DECEMBER 1966

ENGINEERING AND SCIENCE

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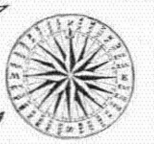
Go Westinghouse, Young Man!

A modern fable with technical overtones

Once there was a young college senior named Jack who wanted desperately to climb the beanstalk of success, facing the kind of challenges his forefathers faced on the frontiers of early America.



But Jack wasn't sure which kind of beanstalk he wanted to climb.

His mother wanted him to take a job at the local store so he'd be close to home.

His friends urged him to join a protest movement.

His professors wanted him to go on to graduate school.

Then Jack met a Mr. Greeley from Westinghouse. Mr. Greeley was a recruiter of college students. He was a kindly man with a warm smile, and he explained how Jack could get an advanced tuition-free degree while working at Westinghouse.

Mr. Greeley also explained that Westinghouse, being a giant organization, was in a much better position than most to undertake projects that would benefit the less fortunate peoples of the world.

Mr. Greeley's advice was:

"Go Westinghouse, young man!"

And Jack did.

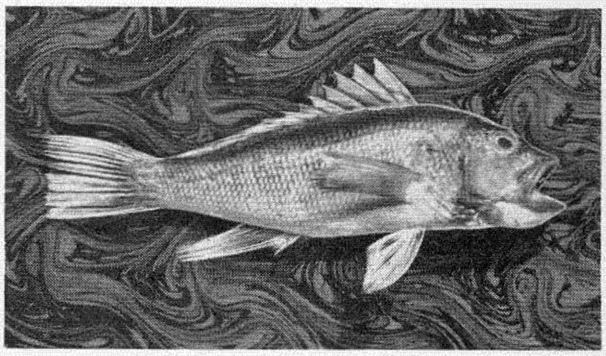
Given a choice of six large operating groups* within Westinghouse, Jack elected to join the Atomic, Defense and Space Group and was promptly assigned to work on an oceanographic project.

A fast learner, Jack took root quickly, reassuring his graying but still pleasant-faced mother, "Don't worry, Mom, I'm on my way to the top."

Though officially a trainee, Jack was a big help in the development of *Deepstar*—a Jules Verne-like underseas vehicle designed to explore the ocean depths. One of *Deepstar's* many missions was to search for food sources to meet the growing needs of a hungry world.

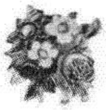
The project was an enormous success; Jack's management was delighted.

But before a grateful UNESCO could honor him publicly, Jack obtained a transfer to one of the many space projects Westinghouse coordinates.

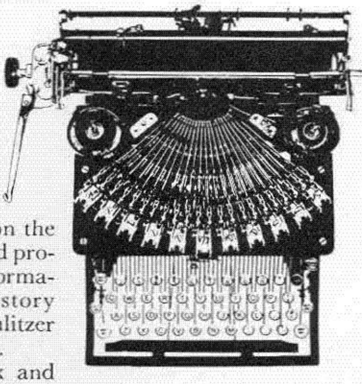


Jack's assignment: help develop a rendezvous system for Gemini capsules.

To the news publications of the nation, this was the story of the year. In fact, one of the big syndicates assigned their most beautiful, technically oriented woman reporter to get an exclusive story from Jack . . . at any cost.



One night while returning from work . . . Jack was accosted by the beautiful young newswoman, who suggested that Jack give her an exclusive bylined story describing the project in detail.



Though taken aback by her beauty, Jack never lost sight of his duty. He pleaded with the reporter to hold her story until after the launching. She agreed on the condition that Jack would provide her with enough information for a subsequent story that would win her a Pulitzer Prize for news reporting.

The pressure on Jack and his closely knit engineering team tightened. By day, they'd work on the space guidance system; by night, Jack would feed background information to the beautiful, technically oriented reporter. It was hard work, but it was important work.

Finally the day arrived for which the world had long waited. America's two capsules rendezvoused successfully. Mankind was now assured of a stairway to the stars.

While television-viewing millions rejoiced, Jack was as good as his word, offering the beautiful lady reporter the story she wanted so badly.

However, the girl, now smitten with Jack, turned her back on the Pulitzer Prize, preferring instead to join Westinghouse, attend its Advanced Education School and obtain a degree in engineering. (Women are welcome at Westinghouse, an equal opportunity employer.)

Now they both work at Westinghouse—while Jack designs atomic reactors for America's newest missile-firing submarines, his beautiful ex-reporter wife, an education specialist, helps train Peace Corps volunteers for overseas duty—and they're only a bean's throw from the neat white cottage they share with his mother.

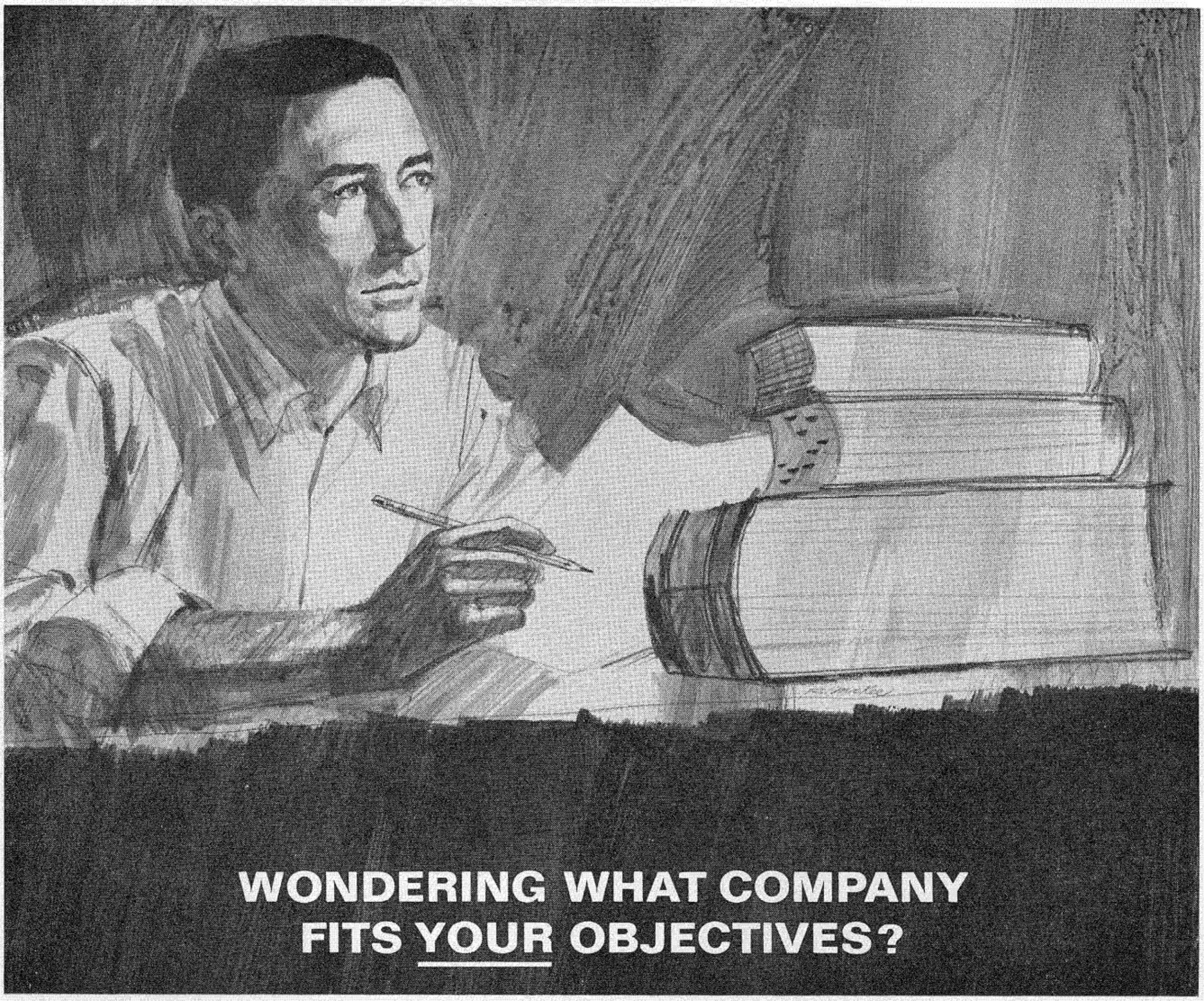
And they all lived happily ever after.

Moral: By planting your career seeds with Westinghouse, you, too, can climb the beanstalk of success, overcoming giant obstacles and earning a lot of golden rewards.

You can be sure if it's Westinghouse

For further information, contact the Mr. Greeley from Westinghouse who will be visiting your campus during the next few weeks or write: L. H. Noggle, Westinghouse Educational Center, Pittsburgh, Pennsylvania 15221.

*The Westinghouse Operating Groups: Consumer Products; Industrial; Construction; Electronic Components & Specialty Products; Atomic, Defense & Space; Electric Utility.



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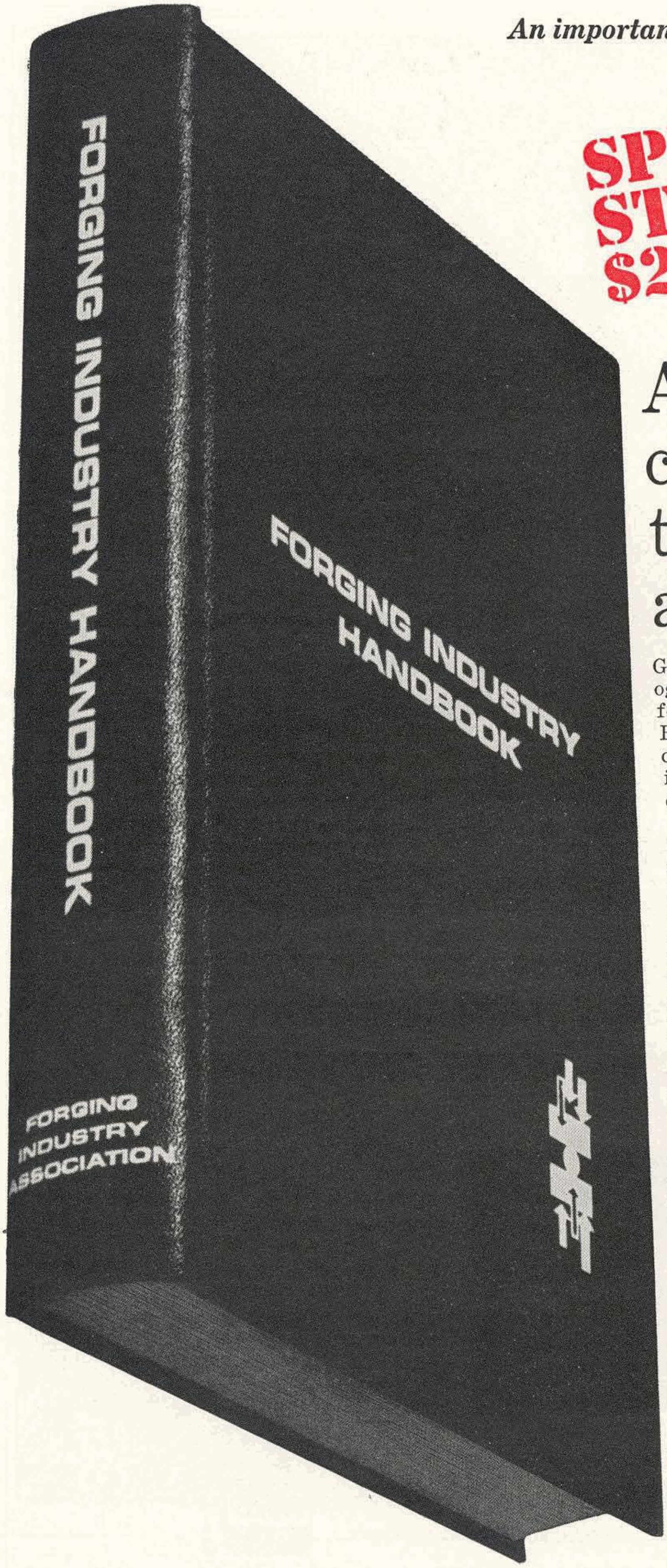

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COVER

President and Mrs. DuBridge take a curtain call with the cast of the faculty production, "Lee and Sympathy," in Beckman Auditorium on November 18—as the climax of a surprising evening arranged by the Caltech faculty to celebrate President DuBridge's 20th anniversary as president of the California Institute of Technology. Some highlights of this happy occasion are shown in the photographs on pages 16-17 of this issue.

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THE END OF THE BEGINNING

by Robert L. Sinsheimer

A few hundred miles from here on the towering cliffs of gorges in Utah and Arizona one can read hundreds of millions of years of earth's history. On that immense scale a foot represents the passage of perhaps a hundred thousand years; all of man's recorded history took place as an inch was deposited; all of organized science, a millimeter; all we know of genetics, a few tens of microns. At odds with our need for stability, prophecy often strains our credulity, but if we remember that scale, what vision can seem too long?

It seems to me to be peculiarly appropriate to our era to ask, in all seriousness, that scientists emerge from their laboratories to exercise their prophetic vision—to become responsible prophets to the people. It has become quite evident that the prime mover of the tides of change sweeping our society is the ever-widening impact of scientific discovery. Those who would, for better or worse, anticipate the future must needs ask those who live on the surging frontier of science what social institutions may next be inundated and what social bonds may next be strained, perhaps to rupture.

