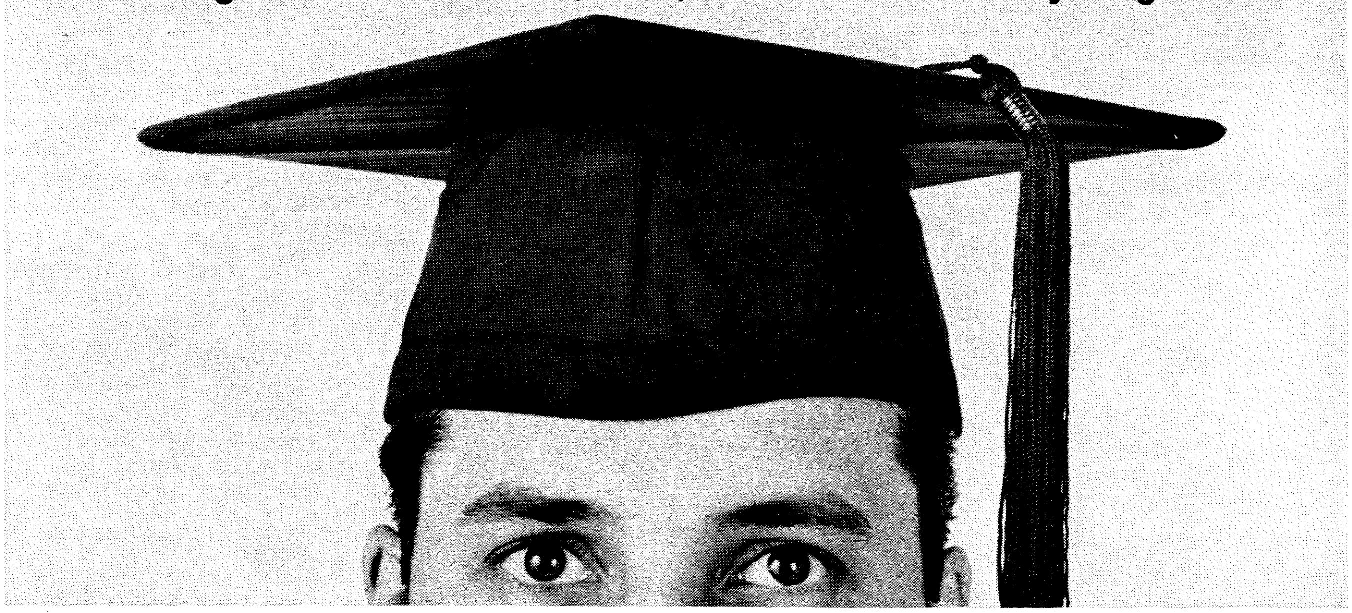
CIT's honor system is one of its greatest attributes.

I hope someday that I can repay in some manner what I feel Caltech gave to me.

I think that this is a fine survey and your continued interest is to be commended.

Would you want your daughter to marry one?

Looking towards a Ch.E., E.E., M.E. or Chemistry degree?



Look ahead to the advantages of a career in Monsanto production

Let's face it. Production is the very heart of a billion-dollar *producer* like Monsanto. Here's where the young engineer meets technical challenges second to none. Here's where he can display his talents daily . . . helping increase yields, improve processes, raise efficiency, lower costs, boost profits. Here's where Monsanto's on-the-job training can help him move ahead faster . . . personally and professionally.

Monsanto production men are known by many titles—Maintenance Staff Engineer, Plant Technical Services Engineer, Production Supervisor . . . to name a few. Try one on for size *now* . . . then see your Placement Director to arrange an interview when we visit your campus. Or write for our new brochure, "You and Monsanto," to Professional Recruiting Manager, MONSANTO, St. Louis, Missouri. 63166

An Equal Opportunity Employer

Personals

1925

WILLIAM U. DENT is now on the staff of the electronics engineering department at the University of California Radiation Laboratory in Livermore. He was formerly an electrical engineer with Westinghouse in San Francisco.

