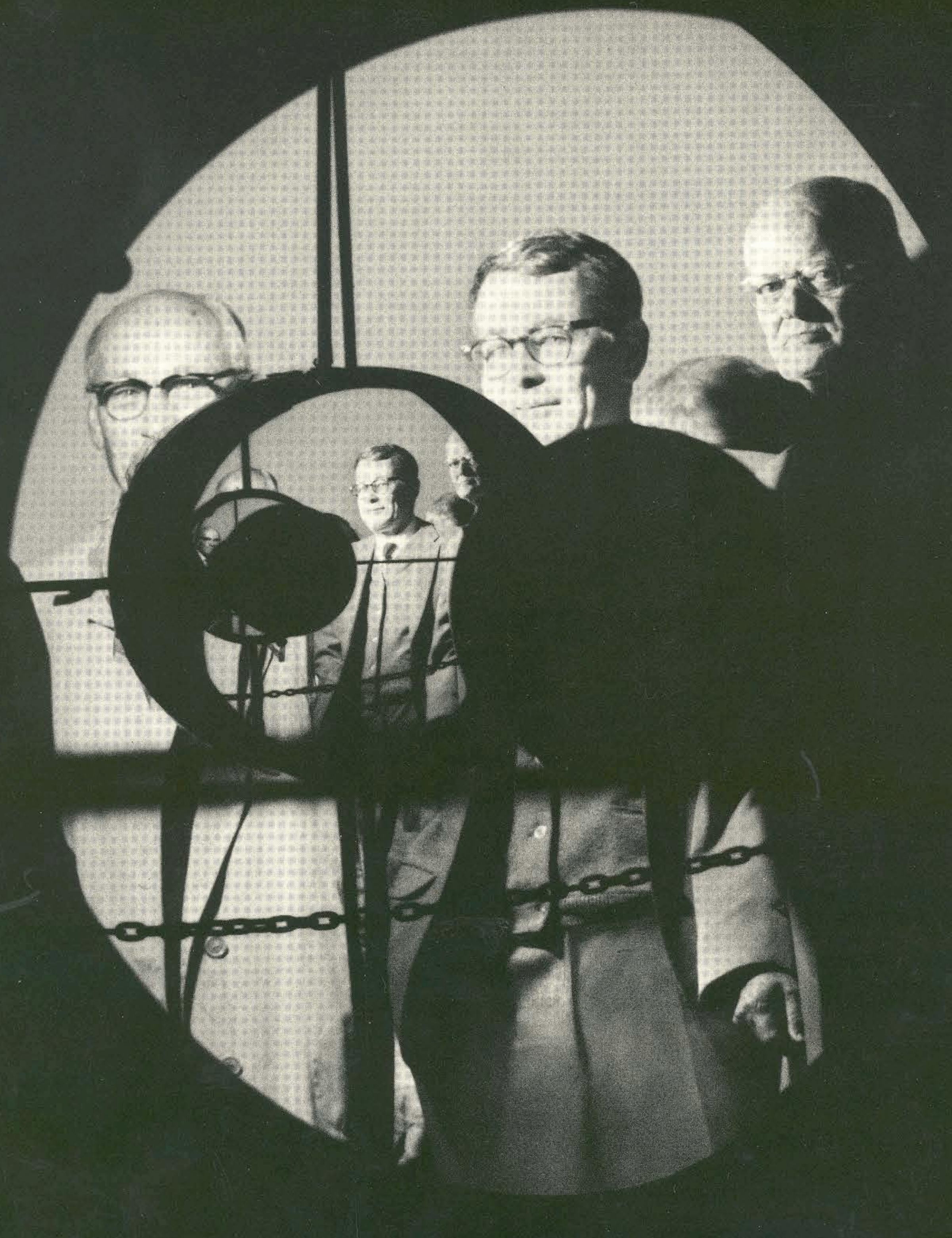
CALIFORNIA INSTITUTE OF TECHNOLOGY

Engineering and Science

NOVEMBER 1970



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the crime fighter?
the urban planner?
the ecologist?

Westinghouse Learning Corporation has launched a computerized teaching system that lets each child learn at his own rate.

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It makes sense that if we can help a diver dive to 1000 feet, we can give a man with emphysema the air to get to the top of the stairs.

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In the minds of many, modern technology has created a monster.

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Do we really believe that our achievements in space could have been accomplished without computer assistance?

Do we really believe that we can function efficiently in our complex modern environment without computer assistance?

The answer, of course, is obvious.

In truth, the invention of the computer can be compared with the invention of the printing press.

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Yet, computer-assisted instruction is not a concept which has been enthusiastically embraced by all. There are many who feel that the computer will replace teachers.

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We must insure that this technological potential is applied for the benefit of all mankind.