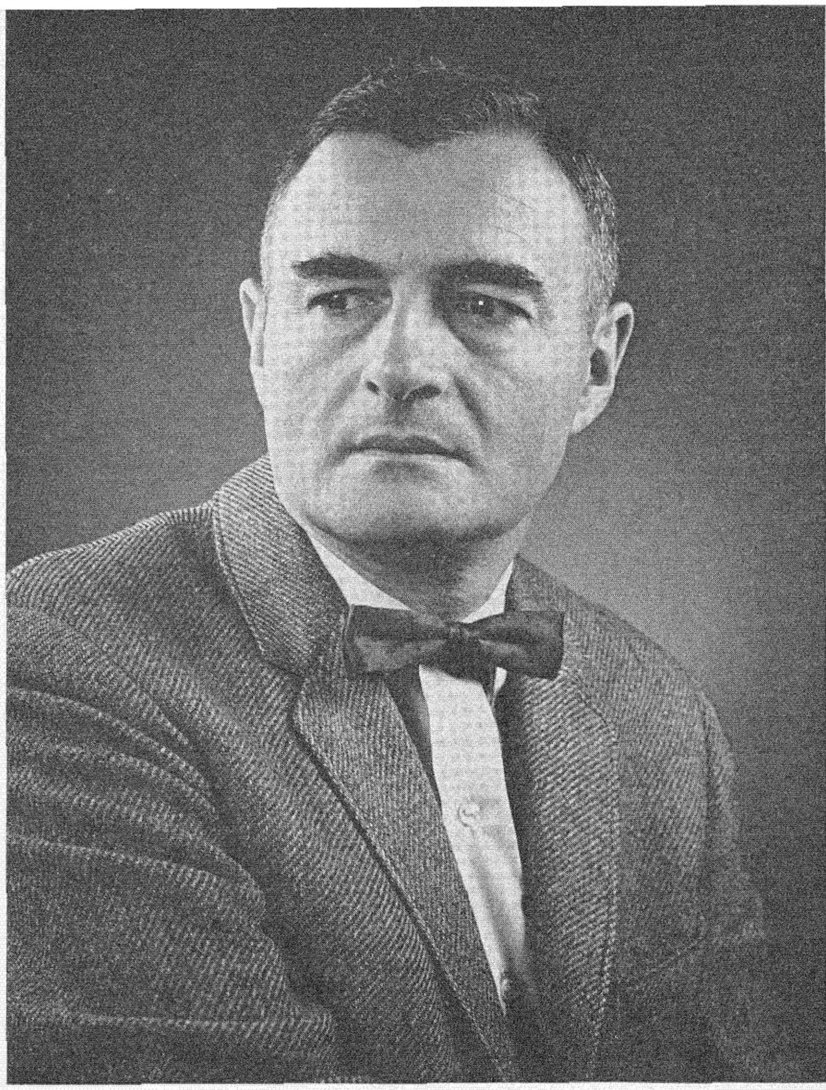
The ancient profession of prophecy has a long and not very honorable history. Over the centuries the hardware, if that is the right word, has changed—from entrails to crystal balls to electronic computers—but the percentage of success has remained quite dismal. Indeed, the very persistence of the profession can only be attributed on the one hand to a deep, if dark, belief in causality and on the other to the importance of the issues. Most of us have a conviction that the future will unfold in an orderly manner out of the present. Such a belief is inherent in our culture; it underlies all our morality. If a man could not possibly be aware of the consequence of his actions, what basis could there be for moral judgment? And an orderly nature equally is the basis of our science. Science could never cope with a universe of caprice.

The importance of this problem, of anticipation in a world of flux, is truly transcendent. The injustice and the suffering that might be mitigated had we but a modicum of reliable foresight—*and* the resolution to use it—are so cruel a burden that alone they can justify the persistence of a profession with such a historically low batting average.

In this regard the importance of prophecy—the moral necessity of anticipation—becomes ever greater as we move increasingly into a world of our own making. In our time we are moving out of a world we never made—but were biologically more or less adapted to—into, for better or worse, a world of our own creation, a world shaped increasingly by the motivations and limitations of man alone. We can, and must, and will, direct the form of that world, and how well we do must depend increasingly upon our ability to anticipate the consequences of our acts. The very mission of prophecy is changing from one of almost frivolous whimsy, the role of the gambler's mistress, to one of deep moral responsibility.

But urgency is seldom a substitute for capability. Granted the necessity, can we really hope to do any better than the many oracles of the past? The difficulty of anticipating the future lies first in obtaining a clear view of the present, and second in recognizing those trends that would permit a calculation of the changes to be expected. The one reason that does lead me to hope that *we* may be more successful than were our predecessors lies in my earlier premise—that *science* has become the prime mover of change in our society. For of all human endeavor science is the most open, and its pattern of development would seem the most rational. Some of you may be thinking that that's not saying a great deal, and in any case it is the impact of scientific discovery upon man and society that we must consider, and what of rationality there? But I do think that we can know, and know well, the present status of

"The End of the Beginning" has been adapted from a talk given by Robert L. Sinsheimer, professor of biophysics, at Caltech's 75th Anniversary Conference on October 26. The full proceedings of the Conference will be published in the spring.



Robert L. Sinsheimer, professor of biophysics.

a science; and we can make quite plausible predictions about the more immediate developments to come in and from it, and this is a long first step.

What consequences may we expect from the recent extraordinary advances in molecular biology? I would like to consider this question on three levels: first, the direct consequences that we may sensibly expect from the applications of this new knowledge to outstanding questions in biology and medicine; secondly, since any such major advance in knowledge changes the whole intellectual climate in which students learn and scientists think, some of the potential consequences of this change in the *Zeitgeist;* thirdly, the impact of these practical and intellectual changes upon our society

The dramatic advances in molecular biology of the past few decades have laid bare the essential molecular mechanics of inheritance, and of the processes of cellular function and control. They have led to the discovery of DNA, the agent and the repository of two billion years of evolution; and to the decipherment of the universal hereditary code, the age-old language of the living cell.

They have led to the determination of the complete three-dimensional architecture of a protein catalyst, a molecule composed of over two thousand atoms, and thereby to an understanding of how this enzyme performs its unique and specific functions. They have led to the analysis and the mapping of the molecular pathways of biochemistry, including the degradative paths that provide usable energy and the synthetic paths that provide the complex and specific macromolecules, so characteristic of and essential to life.

In so doing, a secure base has been laid for *further* advances in our understanding of development and physiology and pathology—a base that can only be compared in this century with that which quantum mechanics provided for the development of modern physics and chemistry. And with this understanding will come the potentiality for intervention and the intelligent control of processes that have known only the mindless discipline of natural selection for two billion years. What we understand we can alter or repair, extend or duplicate, or even translate into other media.

It is probably as difficult for us today to envision the possibilities that will be provided by our new understanding for the control of the biological world as it must have been for our ancestors a century ago to envision the consequences that their new knowledge would bring in our physical environment. For instance, what reception would have greeted the prediction in 1866 that within a century we would transmit telepictures instantly from Europe to California. The analogous predictions that we can make today only seem brash or absurd, or fatuous or fantastic, or even inhuman; but they are all visibly etched on the near horizon.

Consider the proteins of cells, which serve as the catalysts of all the manifold and necessary reactions therein. They are also the structural elements, as in skin and tendon and hair; the contractile elements in muscle; the clotting agent in blood; the detector of light in vision.

We now know how nature makes the vast variety of proteins. We can carry out the process—as yet relatively feebly—in the test tube. But we will learn to do as well as nature. And then the chemist's mind will begin, gently, to introduce modifications; and soon we will make proteins nature never conceived, proteins with new permutations, new amino acids, and perhaps wholly different monomers.

Now, of course, in two billion years nature, by simple selection, has become very skilled; and I do not presume that we will ever make, say, a cytochrome that will perform better in a human cell than does the one nature already provides. But we may make proteins to catalyze reactions nature never conceived, and we may make fibers to perform tasks that were never intended for natural fibers. And beyond the proteins we will make viruses in the test tube, and beyond the virus at some historic point we will make a self-reproducing cell—the second Genesis.

But before that day, as we understand life we can control life. This has been the historic pattern in physical sciences, and we have today a vast control of our physical environment. We will soon be acquiring a similar control of the biological world. Now the impact of science will strike straight home, for the biological world includes us.

How will you choose to intervene in the ancient designs of nature for man? Would you like to control the sex of your offspring? It will be as you wish. Would you like your son to be six feet tall? seven feet? What troubles you—allergy, obesity, arthritic pain? These will be easily handled. For cancer, diabetes, and phenylketonuria there will be genetic therapy. The appropriate DNA will be provided in the appropriate dose. Viral and microbial disease will be easily met. Even the timeless patterns of growth and maturity and aging will be subject to our design. We know of no intrinsic limits to the life span. How long would you like to live?

And in the end, after all these smaller steps to improve man's lot are taken, we may come to change man himself, his physique, his emotions, his intelligence, all of which are, in large part, the outcome of an inheritance pattern, which too can come under rational control. Not tomorrow. Perhaps not this century or the next. But it is only three centuries since Francis Bacon, and there are many centuries ahead.

In a sense, what I have been saying could have been said once Bacon projected his view of a world subject to rational laws that were comprehensible to man—if only he would approach nature with an open mind and with an unending reference to experiment as the source of truth. Or it could have been said once Mendel showed that the seeming complexity of inheritance could be rationally explained with a few assumptions concerning dual sets of genetic factors. But until now the means were mysterious—and doubt spawns in mystery. Now we have translated those genetic factors into physical entities, and the whole power of physical science is at our call.

These advances have also changed importantly the way man looks at life in the universe and at himself in nature. The kinship of man to the rest of the living world was, of course, demonstrated by Darwin a century ago; but it has now—in the universality of the hereditary code and in the detailed structure of common proteins—been documented anew on the most basic level and over a far wider range. For our molecules disclose our relation to life forms to which all superficial resemblance was lost countless aeons ago.

"In our time we are moving out of
a world we never made . . .
into, for better or for worse,
a world of our own creation."

Thus man becomes ever more surely a part of life, and in the process life has become ever more surely an integral part of nature. As we have penetrated the processes of the living cell, as the domains of mystery have receded, it has become ever more clear that all the properties of life can be understood to be simply inherent in the material properties of the complex molecules which comprise a cell. And thus that seemingly qualitative gap—self-evident to the most naive—between the living and the non-living has in our time been bridged. Life is but a property of matter in a certain state of organization, and, given an organization which can reproduce itself, then adaptation and natural selection and, consequently, evolution will be just as inevitable a process as is the action of the second law of thermodynamics.

It is then most natural, at least in the flush of our enthusiasm, to suppose that the same is true of the other great mysteries of biology, to suppose that the seemingly magic process of development—the growth of a man from a single fertilized cell—is also but a material consequence of the molecular organization of that cell. Indeed, it may be supposed that even the deepest mystery, the nature of mind and sensation and consciousness, will be understood in the end as a natural consequence of matter in a certain state of organization.

I do not pretend to understand how to bridge the seeming gap between matter and conscious sensation; but I suggest that having bridged one seemingly qualitative gap will give confidence to those who will bridge the next. In time we will come to understand the molecular and organizational basis of memory and emotion and intellect, and we will comprehend the strange spectrum of sensations and the dimensions of consciousness.

We must ask what the impact of these changes will be upon society—and vice versa—for there is an interaction between science and society. The prospect is awesome in its potential for deliverance or, equally, for disaster.

Much of the structure of our society is very naturally determined by the biological aspects of man. Indeed this state is so natural, and the boundary conditions of our society are so interwoven with the biology of man, that it is often difficult to dissociate them and to see the changes that will become necessary as we change our biology. The life span of man—the size, the sexuality, the diseases, the hunger, the intellectual range and capacity of man, the simple density of man on this planet: these factors do form and underlie our society. And as these change—and the changes have already begun—so must our social structures and our ways of life.

Even some of the most elementary, in the scientific sense, of these prospects, such as the control of progeny gender, will send shock waves through our society. We have throughout history relied upon nature to provide essentially equal numbers of men and women. Shall we continue this ratio? And if not, how shall we arrange it when the choice is ours? When this prospect is combined with the already pressing problem of the expanding world population, it seems ever more clear that in the future world the right to give birth to life, as is today the right to take life, will have to be controlled to preserve some semblance of balance. But how this will be achieved, I do not know. It merits much thought.

Likewise, even modest changes in the life span of man—say a factor of two—would rack our social structure almost beyond recognition.

Eventually we will surely come to the time when man will have the power to alter, specifically and consciously, his very genes. *This* will be a new event in the universe. No longer need nature wait for the chance mutation and the slow process of selection. Intelligence can be applied to evolution.

How might we like to change our genes? Perhaps we would like to alter the uneasy balance of our emotions. Could we be less warlike, more self-confident, more serene? Perhaps. Perhaps we shall finally achieve these long-sought goals with techniques far superior to those with which we have had to make do for many centuries.

Most likely we would like to improve our intellectual facilities. Presumably this can be done. Even nature has had only a limited experience in the evolution of intelligence. It can hardly be thought to have achieved perfection. When cerebral mechanisms are understood, they can doubtless be improved and rearranged—if one thinks this is more desirable than duplicating the process with faster and less expensive transistors.

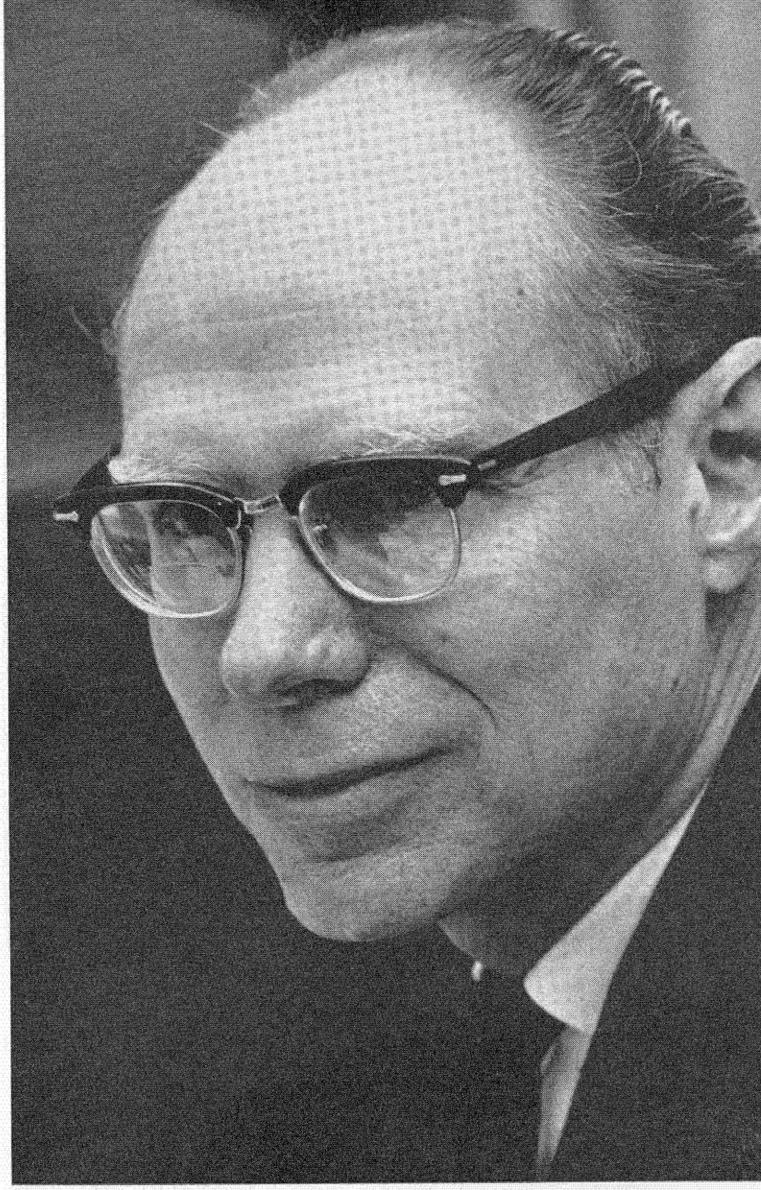
One may wonder if a brain can really act to improve itself. I think so—within limits. The modes of improvement that the brain can conceive are doubtless limited by its own patterns of thought. Wholly different thought processes might be possible that it could never envision, and this raises a venerable question. Can we *really* change anything? Are we not the prisoners of our nature and our culture—merely passengers on a fantastic streetcar named evolution? Can there be—as I have implied—a free will for a species? I do not know, nor do I think we can know—certainly not now, and perhaps never. Man is psychologically the most plastic, least programmed animal; and by coincidence or by design he is self-aware. Thus he knows conflict, and thus he knows hope.