1926

SAM PARNALL died on November 6 in Carmel, California, of congestive heart failure. He had been employed as a mechanical engineer with Ingersoll-Rand Company for 25 years prior to his retirement in 1951. A bachelor, he leaves two sisters, Miss Mary Parnall and Mrs. Katherine Townsend, in Carmel.

1931

ALFRED S. VOAK, listed as a "lost" alumnus, reports that he is president of Voak Engineering Company, Inc., in Upland, California. The firm manufactures multi-turn wire-wound potentiometers for manufacturers of electronic equipment.

1935

ARTHUR B. ENGELDER, MD, manager of bio-instrumentation at the Lockheed Missile and Space Company in Sunnyvale, California, died on January 22, of a heart attack. He had been with Lockheed since 1961.

After graduating from Caltech, Dr. Engelder went to San Jose State College for two years where he did graduate work in advanced biology. In 1939 he received his MD from Johns Hopkins University and was a practicing physician in Arizona until he moved to California three years ago. As an inventor, he held patents on medical and surgical instruments and bio-metrical computers. He is survived by his wife and two daughters, Barbara and Sally, and three grandchildren.

1937

CLAUDE B. NOLTE, president of the L. J. Cannon Manufacturing Company, Inc., in Placentia, California, has been elected a Fellow of the Instrument Society of America "for distinguished achievements in the field of pressure measuring instrumentation." The Noltes are now living in Yorba Linda.

BERNARD WALLEY has been appointed manager of Sales Engineering, Electronic Components, RCA International Division, for Europe, Africa, and the Near East – with headquarters in Geneva, Switzerland. He has been with the RCA electron tube division since 1937 and has worked both at Harrison, N. J., and Los Angeles – most recently as manager of the West Coast microwave engineering operation.

LEWIS A. DELSASSO, PhD, died on September 23 of a heart attack at Aberdeen Proving Ground in Maryland, where he was chief of the ballistic measurement laboratory. He leaves his wife; two sons, Richard and Robert; and a daughter, Betty.

1938

HOWARD S. SEIFERT, PhD, professor of aeronautics and astronautics at Stanford, and director of advanced planning at United Technology Corporation, has now been appointed manager of UTC's physical sciences laboratory. He will continue as professor at Stanford.

1942

STANLEY CORRSIN, MS, AE, PhD '47, professor of fluid mechanics at Johns Hopkins University in Baltimore, Md., is now a Fellow of the American Academy of Arts and Sciences and a Fellow of the American Physical Society.

1945

HUGH S. WEST is now director of field training and research at the Connecticut General Life Insurance Company in Hartford, Conn. He has been with the

ALUMNI FUND PROGRESS REPORT

Here is where we stand as of December 31, 1963:

	Number of Gifts	Number of Dollars
Alumni gifts received through the Fund:	1,143	$38,262.55
Other alumni gifts received and credited through the Fund:	16	21,525.05
Corporate gifts matched:	(29)	2,402.00
Totals:	1,159	$62,189.60

The response to this year's Fund solicitation has been considerably more enthusiastic than in previous years. The percent of alumni participating is currently 13.8, an increase of 12 percent over last year at this time. We hope this enthusiasm will continue to grow and that our goal of $100,000 will be exceeded in the near future.

–G. Russell Nance '36 and David L. Hanna '52
Directors of the Caltech Alumni Fund

company since 1953. The Wests have two sons, Hugh and William, and two daughters, Kathryn and Mary.

J. V. WERME has been appointed manager of product engineering at the Bailey Meter Company in Cleveland, Ohio. He has been with the company since 1956, and was with the Brown Division of Minneapolis-Honeywell for seven years prior to that.

LINDEN R. BURZELL is now general manager and chief engineer of the San Diego County Water Authority. He had been chief engineer and general manager of the Vista Irrigation District since 1952, and has also served as city engineer for the recently incorporated city of Vista, where he lives.

1950

BRUCE B. STOWE is now an associate professor in the department of biology at Yale University and is also secretary of the American Society of Plant Physiologists. The Stowes, who live in Hamden, Conn., have two sons.