There are those who will be concerned with the ethics of the potential modification of man, yet it seems to me this issue poses a quandary that is beyond ethics. The foundation of ethics is foresight. It is our ability to forecast the consequences of our actions that engenders our responsibility for them. But how can we possibly predict the ultimate consequence of our alteration of ourselves? Each small step will lead inexorably to another, in a cumulative, positive feedback mechanism to patterns of life and forms of knowledge and even systems of thought beyond our scope. We will have need of hope.

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

Alfred Whitehead said, "The art of progress is to preserve order amid change and to preserve change amid order." We must, I believe, devote much more thought to the achievement of that balance in a world always impelled toward change by the anguish of the human condition, and always inclined to disorder by the mindless flux of statistical law. We must ask that the changes we introduce be orderly and with humanity aforethought. At Caltech, and in all of science we have been, in a sense, children, spewing change into society with scant thought for the consequence. We in science are growing up now. Our toys become more potent. The little games we play with nature are for great stakes, and their outcome moves the whole social structure. We must accept our responsibility.

COMMUNICATION – OUTLOOK FOR THE FUTURE



by John R. Pierce

Modern electronic inventions have profoundly altered our lives, but in one way they have not altered the way in which we live. Today's child accepts the telephone and television with the same sense of familiarity and lack of understanding that earlier generations accorded natural phenomena. We do not need to know the physical basis of telephony in order to use a telephone any more than we need to understand the biological intricacies of a horse in order to ride one.

This sort of understanding is powerful in our world, but it is rare in connection with any common thing that is not a product of science and technology. For example, even though men have studied languages for centuries, we understand very little about language. In contrast, everyone uses television sets and telephones, and a few people do understand them deeply.

Science and technology inject into our environment an increasing part that is inherently understandable and controllable. To this we adapt, behaviorally, linguistically, and in attitude, in the old mysterious way in which man has always managed to live. In so doing we acquire new needs and new standards. A society that functioned well in the absence of telephones, automobiles, and electric power is replaced by a society that would collapse without them.

Communication is a particularly apt field in which to discuss and illustrate the impact, actual and potential, of the understanding of science and power of technology on society. Electrical communication has changed our lives profoundly within the span of our memories. Further, electrical communication clearly exemplifies the applicability and power of science. And it illustrates as no other field can the range from the comparatively simple, exemplified by the local broadcasting station and the

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This article has been adapted from the talk given by John R. Pierce at Caltech's 75th Anniversary Conference on October 25. Dr. Pierce is research director of the Bell Telephone Laboratories. A Caltech graduate ('33, MS '34, PhD '36), he was one of 23 alumni who were presented with distinguished service awards at the 75th Anniversary.

home receiver, to the incredibly complicated and interdependent, exemplified in common-carrier communication systems.

This division between the technologically simple and the technologically complex reflects a difference in the purpose and function of mass communication, such as television, and the purpose and function of personal communication, such as telephony. Mass communication is necessarily aimed at majorities or large minorities. It is one-way; it is aimed from the few to the many. It is a unifying and conservative element in our society. As such, its effects have been tremendous.

We are rapidly approaching a society without "sticks" or "boondocks," except those which are growing in the central slums of metropolitan areas. Television brings, into the remotest home, launchings from Cape Kennedy, sports from all parts of the continent, even (via satellite) live events from across the ocean, and a nationally uniform brand of music, comedy, and soap opera.

In the face of television it is difficult for differences of dialect, of interest, or of attitude to persist. This makes television the greatest unifying force ever to act upon man. A voice and a picture on television may not yet be able to tell us what to think about a matter, but they very effectively decide what we will be thinking about, and that may be as remote physically as the war in Vietnam.

The impact of the telephone and other common-carrier communications is quite different from that of mass communication. The telephone is inherently the tool of the individual, not of the majority, or the society. It is the means by which we conduct the business of life—ordering groceries, calling the doctor, making appointments and reservations.

Unlike mass communications, which could have a profound impact on even a primitive society, the telephone is inherently a part of a way of life which has been shaped by automobiles, airplanes, electric power, standardized uniform merchandise, and a pattern of credit—and especially by the telephone itself. We use the telephone because we have come to have interests that lie beyond the home, the family, and the neighborhood. It seems to me that, except for some government and business usage, a telephone system would have little immediate impact or value in a primitive society.

But how did these revolutionary powers of communication come into being? Their source is discovery and invention. Discovery and invention may or may not meet the needs of society; in fact, needs are as often created as satisfied by them.

I am sure that, when Alexander Graham Bell invented the telephone, what common-carrier communication felt it *really* needed was better multiplex telegraphy, and perhaps practical automatic telegraphy. In fact, Bell was working on a new kind of multiplex telegraph—the harmonic telegraph—when he invented the telephone. What the world got through this invention was a revolutionary system of communication which has swamped the telegram, and indeed the letter, as a means of interpersonal communication.

De Forest was seeking a detector for wireless telegraphy when he invented the vacuum tube. The invention led to worldwide telephony and to radio broadcasting. Television languished as an interesting idea for years until science and technology gave us an advanced electronic art and Zworykin invented the iconoscope. Babbage tried to make a well-thought-out and sophisticated computer in the nineteenth century and failed. The computer was reinvented and easily realized, using the art supplied by telephone switching, by Aiken and Stibitz around 1940. The vacuum tube made it possible for Eckert and Mauchly to make a fast electronic calculator. Von Neumann provided the stored program. And the transistor made the computer economical, reliable, and profitable.

If discovery and invention have been so vital in the revolutionary effect which communication has already had on our lives, what may they do to and for us in the future? What, for instance, may we expect from advances in mass communication? For one thing, we expect its effective extension into lands with less advanced communication technology. Already, the transistor radio has provided a direct link between otherwise isolated people and their central governments. Even the Bedouin on his camel can hear that he is part of a nation and learn of its problems and aspirations.

A television receiver is expensive and complicated compared with a transistor radio, but I believe that communication satellites may make television available in undeveloped countries. It is at present impractical to broadcast from a satellite directly to a standard television receiver; the power required is too large, and such broadcasting may remain impractical for a considerable period. It is practical, however, to launch a satellite which will send out a signal with a few hundred watts power; in fact, the Soviet Union has done this. A ground station costing only a few thousand dollars could receive television signals from such a satellite. The received signals could be carried for short distances by cable or could be distributed in local areas by means of cheap, low-power transmitters.

Thus, by means of an entirely feasible communication satellite, television could be transmitted from the capital of a nation to many towns and villages, where it could be viewed in schools or other public buildings. The cost of such a satellite television distribution system would be considerable, but so are other vital government expenses—those for defense and education, for example. The impact could be tremendous.

Consider Nigeria as an example, a nation of over 50 million people which has established English as the language of its schools. Nationwide television could be of tremendous value there as a motivation for learning English, as a means for establishing and maintaining a standard English, and as a means for making nationhood meaningful and desirable to the population. I believe that television of this sort would be almost equally valuable in far more advanced nations, such as India and China.

Space technology has advanced to a point where satellites may be very economical for domestic communication. But we already have adequate domestic network facilities, and satellites could not make television different for us, but only cheaper to distribute. Indeed, the popular revolution in television distribution now under way is in quite the opposite direction; that is, wired distribution provided by CATV (community antenna television) services, instead of distribution by radio.

CATV was initially established to provide television to remote or shadowed areas where the direct signal is inadequate. Signals from a hilltop antenna were amplified and distributed by cables, which themselves have amplifiers at regular intervals. It was found that subscribers were anxious to pay a few dollars a month for an adequate TV signal, even in cities where a fair, but inferior, signal can be obtained from a rooftop antenna.

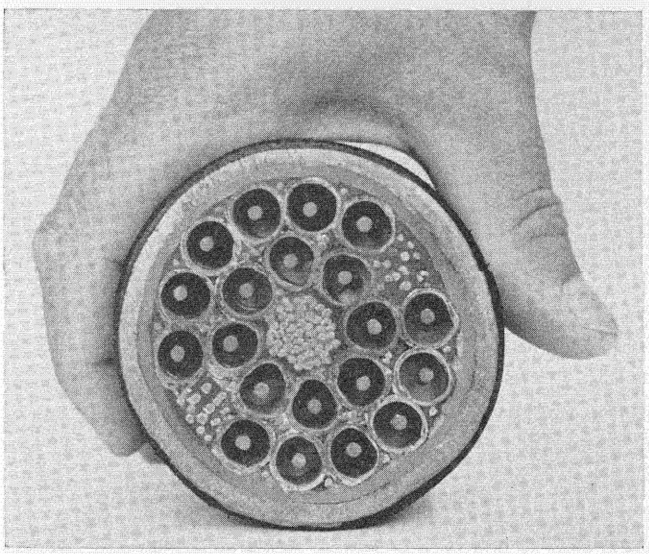
But CATV has another potentiality as well. Through importation of signals from a distance, it can provide any community with as many channels as are available to the residents of Los Angeles or New York. Here indeed is the ultimate in the abolition of the "sticks" and "boondocks."

CATV seems to be a tremendous advance, a real wave of the future compared with anything else on the television horizon. If it survives, it may help to bring about another long-time dream, the delivery of newspapers to homes by wire, though at least two problems must be overcome if this is to succeed. The smaller of these problems is economical broadband transmission. An extra channel on a CATV network could provide this. The other problem is that of the bulk of a newspaper. People *want* big papers, and especially papers with lots of advertisements. But they wouldn't want to have these spew out, unfolded, onto the living room floor, and they wouldn't want to have rolls of newsprint delivered and stored away in their homes. However, a microfilm newspaper might be acceptable. Its success would depend on an economical, convenient, high resolution viewing device and on some practical way of recording images with microfilm resolution. Conventional photography, and even the Land Camera process, seem inadequate. Perhaps science will provide an answer.

If it does, the impact could be tremendous. Experience shows that people want local news and local advertisements in newspapers, as well as national news and national advertisements. In a newspaper distributed by wire, it would seem practical to tailor some news and advertisements to neighborhoods if that proved profitable. Indeed, to some degree, mass communications might be nearly individualized in this process. Television could remain the truly national unifying force that it is.

In the case of individual communication, exemplified by the use of the telephone in our business and private lives, the revolution I foresee will be based on various specific advances which will make cheaper both transmission and the station equipment at the ends of transmission circuits. The cost of transmission goes down as we send more signals over a given path. We can send more signals by providing transmission paths of greater bandwidth.

Today we have advanced far beyond the era in which one pair of wires carried one voice signal. A digital transmission system called T1 can send 24 two-way telephone channels or 1.5 million data bits per second over two pairs of wires in cables. The L4 system sends 3,600 telephone conversations one way over a single "pipe" in a coaxial



This 20-tube coaxial cable handles more than 30,000 voice channels simultaneously.

cable, and there are 20 such pipes in the cable. A microwave transmission route can accommodate as many as 12,000 telephone channels.

What have science and technology provided which will enable us to send large bundles of channels economically? There are several things in immediate prospect, the simplest of which is a potential revolution in microwave systems. The extension of the operation of solid state devices into the microwave range has made it possible to build microwave repeaters of extremely high reliability and extremely low power consumption. Thus, it is possible to build small, cheap, trouble-free repeaters and to power them economically. Perhaps this will lead to use of microwave repeaters spaced frequently along roads rather than on remote hilltops.

The same advances in electronics, together with boosters of the power of the Titan III, have made it immediately practical to launch communication satellites which could supply as many as 100,000 telephone circuits between, say, 5 to 10 principal cities in the United States. Such a satellite system could be established in a few years, and it could in this short time substantially increase the number of long distance circuits available in this country. Further, in concert with terrestrial facilities, the satellite could incorporate switching equipment which would transfer blocks of circuits from one pair of cities to another in meeting fluctuations of demand.

Further in the future, we can see that it will become technologically possible to provide circuits of almost unlimited bandwidth by means of the coherent light generated by lasers. We have suitable lasers. We have, in lenses consisting of gas flowing through alternately hot and cold regions, a means for guiding light through buried pipes. We have modulators for impressing signals on the light and detectors for translating the received light signals into electric current, but we are not yet able to build a useful laser communication system.

We could have new types of microwave systems, satellite systems with a capacity of over 100,000 telephone circuits, and millimeter waveguide systems at any time by deciding to go ahead and by spending the money. In the case of optical transmission, we need more research and experience.

Integrated circuits, or microelectronics, will make it possible to produce a complicated circuit almost as cheaply as a transistor. The circuit configuration is impressed, hundreds at a time, on the surface of a wafer of silicon, and aside from this, the steps in production are essentially those required in making single devices.

This means that it will be possible at a low cost to put very complicated yet highly reliable electronic equipment—as complicated as a very small digital computer—almost anywhere; in your telephone set, in your car, or even in your pocket. What this may do in providing all sorts of new services staggers, indeed paralyzes, my imagination. What we will do with these tools I don't fully know. But I feel that we can describe the impact in general terms.

Initially, in primitive electrical communication, we dealt with two apparently distinct inventions. One of these was the telegraph, which communicated by on-off signals that produced audible clicks. The other early invention was the telephone of Alexander Graham Bell, which transmitted, over a limited distance and faintly, the sound of the human voice.

If we look at the nervous system of man, we find no such distinction. The nerve impulses that travel from our fingers to our brain in using the sense of touch, from the eyes to the brain in enabling us to see, and from the ear to the brain enabling us to hear are all the same distinct, spikelike electric signals. They do not differ at all in quality. There is a uniform medium through which all our senses serve us. The same spikelike pulses are used to control the hands that we use in writing and to control the muscles that we use in speaking.

As the arts of telephony and telegraphy advanced, the distinction between them became vague. Telegraph signals were multiplexed, or transmitted many at a time, over telephone lines in much the way that Alexander Graham Bell had envisioned in his work on the harmonic telegraph. Finally, it became clear that telephone signals could be transmitted by off-on impulses, by a method which we call PCM or pulse code modulation. PCM is now coming into increasing use in the telephone system. It was not, however, until 1948 that Claude Shannon gave in his mathematical theory of communication a broad, coherent, and useful theory of the process of communication which includes the telephone, the telegraph, and all other means of communication.

Through advances in technology and through the understanding provided by Shannon's work, we are now achieving in electrical communication, both conceptually and practically, something approaching the universality that has been built into the communicating senses of man since before the time he learned to talk and write.

We can expect that in the future there will be many new signals and many new uses of communication. Whatever these may be, we can be sure of two things: modern electrical communication networks will be adaptable to the transmission of all of them, and Shannon's general theory will be a common measure and tool for studying and relating all these forms of communication.

What will these new forms of communication be? I have already mentioned the possibility of greatly improved mobile telephony, such as a phone in every car and even telephones in the pocket. But future communications will embrace much more than voice. The Bell System is engaged in a determined effort to introduce person-to-person television on a large scale. Facsimile may have an increasing use for business and library purposes. Even telewriting may find its place in connection with conferences and lectures convened through electrical communication rather than physical travel.

In conferences, as in a two-party communication, we will want to make data available and to send letters and reports by means of data transmission. I believe that within a few years virtually all business records and correspondence will be put into machine-readable form when first typed. If this is done, it will be possible to send text from office to office as easily as making a telephone call.

Further, computers can index and search machine-readable material. Computers can be used in editing and correcting text without complete retyping; they can even be used to a degree in proofreading. From a corrected machine-readable copy, computers can automatically produce printed material, correctly paginated and with justified lines. They can also construct charts, graphs, and line drawings and insert them at specified points in the text. Thus, computers will take care of a great deal of office drudgery.

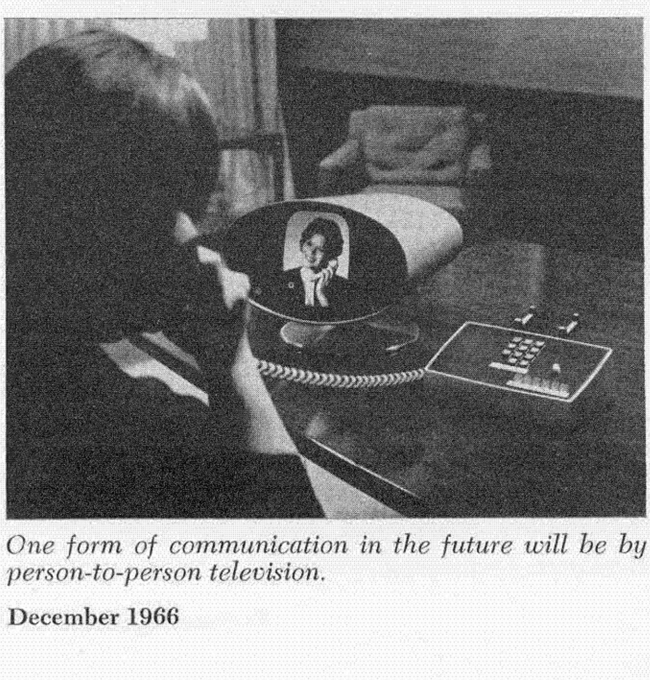
By means of electrical communication, offices will be linked to other offices, to files, to reproduction facilities, and to other resources. This linkage will extend through other business activities as well. The TOUCH-TONER telephone set generates signals that (unlike dial pulses) can travel over any voice circuit, even to the farthest corners of the world. Thus, the system can be used to query computers or to control machinery wherever the telephone can reach. This is already in limited use in banking and merchandising.

If one can query a computer from any telephone, how can the computer reply? It can reply in spoken words. At present, such words are recorded words, but voice recording is an inefficient means of information storage alien to the digital computer. There are fair prospects that computers will eventually be able to read aloud intelligibly from phonetically spelled data stored in their memories and even transcribe between ordinary text and phonetically spelled text.

In the future we may be able to query any number of information sources from a distance about weather, hotels, stores, sports, theatres, or other matters and receive voice replies tailored to our specific queries. We may even make such queries via a keyboard in simple English. As the computer will be able to respond to simple, unambiguous queries only, it will sometimes fail to undertsand or misunderstand. If it replies amiss, or says that it didn't understand the query, we will be able to try again, perhaps in words suggested by the computer. We can use our own intelligence to overcome the stupidity of computers and the accuracy and speed of the computer to supplement our slow and fallible mental processes.

In the future, science and technology, following the trend toward generalization, will increase the capacity of our common-carrier communication network to provide all sorts of communication over the same channels. Microelectronics and other advances will provide terminal equipment or transducers which will link this network to all our senses and to a growing variety of uses. What this will do to our life I can only guess.

The certainty is that science provides an understanding which is alien to everyday life. We understand a little in this way, but that little is extremely powerful. Through research and development, this understanding has so altered our environment that we live lives which are essentially different from those of earlier generations. The man who lives successfully in the world of the future need not understand that world in the scientific sense, but it is the understanding of science which is bringing that world into being.



One form of communication in the future will be by person-to-person television.

President DuBridge is surprised by 550 intimate friends. Mrs. DuBridge produces smelling salts.

SURPRISE PARTY

President and Mrs. DuBridge joined a few close friends for a quiet dinner at the Huntington Hotel on November 18—and found the whole Caltech faculty waiting for them when they arrived. As an added surprise, the DuBridges' son and daughter were on hand for the celebration. The occasion: Dr. DuBridge's 20th anniversary as president of the California Institute of Technology.

Arnold O. Beckman, chairman of the Caltech board of trustees, presented Dr. DuBridge with a special anniversary gift from the trustees, a DuBridge family favorite for special occasions—homemade chocolate pie. The evening ended with a musical extravaganza, "Lee and Sympathy," produced by J. Kent Clark, professor of English, in Beckman Auditorium.

A toast by the faculty—to the DuBridge years.

An added surprise: son Richard.

President DuBridge receives a service pin "suitable to the stature of the recipient."

Robert A. Millikan, Chairman of the Executive Council of the new California Institute of Technology.

THE ROOTS OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY III

by Imra W. Buwalda

In 1913 Throop officially recognized its new status as a college by adopting the name Throop College of Technology, and the trustees were now ready to build their "first-rate technical school" into a world center of scientific research and instruction.

Throop made its first giant step toward this ambitious program when George Ellery Hale brought to its faculty the distinguished chemist Arthur Amos Noyes. Noyes, vice president and former acting president of MIT, agreed to come to Throop as professor of general chemistry from February 1 to March 31, 1914, and to act at all times as consultant in the development of teaching and research in chemistry. Beginning in 1916, Noyes extended his time at Throop to half a year and became director of chemical research.

This is the last in a series of articles on the early history of Caltech, adapted and edited by Elizabeth K. Hutchings from a manuscript by Mrs. Buwalda.

In 1916-17 a $100,000 fund for physical research was provided, and again Hale sought out the country's top man in his field to develop the program. In January 1917, Robert A. Millikan agreed to spend three months each year at Throop to work in cooperation with Noyes in chemistry and Hale in astrophysics. President Scherer told his trustees that the three men would unite in an attack on problems of the electron theory.

The need for buildings to accommodate its expanding research program and its growing student body was Throop's greatest concern in the years preceding World War I. The 22-acre campus still had only one building—crowded Pasadena Hall.

During the summer of 1915, Throop's board of trustees appointed the famous architect Bertram C. Goodhue to supervise all future campus development. Goodhue replaced Myron Hunt, who had fought, and largely lost, epic battles with Scherer and Fleming over the design and construction of

Throop College pauses for the war years, then surges ahead as the California Institute of Technology.

Pasadena Hall. In 1915 P. G. and C. W. Gates donated funds for a new chemistry building to be designed by architect Elmer Gray.

But there was still no housing for students. The trustees solved this problem by having the old North Los Robles dormitory sawed into seven parts, hauled to the new campus, and put together again. The trustees voted $25 for paint with which students covered the scars of the cuts, and the "Old Dorm" opened in the fall of 1916 with rooms for 60 students and a lunchroom, known for decades as the "Greasy Spoon."

Throop's plans for expansion were temporarily halted by World War I, when the faculty, administration, and trustees gave most of their time to the war effort, and the campus became a military training center.

Hale led in the founding of the National Research Council, formed to mobilize the nation's scientific resources for preparedness. He served as chairman of the Council's five-man organizing committee, which included Robert A. Millikan and Arthur A. Noyes. Millikan became its vice chairman and executive officer and in this capacity spent the war years in Washington.

The role played by Hale, Noyes, and Millikan in founding the National Research Council led to a unique role for Throop College in the wartime research program of the Council. At the June 5, 1916, meeting of the trustees, Hale offered Throop the opportunity to be first in the country to "aid the government in research for defense," the aid proposed being the use of the college laboratories and provision of a special endowment.

Throop's response was such that the Council sent a letter to a "selected list of educational institutions with a view to the stimulation of interest in research," citing Throop as a "concrete illustration of what can be done."

The letter enumerated specific steps Throop had taken in connection with the work of the Council, including its promise of all available research men and facilities in the event of war, the establishment of a wind tunnel and aerodynamics laboratory, and cooperative physical, chemical, and astronomical research under Millikan, Noyes, and Hale.

Research in aeronautics at Throop was established in 1917 at the suggestion of the National Research Council. Trustee Tod Ford donated funds for the construction of a small wind tunnel with a maximum velocity of 40 miles per hour.

In cooperation with the Mt. Wilson Solar Observatory and Stanford University, a war laboratory was erected at a cost of $4,500 to study problems of supersound and of nitrate supply, and a laboratory for research in submarine detection was established. Both of these programs were conducted under the direction of the National Research Council.

On April 22, 1916, President Scherer announced at a student assembly that Throop would introduce military training, on a voluntary basis, the following September. A petition signed by 80 percent of the students requested that the program be made compulsory. The Throop College Battalion, established in the fall of 1916, became the first ROTC unit in southern California and the first for engineers in the country.

The Camp Throop project came next in a series of military training programs. The idea of establishing an official training camp in southern California, as a "subsidiary to the Army's Presidio" in San Francisco, was conceived by the Military Training Camps Association. On April 3, 1917, the trustees voted to provide facilities for "intensive training for officers with the understanding that this would not involve additional expense to the college, or interference with the regular college work."

Camp Throop was made ready with incredible speed. The college cleared all the orange trees from the campus (a move which resulted in considerable loss of revenue), and Throop engineers ran all the survey lines. By May 4 the Los Angeles *Examiner* reported that:

> . . mess tents, headquarters tents, the post office and camp exchange tents are erected and scores of men are busy at work . . . laying out the streets and locations for the company tents which are expected to be here tomorrow.

By May 7 water and sewer lines were laid and, according to the *Star-News* of that date:

> Several truck loads of lumber were delivered yesterday to make the cook house, while the mess tent, as large as the ordinary circus tent, is already in place in rear of the company streets. These streets are made of eighty regulation size pyramid tents made in Los

continued on page 22

NEWS for

1966 1967

ENGINEERING GRADUATES

The Roots . . . *continued*

Angeles for the camp . . . 15 tons of straw to fill bed sacks have been delivered . . .

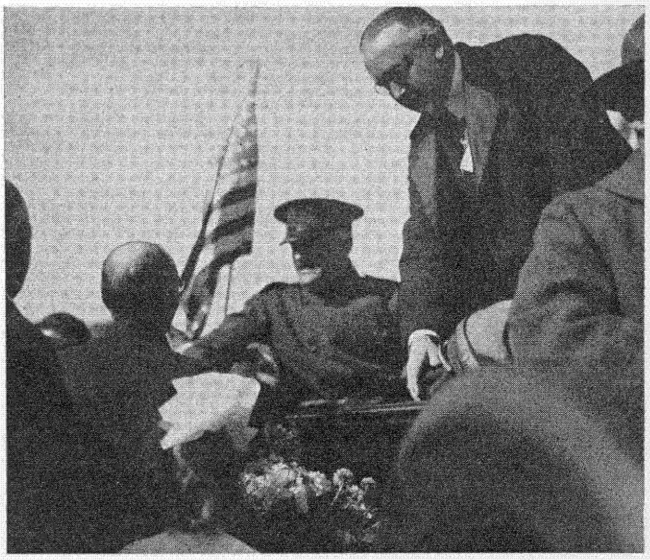
Extensive off-campus training was also planned. A headline in the Los Angeles *Express*, May 8, 1917, reported:

TRENCH FIGHTING TO BE FEATURE AT THROOP
MEN TO LIVE, EAT AND SLEEP LIKE SOLDIERS
"SOMEWHERE IN FRANCE"

About 2500 acres of land, south and east of Camp Throop and extending down as far as Wilson's Lake have been placed at the disposal of the camp by Henry E. Huntington, William R. Staats and Company, and the Oak Knoll Company . . . This acreage will be converted . . . into a European battlefield, complete with trenches, fortifications, miniature rivers, and every device possible to give the men in training a conception of warfare as it is to be.

The Camp Throop project collapsed completely, however, one week before its opening date. On May 11 the War Department announced that it could not furnish instructors, arms, or equipment to any camps but its own. Although the department expressed the hope that the camp would go ahead with whatever equipment the school could supply, both the Military Training Camps Association and Throop College agreed to abandon the costly and frustrating project.

In the autumn of 1918 Throop College started training enlisted men in the nationwide Students Army Training Corps program. Under the SATC, in which 500 colleges participated, all students over 18 became "enlisted members of the military forces." A mess hall and barracks to accommodate 300 men were erected on campus, and on October 1, 1918, the Throop College unit of the SATC officially began operations.



General Pershing tours campus with President Scherer.

Then came the Spanish influenza epidemic. In an attempt to prevent its spread, all furloughs were cancelled, and the students were confined to the camp. The first floor of the Old Dorm became the hospital where ladies from the Red Cross cared for the desperately ill boys.

Royal Sorensen, professor of electrical engineering, recalling the epidemic, wrote that "during mass quarantine, daytime activity and all business of soldiering went on at full tilt. But what could be done at night for recreation? The only club or entertainment room was a huge tent provided by the college YMCA. This became, for three nights of the week, a movie theatre operated by an engineering professor who passed the hat after each movie in order to rent another film."

"The most conspicuous countermeasure in the flu combat," Sorensen also wrote, "was the gauze flu-mask which, by order through the land, was a demand regulation . . . To be seen off limits (the home) without a mask was cause for arrest. We were a spooky-looking, disgruntled lot, for though everyone feared to be without a mask, there was an almost universal opinion the masks were just a damned nuisance and wholly ineffective. On November 11, 1918, when the sudden clamor of bells, horns, and whistles announced the signing of the Armistice, most of Pasadena headed for Marengo and Colorado Streets to join the unorganized but orderly parade which continued for hours. Some had their masks as required by law, but they were off the face hanging by a loop over one ear. Most people had forgotten their masks."