1952

ROBERT S. DAVIS, MS '53, is now an assistant vice president of Halcon International, Inc., in New York. He also serves as director of development.

ROBERT E. STANAWAY has been appointed director of engineering and product development at Houdaille Industries, Inc., in Buffalo, N.Y. He was formerly board chairman and president of Montronics, Inc., in Bozeman, Montana, before that corporation was merged with the John Fluke Company in Seattle. He is also owner of Stanaway Associates, consultants and product development engineers. The Stanaways have four children; Susan, John, Robin, and Sharon.

SULLIVAN G. CAMPBELL, MS, is now director of technical planning for the research and engineering division of the Xerox Corporation in Rochester, N.Y. He was formerly manager of advanced systems programming and special contract systems at IBM in Poughkeepsie. The Campbells have three children.

1957

DANVER SCHUSTER, MS '59, research group supervisor at JPL, died on October 9 while working at the Goldstone Tracking Station. He was 39, and had worked at JPL since 1957. He is survived by his widow and two daughters, Elizabeth and Stephanie.

1961

THOMAS GORDON, a member of the technical staff at Scientific Data Systems in Santa Monica, was killed in an automobile crash on December 24.

PLACEMENT ASSISTANCE TO CALTECH ALUMNI

There are two ways in which the Placement Service may be of assistance to you:

(1) To help you seek new employment or a change of employment.

(2) To inform you when outstanding opportunities arise.

This service is provided to Alumni by the Institute. A fee or charge is not involved.

If you wish to avail yourself of this service, fill in and mail the following form:

To: Caltech Alumni Placement Service
California Institute of Technology
Pasadena, California 91109

Please send me:

☐ An Application for Placement Assistance

☐ A form to report my field and operation so that I may be notified of any outstanding opportunities.

Name .... Degree (s) ....

Address .... Year (s) ....

....

CALTECH CALENDAR

ALUMNI EVENTS

May 2
Alumni Seminar

June 10
Annual Alumni Meeting

FRIDAY EVENING DEMONSTRATION LECTURES

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

February 21
Exploring the Interior of a Glacier
--W. Barclay Kamb

February 28
Electron Microscopy of Genetic Material in Plant Cells
—Beal B. Hyde

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G. Russell Nance, '36
Richard W. Powell, '40
Richard P. Schuster, Jr., '46
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Meetings: 15th 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.

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P.O. Box 1952, Sacramento 9, Calif.

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4535 Marble Way, Carmichael, Calif.

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2551 Carson Way, Sacramento 21, Calif.

Meetings: University Club, 1319 "K" St.
Luncheon first Friday of each month at noon.
Visiting alumni cordially invited—no reservation.

This kind of engineer designs jobs instead of things

Once upon a time there was a creature known to joke-smiths as "the efficiency expert." When he wasn't being laughed at, he was being hated. Kodak felt sorry for the poor guy and hoped that in time he could be developed into an honored, weight-pulling professional. That was long ago.

We were then and are much more today a very highly diversified manufacturer. We need mechanical, electrical, chemical, electronic, optical, etc., etc. engineers to design equipment and processes and products for our many kinds of plants, and make it all work. But all the inanimate objects they mastermind eventually have to link up with *people* in some fashion or other—the people who work in the plants, the people who manage the plants, and the people who buy the products. That's why we need "industrial engineers."

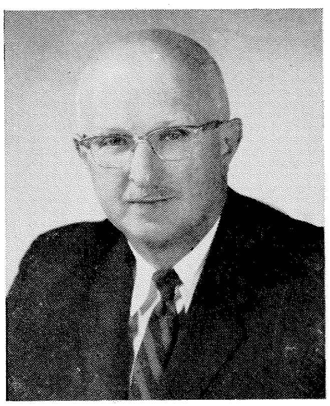
A Kodak industrial engineer learns mathematical model-building and Monte Carlo computer techniques. He uses the photographic techniques that we urge upon other manufacturing companies. He collaborates with medicos in physiological measurements, with architects, with sales executives, with manufacturing executives, with his boss (G. H. Gustat, behind the desk above, one of the Fellows of the American Institute of Industrial Engineers). He starts fast. Don Wagner (M.S.I.E., Northwestern '61) had 4 dissimilar projects going the day the above picture was sneaked. He is not atypical. *Want to be one?*

Kodak

EASTMAN KODAK COMPANY, Business and Technical Personnel Department, Rochester 4, N. Y.