The Student Army Training Corps program was not considered successful by either the administration or students at Throop. "There was grave disorganization," Scherer wrote in his 1919 annual report, "due to the constant influx of confused and confusing orders from Washington—further accentuated by an epidemic of influenza . . . My opinion of the SATC as a whole is emphatically unfavorable." A student editorial in the *Throop Tech* called "the plan of attempting to train soldiers and students simultaneously . . . one that could not possibly succeed . . ."

The winter following the Armistice was a difficult time for Throop, now faced with the enormous job of "retooling" for peace as quickly as possible. By 1919 Throop's student body numbered 340, as compared to 31 in 1910 and 185 in 1916, and new buildings were badly needed. Furthermore, the board's new policy of increased emphasis on research had to be implemented. Because the flu epidemic, though past its peak, was not over, classes were suspended from January 18 to February 3, 1919.

President Scherer, exhausted both physically and mentally by the stresses of the war years, requested a leave of absence from February to September 1919. He had plunged enthusiastically into war service as early as the spring of 1916. In the spring of 1918 Scherer publicly protested what he felt to be the anti-Japanese editorials of the Hearst newspapers. When he was mildly rebuked by Secretary of War Newton Baker for this open criticism of Hearst policy, he resigned from the Council of National Defense. He then became field representative of the United States Emergency Fleet Corporation until the autumn of 1918 when he returned full time to Throop College.

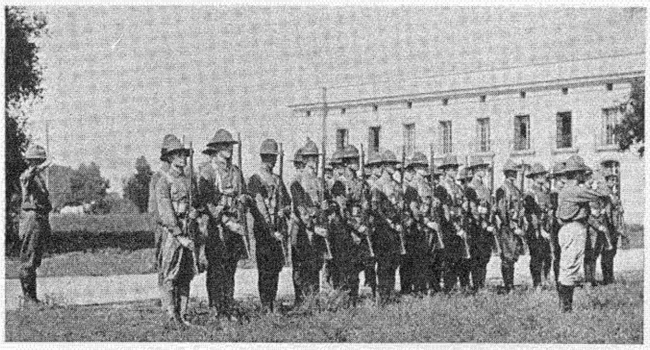
The war service obligations of the trustees, some of whom had served as $1-a-year men in Washington, continued during much of the winter, and it was not until May 13, 1919, that the board was able to hold its long-deferred annual meeting. Though technically on sick leave, President Scherer compiled his Ninth-Tenth Annual Report (February 1917 to May 1919), stressing the pressing need for buildings, equipment, and endowment for faculty salaries. The board voted to undertake a "quiet financial campaign" to raise two million dollars.

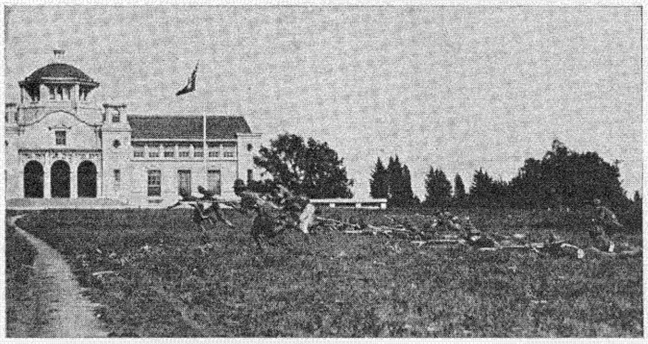
The campaign had, in fact, already begun, for on March 27, 1919, Arthur Fleming had signed a contract subscribing $1,000,000 to the college. Of that sum, $200,000 was to be set aside for research in physics to match $200,000 already donated for chemical research by Mrs. Milton Loyd-Smith. By January 1920, when the Fleming gift was made public, Throop was able to announce gifts of $150,000 (later raised to $250,000) from Dr. Norman Bridge for a physical laboratory, $75,000 for the first unit of an auditorium, and $50,000 from the R. R. Blackers "with no strings attached."

In a brief period immediately following the war, the modern California Institute of Technology was created. Between 1919 and 1921, Throop secured an endowment rivalling that of any scientific institute in the country, established a new policy to govern its future conduct, changed its name, and found a new administrative head to lead it in its next quarter century of growth.

In 1919 Arthur Amos Noyes resigned from MIT to give full time to Throop; and in January 1920, Robert A. Millikan, after a long wartime absence, resumed his quarter-of-a-year service as director of physical research.

In February 1920 the board met for the last time as trustees of Throop College of Technology. On February 10 they voted to change their school's name to The California Institute of Technology, "in order to denote and signalize its altered scope, recent developments having transformed it from a college of primarily local significance into a scientific school of national importance."

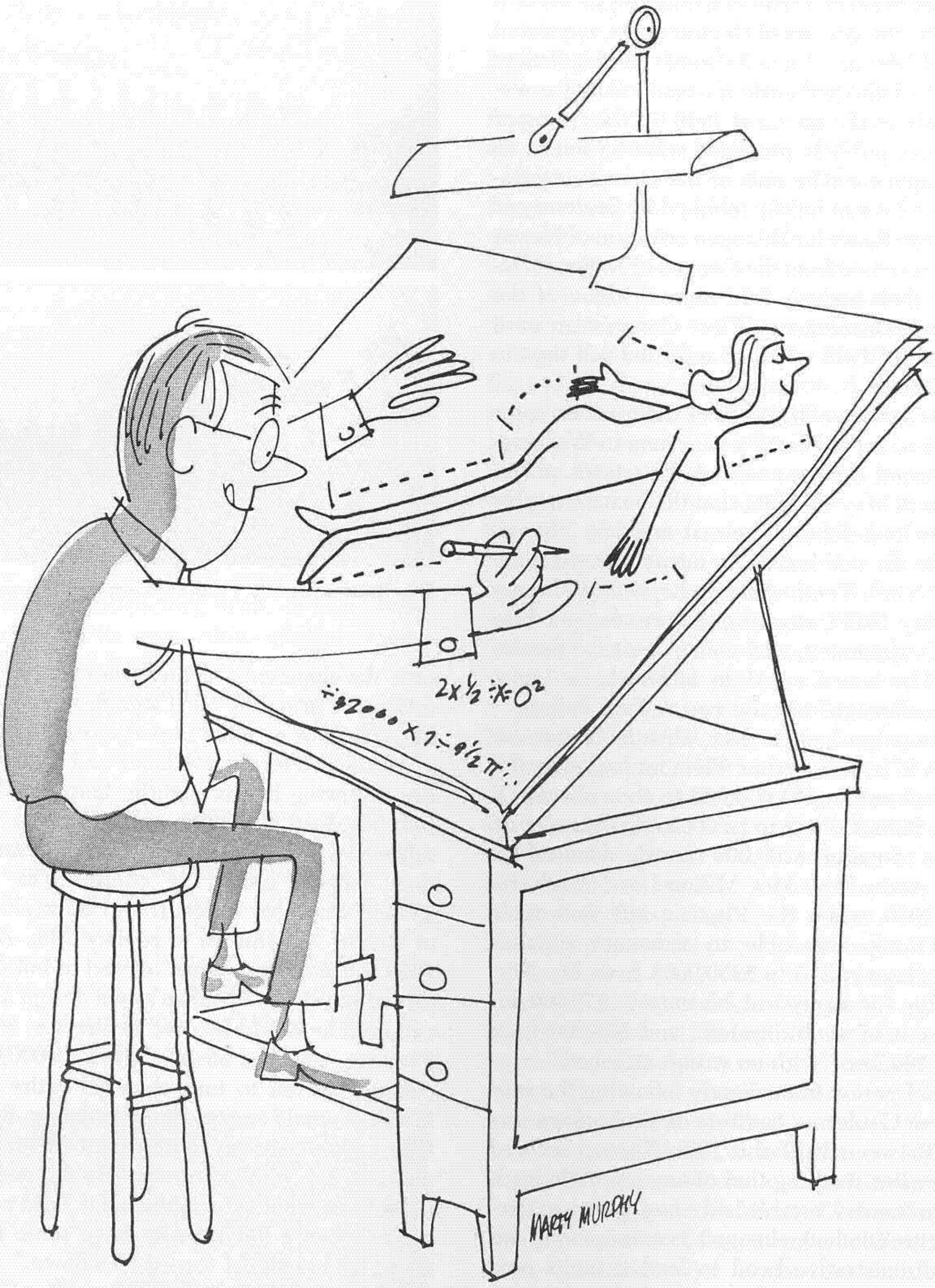




The Student Army Training Corps on Throop campus.

Although President Scherer had resumed his duties following his six months' leave, he had never fully regained his health, and on March 3, 1920, he submitted his resignation. When it became evident that Scherer could not continue as president, Throop's trustees concentrated on zealous pursuit of Robert A. Millikan to replace him. As early as 1919 Norman Bridge had offered to build a laboratory of physics to Millikan's own design and specifications if he would become its director. Now Arthur Fleming, who had already given $1,000,000 to the college, offered to turn over his entire fortune if Millikan would accept the presidency. But George Ellery Hale "was my most ardent wooer," Millikan wrote in his *Autobiography*. "He did not quite tell me that he would shoot himself if I did not yield to his suit, but I did actually have some misgivings about his health if I turned him down."

On April 4, 1921, the board formally offered Millikan the position of president of the Institute and director of physical research, with the guarantee that not more than a fourth of his time would be devoted to administrative work. Millikan accepted the offer, with the stipulation that he be called Chairman of the Executive Council, which would consist of three trustees and three faculty members. He arrived to take up his duties in the fall of 1921, and the modern California Institute of Technology was launched.



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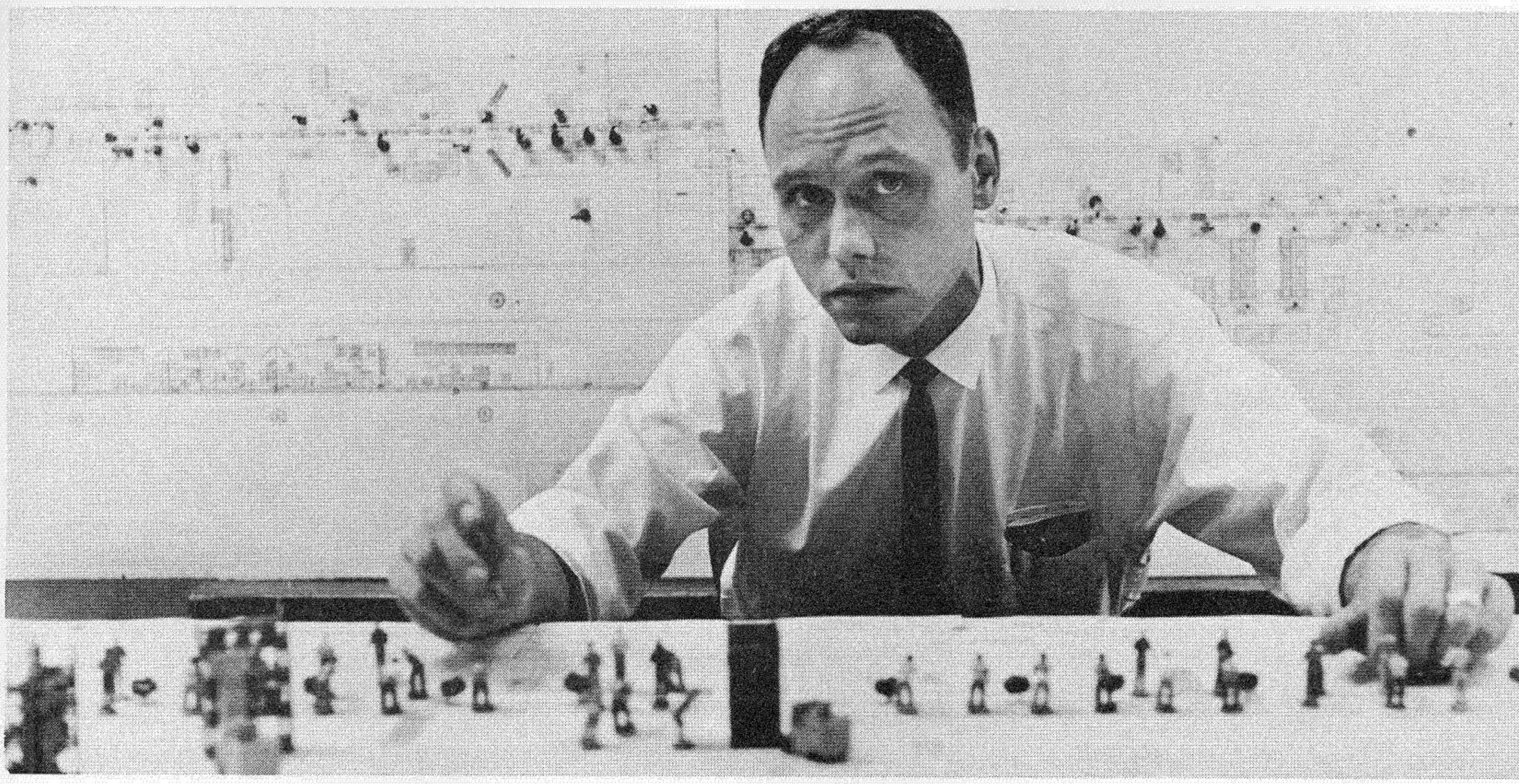

Bill Geshwiler is a Methods Engineer, quarterback of the engine assembly line for Buick at Flint, Michigan.

He works with miniature men and machines on a three-dimensional board, an actual facsimile of the plant. By moving, changing, arranging and rearranging, he coordinates and balances men and equipment for peak efficiency and productivity. He evens the individual work load so that a smooth, orderly production flow is maintained all the way along the assembly line.

Bill has always been a quarterback—in grade school and high school at Beech Grove, Indiana, near Indianapolis. The fact is, he made the All-State football team in 1954. Passing up scholarships at two universities and an appointment to a service academy, he decided instead on the General Motors Institute in Flint, and was graduated with an engineering degree.

He's the kind that could make any team, but we're glad Bill Geshwiler is in the General Motor's lineup.

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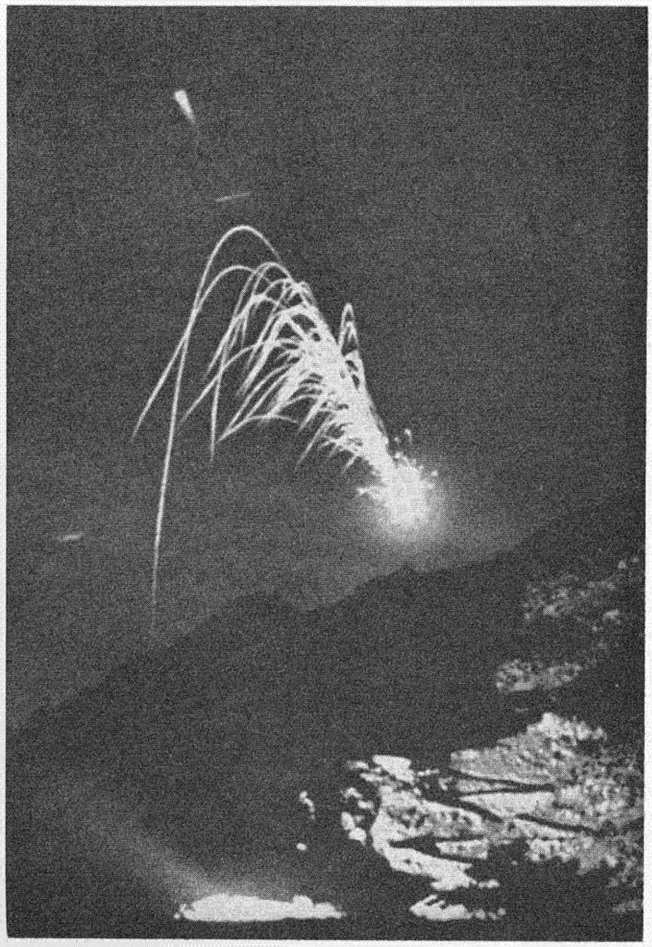
THE ANNIVERSARY OF A HISTORIC FAILURE

by Albert G. Wilson



A test of artificial meteors—December 16, 1946.

The pages of *Engineering and Science* magazine provide a historical record of many of the achievements and successes of Caltech researchers—alumni and staff. The dead ends and failures rarely appear in print. Fortunately for publication costs, few people want their failures recorded. However, now and then certain types of failures become historic and deserve a place in the record.

The 17th of December this year marks the 20th anniversary of such a historic failure—the first attempt to launch particles into space with escape velocity. A team of Caltech men headed by Fritz Zwicky, professor of astronomy, in cooperation with Army Ordnance, the Johns Hopkins Applied Physics Laboratory, the Harvard College Observatory, and the New Mexico School of Mines, put together a project in White Sands, New Mexico, combining the hardware components available in 1946 in a way which, theoretically, would launch a few pellets in orbit about the earth or throw them off into interplanetary space. Two marginal devices and one valid motivation made the attempt worthwhile. The devices were the V-2 rocket and the Monroe rifle grenade or "shaped charge." The motivation was to generate a shower of artificial meteors in order to calibrate the luminous efficiency of natural meteors.

The possibility of throwing something up that would not come down again fired the imagination. Although there had been 16 postwar V-2 rocket firings, this was to be first night firing of a V-2 in the United States. In those days the launching of a V-2, with or without an instrument on board, was as much news as the launching of a Gemini today. Dr. Zwicky, who designed the experiment, placed the event in historical context: "We first throw a little something into the skies, then a little more, then a shipload of instruments—then ourselves."

A V-2 rocket was equipped with six 150-gram penolite shaped charges with 30-gram steel inserts. These were set to fire at times after launching that would eject the slugs of molten steel at heights of approximately 50, 65, and 75 kilometers. At these heights the ejection velocities of from 10 to 15 km/sec would place the slugs either in orbit or on

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Albert G. Wilson is an associate director at the Douglas Advanced Research Laboratory in Huntington Beach, California, where he is in charge of a laboratory for environmental science. A Caltech alumnus (MS '42, PhD '47) and a staff member of the Mt. Wilson and Palomar Observatories from 1947 to 1953, he was a member of the team which took part in this "historic failure."

escape trajectory. The ultimate fate of a slug would depend on its mass and velocity. Most would be meteors, but some might not be consumed.

To determine the destinies of the meteors, a battery of K4 aerial cameras equipped with rotating shutters was scattered over the White Sands Proving Range. One of these was equipped with a transparent objective grating to obtain spectra of the V-2 exhaust jet and the luminous artificial meteors launched. The sites were selected to acquire optimal triangulation data. In addition the Caltech eight-inch Schmidt camera was removed from its usual house at Palomar and set up a few miles south of the launch site to photograph the flight of the V-2 rocket and of the particles ejected from the shaped charges. Astronomers at nearby observatories with wide angle telescopes also focused in on the firing.

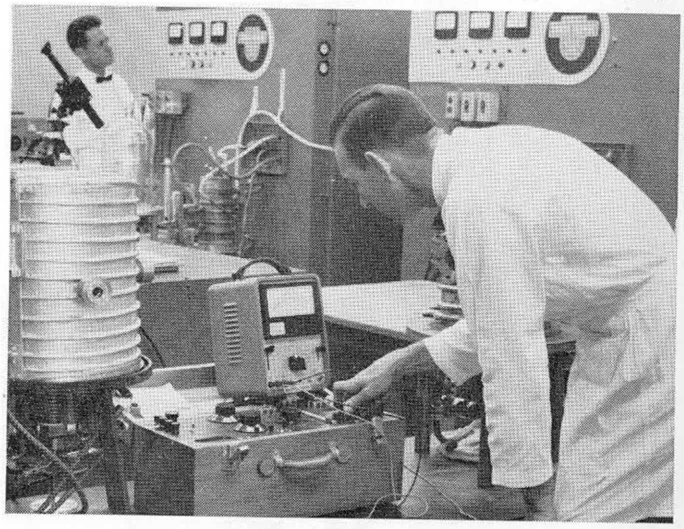
As this 17th postwar V-2 left the pad at $22^h\ 12^m\ 49^s$ mountain standard time, expectations were high. There was a feeling that history was being made. There was also the anxiety that has become as much part of every launching as the countdown. (The 16th rocket, fired a few days earlier, had tilted on lift-off and travelled 131 miles horizontally.) Lifting slowly, No. 17 filled the whole range with sound and, falling upward, held true to its course—5° tilt north. The shutters clicked and telescopes tracked—then burnout. But the rocket could still be followed by the red glow from its exhaust vanes. The time came and passed for the three pairs of charge detonations. Nothing was seen. The rocket mounted to a new record of 114 miles, then returned to earth.

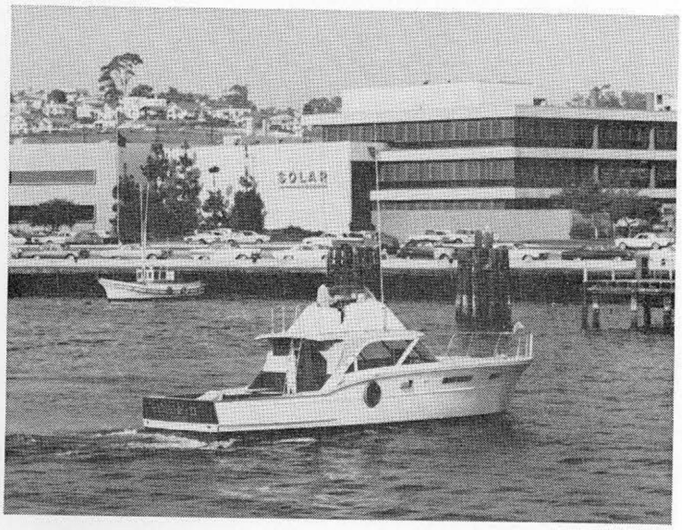
Films were hastily developed in hope of seeing on the emulsion what could not be seen in the sky. But there were no trails. Tests of the charges made on previous evenings had been in every way successful. Had the charges fired, but been undetected? Subsequent investigations have not solved the mystery of just what did happen.

Just as man's first attempts at flight in the atmosphere failed, the first attempt to reach space with a chance of succeeding also failed. It is significant, however, that whereas the span between the first attempts to fly and the first successful flight is measured in centuries, the span between the first attempt to achieve orbital velocity and the successful orbiting of Sputnik was only one decade. Those who participated directly and indirectly in this experiment, though failing to launch the space age on the night of December 17, 1946, have to their credit an important contribution leading to later triumphs. Zwicky's idea was ultimately vindicated, when success crowned the *second* experimental firing of shaped charges from a rocket on October 16, 1957—twelve days after Sputnik.

Graduating Engineers

gas turbine engineering • applied materials research





The Challenge

an opportunity to build your career in the swiftly expanding field of the industrial gas turbine, or in the field of materials development, including advance materials research, applied sciences and manufacturing technology.

The Living

in beautiful San Diego on the Pacific with America's finest year-'round climate. All recreational activities . . . theatres, fine music, educational facilities—every opportunity for cultural and career advancement.

Solar, a division of International Harvester Company, is an organization *on the move*, located in sunny San Diego—a city *on the move!*

Over the past few years, Solar has pioneered the design, development and manufacture of *industrial* gas turbine engines. Thousands of Solar gas turbine engines are in operation throughout the U.S.A., Canada and overseas. Our sales requests are so heavy that Solar has recently made plans for a sizeable additional plant here in San Diego. Needed now are young mechanical engineers interested in analytical, design, controls, test and manufacturing engineering to handle existing career assignments.

In addition to its turbomachinery developments, Solar is a world leader in the field of materials development, including advanced research, applied sciences, and manufacturing technology. Programs are directed toward increasing the utility of materials and emphasize research and applications using metals and alloys, ceramics, cermets and composites for unique and exotic fabrications. These research positions require "self-starters" – young engineers with individual initiative and judgment who like to see their ideas put to work.

With the bulk of its work in *commercial* products, Solar is not subject to the peaks and valleys of the aerospace industry. At Solar you enjoy the satisfactions and the future offered by an expanding medium-size operation, yet one backed by the worldwide resources and stability of International Harvester Company.

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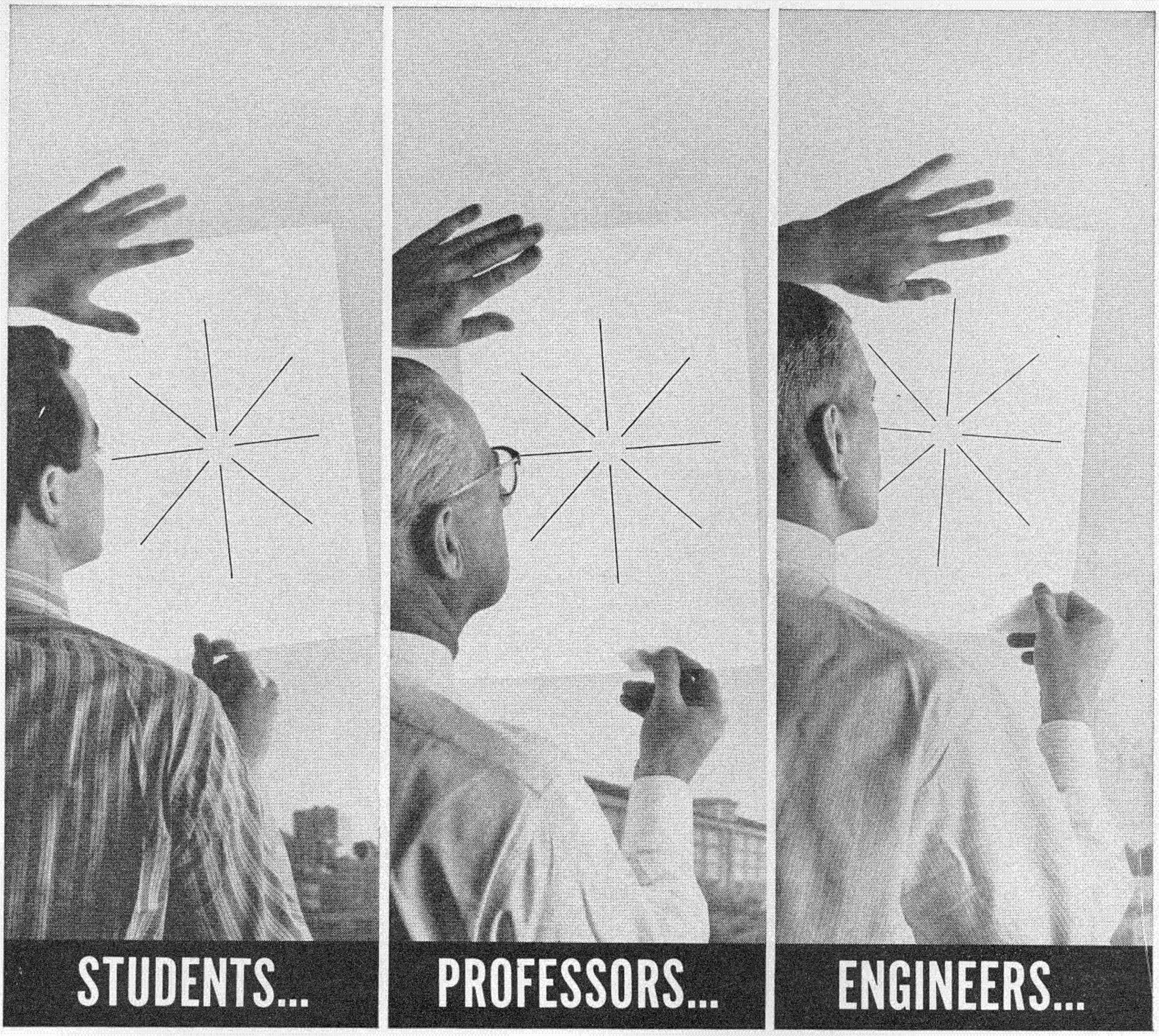

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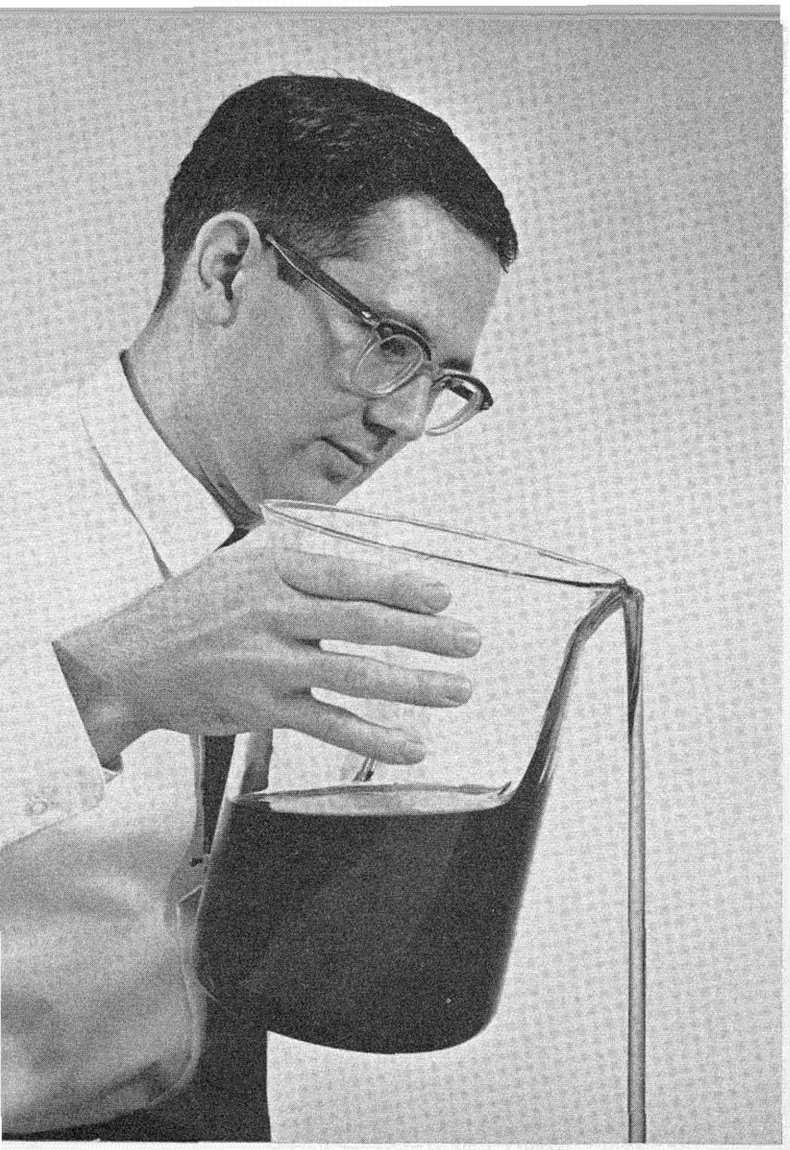


THE MONTH AT CALTECH

A Tubeless Siphon

Engineering graduate student David James shows how a polymer-and-water solution continues to pour even after he has righted its container. James came across "elastic water" during research on heat transfer in flow of polymer solutions. The liquid derives its properties from long polyethylene oxide molecules.