An equal-opportunity employer offering a choice of three communities: Rochester, N. Y., Kingsport, Tenn., and Longview, Tex.

An interview with G.E.'s Dr. George L. Haller Vice President— Advanced Technology



As Vice President—Advanced Technology Services, Dr. Haller is charged with coupling scientific knowledge to the practical operating problems of a Company that designs and builds a great variety of technical products. He has been a radio engineer, both in industry and the armed services (Legion of Merit for development of radar counter-measures); physics professor at Penn State and dean of its College of Chemistry and Physics; and a consulting engineer. With G.E. since 1954, he has been manager of its Electronics Laboratory, and general manager of the Defense Electronics Division. He was elected a vice president in 1958.

For complete information on opportunities for engineers at General Electric, write: Personalized Career Planning, General Electric Company, Section 699-09, Schenectady, N. Y. 12305

GROWTH THROUGH TECHNOLOGICAL CHANGE

The Role of R&D in Industry

Q. Dr. Haller, how does General Electric define that overworked term, Research and Development?

A. At General Electric we consider "R&D" to cover a whole spectrum of activities, ranging from basic scientific investigation for its own sake to the constant efforts of engineers in our manufacturing departments to improve their products—even in small ways. Somewhere in the middle of this range is an area we call simply "technology", the practical know-how that couples scientific knowledge with the engineering of products and services to meet customer needs.

Q. How is General Electric organized to do research and development?

A. Our Company has four broad product groups—Aerospace and Defense, Consumer, Electric Utility, and Industrial. Each group is divided into divisions, and each division into departments. The departments are like separate businesses, responsible for engineering their products and serving their markets. So one end of the R&D spectrum is clearly a department function—engineering and product design. At the other end is the Research Laboratory which performs both basic and applied research for the whole Company, and the Advanced Technology Laboratories which also works for the whole Company in the vital linking function of putting new knowledge to practical use.

Having centralized services of Research and Advanced Technology does not mean that divisions or departments cannot set up their own R&D operations, more or less specialized to their technical or market interests. There are many such laboratories; e.g., in electronics, nuclear power, space technology, polymer chemistry, jet engine technology, and so on.

Q. Doesn't such a variety of *kinds* of R&D hamper the Company's potential contribution? Don't you find yourselves stepping on each other's toes?

A. On the contrary! With a great many engineers and scientists working intensively on the problems they understand better than anyone else, we go ahead simultaneously on many fronts. Our total effort is broadened. Our central, Company-wide services in Research and Advanced Technology are enhanced by this variety of effort by individual departments.

Q. How is Advanced Technology Services organized?

A. There are three Advanced Technology Laboratories: Chemical and Materials Engineering, Electrical and Information Engineering, and Mechanical Engineering; and the Nuclear Materials and Propulsion Operation. The Laboratories do advanced technology work on their own, with Company funds, and on contract to product departments or outside customers and government agencies. NMPO works for the AEC and the military to develop materials and systems for high-temperature, high-power, low-weight nuclear reactors. ATS is the Company's communication and information center for disseminating new technologies. It also plans and develops potential new business areas for General Electric.

Q. So R&D at General Electric is the work of a great many men in a great many areas?

A. Of course. The world is going through a vast technological revolution—in the ways men can handle energy, materials, and information. Our knowledge is increasing exponentially. In the last five years we have spent more than half the money ever spent for research and development. To keep competitive, and to grow, industry must master that mountain of new knowledge and find ways to put it to practical use for mankind. Only by knowing his field well and keeping up with the rush of new developments, can the young engineer contribute to the growth of his industry—and society as a whole.

Progress Is Our Most Important Product

GENERAL ELECTRIC

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