Language Experiment

An experiment in language teaching, a program designed to give graduate students the ability to discuss their research in a foreign language, is now being conducted at Caltech. For years PhD candidates have been required to gain a *reading* proficiency in two foreign languages. Now Caltech faculty members feel it is important for scientists to be able to talk about their work in at least one foreign language. Accordingly, a two-year trial course in French is being offered to a dozen graduate students. The course, which has been developed by Paul Bowerman, associate professor of modern languages, and James W. Greenlee, instructor in French, combines language laboratory sessions and class work. Prerequisite: no previous knowledge of the language.

International Desk

An international desk to give assistance to the record number of foreign students (223) and research fellows (164) and their families now at Caltech has been set up at the Institute by a new faculty committee on foreign students and scholars. Vito Vanoni, professor of hydraulics, is chairman of the committee.

"Assistance," according to Ingrid Gumpel, foreign student advisor, who manages the service, "is nonacademic advice or aid and is liable to include finding an apartment, buying furniture, explaining immigration regulations, planning parties, arranging hospitality, or teaching women how to read supermarket ads. ("What, please, is this *fryer,* and *spare rib*?")

Earthquake Research

Future office buildings, dams, or bridges must be planned and built to resist the destructive forces of earthquakes. With this goal in mind, comprehensive research in earthquake engineering is now under way at Caltech, supported by a $407,400 grant from the National Science Foundation for the first two years of a scheduled five-year program.

An Institute team led by George W. Housner, professor of civil engineering and applied mechanics, and Donald E. Hudson, professor of mechanical

High Sign

Nine stories up, on the east face of Caltech's Millikan Library-under-construction, three Alpine Club members posted a notice of their club meeting on November 29. In addition to practice in mountaineering methods, they got a large attendance at their meeting.

engineering and applied mechanics, will conduct studies of how the ground shakes during destructive earthquakes, how different kinds of soils affect such shaking, and how structures react to earthquake-induced stresses and strains.

The first project started under the grant involves Caltech's new nine-story Millikan Library, now under construction. Earthquake-like forces will be simulated in the building by vibration generators, and the results will be analyzed to predict structural safety. Special permanent seismographs installed on the library's ground floor and roof will also record the building's reactions to future earthquakes and allow comparison studies of predicted and real reactions.

Executive Officer

Ernest E. Sechler, professor of aeronautics and a member of the faculty since 1930, is now serving as executive officer of Caltech's Graduate Aeronautical Laboratories. His appointment, following the death last January of Clark Millikan, makes him the second man to head the laboratories. A Caltech alumnus, Dr. Sechler earned his BS in 1928, MS in 1930, and PhD in 1934.

Honors and Awards

Cornelius J. Pings, professor of chemical engineering, has been named to the editorial advisory board of a new scientific journal, *Physics and Chemistry of Liquids,* which will begin publication in March 1967. Dr. Pings will serve with five U.S. and eleven foreign scientists on the board.

Caltech engineers George Housner, left, and Donald Hudson, right, record the shaking produced by vibration generators temporarily installed in the new Millikan Library. These tests are the first project in an expanded program for earthquake engineering.

Burt Housman, associate secretary of the campus YMCA, talks with a group of Caltech women graduate students at the first Y-sponsored coffee for the ladies last month. A record number of women are enrolled at the Institute.

James J. Morgan, associate professor of environmental health engineering, has been appointed editor of a new monthly journal of the American Chemical Society, *Environmental Science and Technology*, which will appear in January 1967.

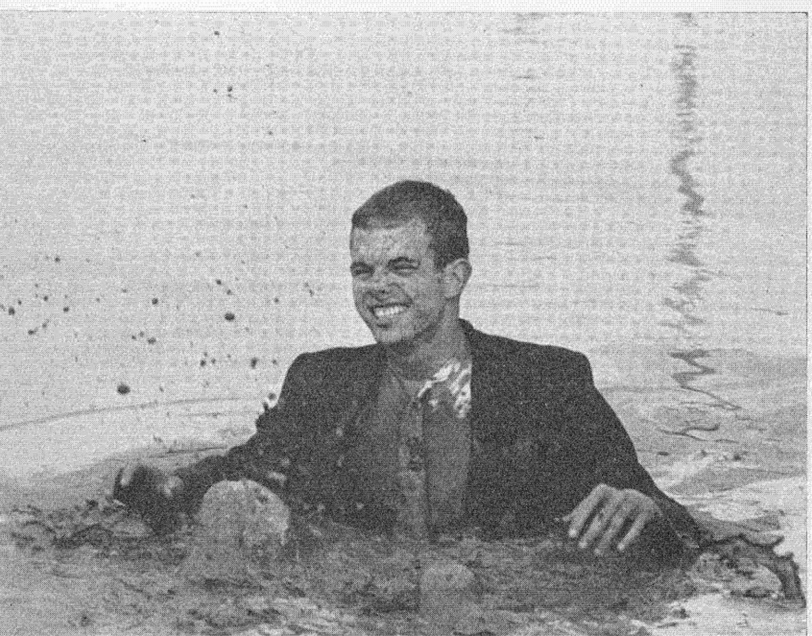
Women by Degrees

Female students at Caltech (once nonexistent, then for years a rarity) are now getting to be an impressive statistic. This semester 38 women graduate students are enrolled at the Institute—more than twice as many as there were five years ago and 12 times as many as a decade ago.

Woman who have earned degrees at Caltech have been still more scarce. Even when the name was Throop and the student body was coeducational, only two women succeeded in getting a BS—the first in 1896, the last in 1906. Forty-nine years passed before another women earned a Caltech degree. In 1955 Dorothy Semenow received a PhD in chemistry, and became a historic "first." Since then only 22 other women have been granted PhD's from Caltech. And of that number, seven were given this year.

Alumni Speakers

Two former Caltech students whose careers have followed radically different paths came back to the campus last month to talk about those careers. Paul Saltman, '49, PhD '53, professor of biochemistry at USC, spoke to a Caltech YMCA Luncheon Forum on November 23 on "Science Is a $9.95 Dress." He confessed that he has found scientists can be as greedy and corruptible as anyone else—even though they don't often admit it to themselves. The unfortunate result of their hassle for status and grab for grants is an educational environment that frequently destroys genuine scientific enthusiasm in students. Saltman himself was on his way to business school after four years at Caltech, but in the last ten weeks of his senior year was "intellectually seduced by Professor James Bonner . . . who rekindled old fires and aroused dormant passions concerning science as a way of life."



52nd Annual Mudeo

Caltech's freshman-sophomore wallow in the mire was won this year by the freshmen, who cheated more skillfully than the sophomores—who took their revenge on the judges, including the president of the junior class, Leonard Erickson (left).

Bridges On Automation

Harry Bridges, president of the International Longshoremen's Union, talks to Caltech's National Security seminar on November 30, on the subject of automation.

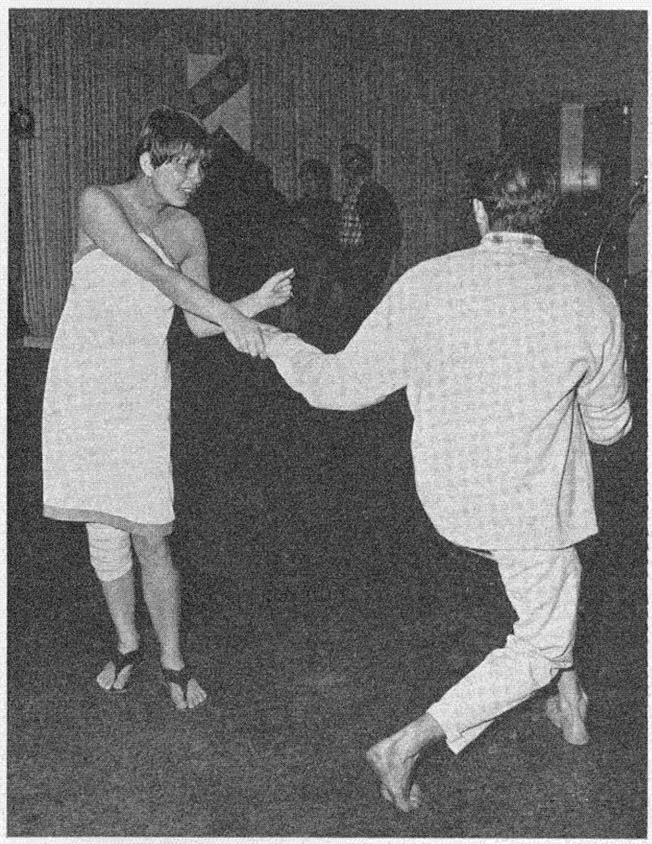
In the case of the other visitor, George Starbuck, science did lose out. He left Caltech in his sophomore year (1949)—and became a poet. Now teaching in the University of Iowa's Program in Creative Writing, Starbuck spent an evening reading from his second book of poems, *White Paper,* to a responsive audience in Dabney Lounge on November 29. His relatively uncomplicated poetry, often dealing with current social or political issues and displaying considerable technical virtuosity, has appeared in such magazines as *The New Yorker* and *Atlantic.* His audience included several faculty members who had known him as a student; undoubtedly they were wondering if the world would have one less poet if Starbuck had stayed at Caltech for a full four years.

Students' Day

More than 892 students and 171 teachers from 215 southern California high schools came to the Caltech campus on December 3 for the 17th annual Students' Day. The day-long program included tours of 61 research and engineering project exhibits; a noontime performance by the Caltech Glee Club in Beckman Auditorium; and afternoon lectures by Caltech's President DuBridge, Robert A. Huttenback, professor of history, and Leonard D. Jaffe, Surveyor Project scientist from JPL.

Conference on TV

"A Conference on Scientific Progress and Human Values," a series of weekly television programs featuring the lectures given at Caltech's 75th Anniversary Conference in October, will begin on Sunday, January 8, (from 4 to 6:30 p.m.) over KCET, Channel 28, in Los Angeles. The six programs scheduled will present the speakers in the order in which they appeared at the Conference (*E&S,* October 1966). The series will be shown later in other parts of the country.



Interhouse Dance

To the noise of five, live "stomp bands" (electric guitars, drums, long hair, and overamplification systems) Caltech students and their dates enjoyed both the activity and the decor at the annual Interhouse Dance on November 19. Entertainment this year included such unlikely fare as medieval jousting and an oldtime Western movie run backward.

Opportunities at Anaconda

in mining and metallurgy here and abroad, at Anaconda American Brass Co., Anaconda Wire & Cable Co., and Anaconda Aluminum Co.

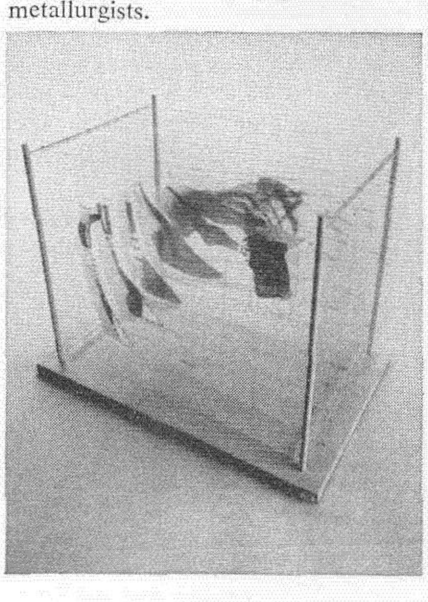
Looking inside the earth for metals

The legendary prospector trudging on foot through the wilderness scours the surface of the earth—with luck gets a hint of treasure inside through an outcropping of ore. But not all ore bodies come near the surface. And pressures to find more metals for the needs of growing populations are so great we can't wait for infrequent bonanzas.

Modern mineral exploration must have "eyes" that see under the earth's surface. Anaconda's program is based on an ever greater understanding of the distribution of elements in the earth's crust and the processes by which they are concentrated into ore deposits. Geology and geological research are thus "eyes" that help outline broad areas of potential mineralization. Gradually, the search is narrowed to smaller target areas through scientific application of geological, geophysical, geochemical techniques and other tools that are additional "eyes" for modern prospecting.

Then these target areas must be tested and evaluated in the light of experience and the critical and significant features commonly associated with ore-forming processes. The three-dimensional geological model shown below was prepared to help Anaconda geologists look under the earth's crust at a later stage in this process of evaluation.

Anaconda is a pioneer in the application of geology to mining and exploration. And it is intensifying and enlarging its program of laboratory and field research at geological headquarters throughout the hemisphere. This opens broad new job opportunities in all areas of earth sciences for geophysicists, geochemists, geological engineers, chemical engineers, physicists, and metallurgists.



Anaconda settles an old argument

The Statue of Liberty is one of the finest examples of natural patina in the world. And for years experts have argued whether this patina is basic copper sulfate or basic copper carbonate. Some felt there should also be a good percentage of chloride salts because of the salty atmosphere whipped up by the winds from the bay.

Anaconda spoiled all the fun by offering to get the answer. With the permission of the statue's custodians, metallurgists from the Research and Technical Center of Anaconda American Brass obtained adequate samples and made an extensive analysis.

The talents and skills of technically qualified men and women will always be needed by Anaconda in important positions in exploration, mining, extractive metallurgy, manufacturing, scientific research, sales, and administration.

If you would like more information about Anaconda or wish to apply for employment, write to: Director of Personnel, The Anaconda Company, 25 Broadway, N.Y., N.Y. 10004.

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Results of X-ray diffraction, semimicro chemical, and wet chemical processes proved a predominance of copper sulfate. This is easily explained by the high estimate tonnage of sulfur-bearing acids produced in New York's atmosphere every day—and by the difference between the free energies of formation of copper chloride and copper sulfate.

Basic copper chloride content was less than five per cent. And basic carbonates are virtually absent because they can't survive in the acid environment. This pleasant little side trip was by no means unrelated to the regular work of the Anaconda research teams. They are concerned with everything that happens to copper metals—and all the combinations of useful properties they can supply. They work on new finishes for copper metals and on industrial corrosion problems. They develop new alloys to meet new needs. They pursue pure research.

Anaconda's research and development are key factors in expanding copper's role in a rapidly advancing technology. It is opening new opportunities for college graduates at Anaconda American Brass in all fields of engineering, in business administration and sales.

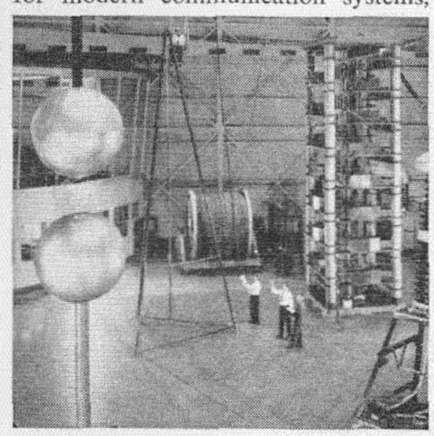
Cable to feed our growing, power-hungry cities

Our big cities keep getting bigger. They need much more electric power every year, in big concentrated chunks of load. And generator output must be carried at high voltage to these new load centers.

You can't string the transmission lines down such places as Broadway, or across 42nd St. So you dig—carry the power in the already crowded space under busy city streets.

Anaconda, anticipating this need, built the best equipped high-voltage research laboratory in the cable business (see below)—and used it to develop the 345,000-volt cable now actually in use. And now, Anaconda Wire & Cable Co. is busy working on plans to satisfy power needs of tomorrow's cities.

Anaconda produces wire and cable not only for the utility industry, but also for modern communication systems,



telephone and CATV; and for countless applications in building and industry. Constant engineering investigation at the Company's four research centers is opening new frontiers of knowledge in wire and cable technology—new opportunities for engineering graduates.

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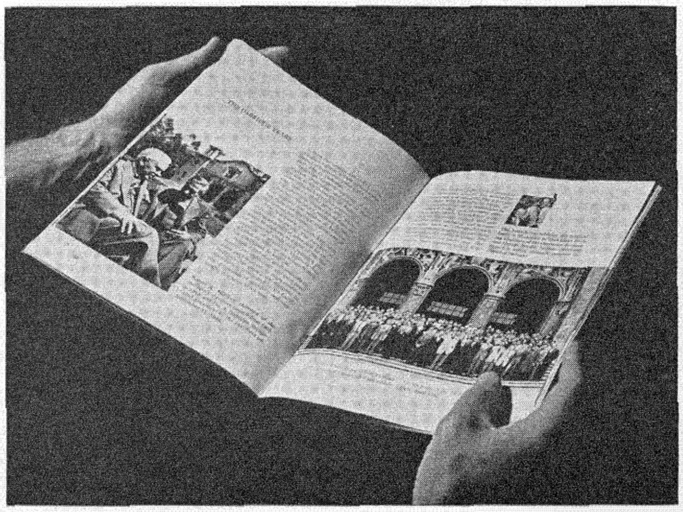


A CALTECH HISTORY

This alumnus is reading *An Informal History of the California Institute of Technology*, a special 75th Anniversary publication. This 52-page pictorial history of Caltech is also in the hands of all donors to the 1966-67 Alumni Fund. Through November 30th, copies have been sent to 466 alumni who have already made their gift in support of the Institute. A copy is waiting for you.

This book may also be purchased through the Caltech bookstore.

PERSONALS

1920

IVAN L. PAYNE died on October 7 at the age of 68. He had been retired from the engineering section of the State of California Department of Employment since 1958. Payne was known in the southern California area for his prize-winning gladioli and was a past president and member of the executive board of the Southern California Gladiolus Society. He is survived by his sister, Lucile H. Payne.

1925

CARYL KROUSER, former newspaper editor and publisher in Barstow, Calif., was recently honored by the Rotary Club for "outstanding and meritorious service in the community." He also holds the Legion of Merit in Kiwanis International.

1937

WARREN E. FENZI has been appointed to the new post of executive vice president of the Phelps Dodge Corporation in New York. He joined the company in 1937 and has served as a vice president since 1962.

1938

STANLEY T. WOLFBERG, principal with the Los Angeles management consultant firm of Cresap, McCormick & Paget, recently completed a three-month assignment in England for Gillette Industries. Wolfberg is president of the Los Angeles chapter of the American Institute of Industrial Engineers.

1939

JOHN W. BLACK is taking a year's leave of absence from his position as vice president of the Hughes Aircraft Co. and is on an extended cruise of the Pacific islands on his 44-foot ketch, "Alegria." He is accompanied by his wife and two teen-age sons. RAY JENSEN '36, MS '37, has received letters from the Blacks from the Marquesas and Tahiti.

1940

WILLIAM W. STONE JR., MS '41, a career chemical officer in the U.S. Army, has accepted a new assignment as commanding officer of Edgewood Arsenal in Maryland. He has been serving as director of research at the U.S. Army Munitions Command in Dover, N.J. Colonel Stone and his wife have two teen-age daughters and a 28-year-old son.

DONALD H. KUPFER, professor of structural geology at Louisiana State University in Baton Rouge, spent the past summer in Turkey as a member of a three-man teaching staff participating in the first Central Treaty Organization symposium on geologic mapping.

1945

RALPH D. WINTER has completed his second five-year term of service under the Presbyterian Church of Guatemala, where he has been working on rural, social, Indian problems and teaching part time in the Catholic University. He is now on a sabbatical and will be a visiting lecturer at the Fuller Theological Seminary in Pasadena from January to March.

1946

HENRY T. PONSFORD, MS, AE '47, PhD '53, has been appointed deputy manager of the military systems division at the Los Angeles headquarters of the Planning Research Corporation. He will also retain his position as manager of the systems integration department.

1948

JAMES C. ELMS has been named director of the National Aeronautics and Space Administration's electronic research center in Cambridge, Mass. Since he joined NASA in 1965, he has been serving as deputy associate administrator for Manned Space Flight.

THORNTON A. WILSON, MS, has been named to the newly created post of executive vice president of the Boeing Co. of Seattle. He has been serving as vice president in charge of operations and planning. An employee of Boeing since 1943, Wilson was elected a member of the board of directors in April of this year.

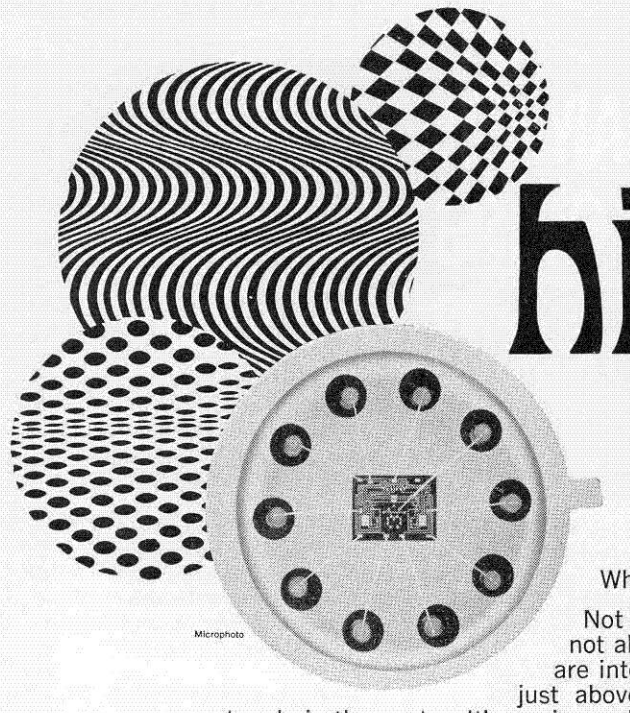
HARVEY FRASER, MS, became the 13th president of the South Dakota School of Mines and Technology at inauguration ceremonies in Rapid City on October 30. He was appointed to the post last spring (*E&S*, March 1966).

1949

EDWARD P. FISK is in Saudi Arabia working for Basil, Tac, Metcalf, and Eddy as a hydrologist and engineer.

continued on page 38

CONSUMER PRODUCTS ★ COMMUNICATIONS ★ SEMICONDUCTOR PRODUCTS ★ GOVERNMENT ELECTRONICS ★ AUTOMOTIVE PRODUCTS ★ CONTROL SYSTEMS



hip chip

What is it?

Not the op art discs — we're not about to describe them. We are interested in the micro-photo just above — specifically the little rectangle in the center. It's a minuscule chip of silicon produced in Motorola's semiconductor labs—on the verge of creating a scientific revolution all its own.

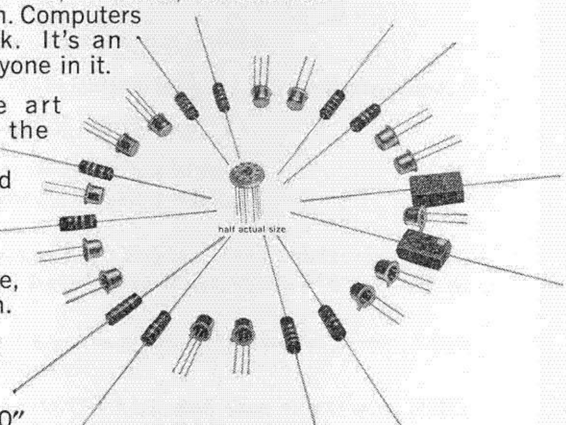
The chip's dimensions are 0.060″ by 0.080″—about the size of a baby B-B. That tiny area incorporates 14 transistors, 10 resistors and 2 capacitors—performing the same circuit functions as the 26 discrete components shown below. It's Motorola's chip off a new block of electronics—it's an integrated circuit.

But why all the fuss?

Because the integrated circuit is the key to untold electronics marvels, hitherto impractical. Because its small size, weight, and power consumption lessen the cost of complex systems and improve performance. Because it's more reliable, to boot.

Integrated circuits already are used in design plans for amazing new computers — computers which will, in effect, function as special extensions of the human brain. Computers which, in time, will almost think. It's an exciting business. It challenges everyone in it.

Within a year, the solid state art will develop the means to store the content of the Encyclopaedia Britannica in a one inch cube—a solid state memory system. One day, every important university library will have electronic knowledge banks connected, perhaps by satellite, for instant exchange of information.



People generally are impressed by the chip with 26 components. But hang on. We've now got one in the lab not much larger (0.120″ by 0.120″) . . . **with 524 components!**

Hip chip? You bet.

TRUST THIS EMBLEM WHEREVER YOU FIND IT

MOTOROLA

Personals . . . *continued*

ROBERT B. FUNK has been named by the Dow Badische Co. of Williamsburg, Va., to the newly established post of manager of the product and process development section of the fibers research and development department. Funk has been with Dow since 1950.

1953

FRED W. RANKIN JR., MS, writes that he is retired from the U.S. Army and is assistant professor of civil engineering at the University of Houston.

1956

SALVATORE P. SUTERA, MS, PhD '60, associate professor of engineering at Brown University in Providence, R.I., has recently been appointed executive officer of the engineering division. Sutera and his wife have three daughters, Marie-Anne, 6, Annette Nicole, 4, and Michelle Cecile, born last May.

ERIC A. JOHNSON, MS '57, writes that he has left the Standard Oil Company of California (where he was a lead engineer) to sail around the world as navigator and engineer on an 83-foot schooner.

1958

GORDON E. BROWN has been appointed to the University of Colorado's department of mathematics as assistant professor. He has been at the University of Illinois.

1961

RICHARD T. JONES, MD, PhD, a member of the faculty at the University of Oregon Medical School in Portland, has been appointed chairman of the school's biochemistry department. Formerly professor of biochemistry and associate professor of experimental medicine at the University, he is nationally known for his research in the area of proteins and amino acids and their relation to inherited diseases. Jones and his wife, Marilyn, and three sons live in Beaverton, Oregon.

1962

PETER FORD finished work on his PhD in chemistry at Yale, and is now a post-doctoral fellow at Stanford.

STANLEY FLATTÉ is a research physicist at the University of California's Lawrence Radiation Laboratory working on one of the first experiments on the Stanford Linear Accelerator. He writes that he received his PhD in physics at the University of California at Berkeley in June and was married the same month to Renelde Marie Demeure. Flatté also sends news of classmates LYNDON M. HARDY and RICHARD HESS, who also received their PhD's at Berkeley last summer. Hardy married Joan Taresh and is working for TRW Systems in Los Angeles. Hess works for Logicon in Redondo Beach.

ALUMNI DIRECTORY SUPPLEMENT

A supplement to the 1966 Alumni Directory will be ready for distribution some time after the first of January, 1967. This supplement will list the names and addresses of those who *received degrees in June 1966.* Copies of this supplement will be sent automatically to Association members who received degrees in 1966. Other Association members may secure a copy of this supplement by filling in the form below and sending it to the Alumni Office.

Please send the 1967 Supplement of the 1966 Alumni Directory to:

Name..

Address..

City......................State..............Zip Code............

PLACEMENT ASSISTANCE TO CALTECH ALUMNI

The Placement Service may be of assistance to you in one of the following ways:

(1) Help you when you become unemployed or need to change employment.

(2) Inform you of possible opportunities from time to time.

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: (Check one)

☐ An Application for Placement Assistance

☐ A form indicating a desire to keep watch of opportunities although I am not contemplating a change.

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

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

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