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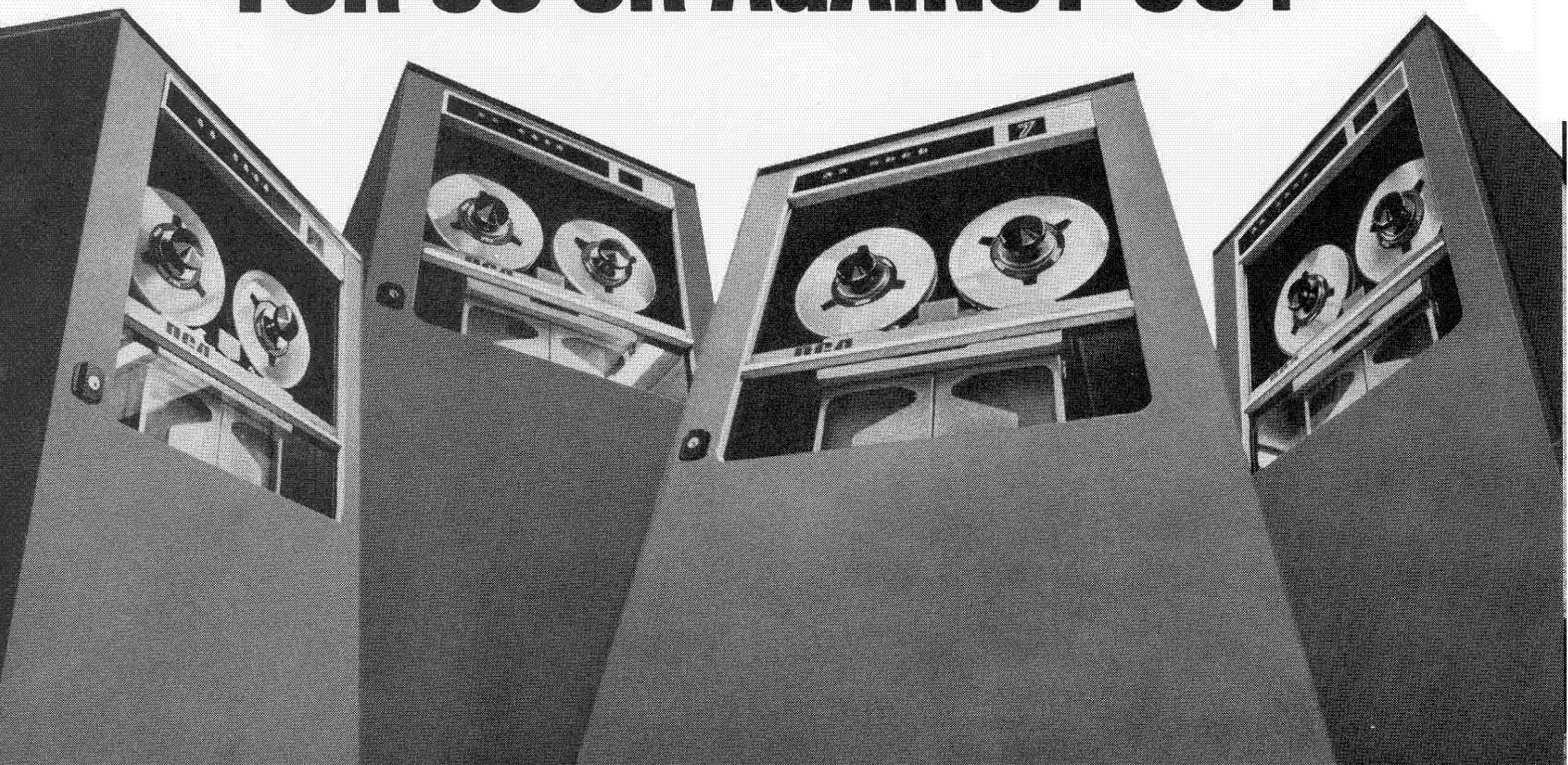

NOVEMBER 1970/VOLUME XXXIV/NUMBER 2

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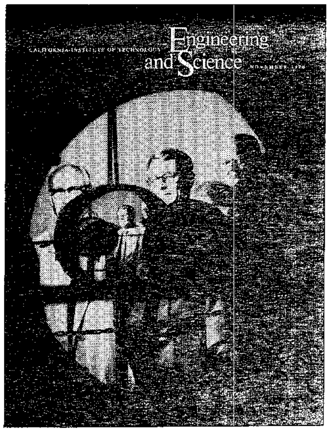

In this issue

New Telescope

On the cover—a star's-eye view of who's at the other end of a telescope. Arnold Beckman, chairman of Caltech's board of trustees; President Harold Brown; and Caryl Haskins, president of the Carnegie Institution of Washington, are reflected in the primary and secondary mirrors of the six-mirror optical system of Palomar's new 60-inch telescope, at the dedication on October 23. "A New Telescope at Palomar," the story of this unique new instrument, is on page 10. On page 12 in "Automated Astronomy: Computerization Comes to Palomar" Edwin Dennison, staff member of the Hale Observatories and head of its astroelectronics laboratory at Caltech, discusses the telescope's control system.

Science and Technology

"Faith or Good Works—the Justification of Science and Technology," page 6, is adapted from a talk given by Harold Brown at the Los Angeles Town Hall meeting on October 6.

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PICTURE CREDITS: Cover, 10, 11, 13 —Hale Observatories/All others— Floyd Clark.

Published seven times each year, in October, November, January, February, March, April, and May, at the California Institute of Technology, 1201 East California Blvd., Pasadena, California 91109. Annual subscription $4.50 domestic, $5.50 foreign, single copies 65 cents. Second class postage paid at Pasadena, California, under the Act of August 24, 1912.

PUBLISHED BY THE CALIFORNIA INSTITUTE OF TECHNOLOGY AND THE ALUMNI ASSOCIATION

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1971

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FAITH OR GOOD WORKS

the justification of science and technology

We have not yet found a social and political mechanism to weigh and balance the positive against the negative effects of technological advance.

A local businessman asked me recently how long I had been in the Los Angeles arca. Learning that it had been about a year and a half, he asked what I had done before that. I told him that I had been Secretary of the Air Force. He scowled and muttered something about the military-industrial complex. Then he asked me what I was doing now. When I said I was at a university, his expression became still less friendly. I could almost see his vision of of students bent on revolution, with their professors handing out matches in front of the ROTC building. Finally, I confessed that I was president of Caltech. He said, "What a mess you scientists have got us into! How are you going to get us out of it?"

The conversation made it clear that three of the least popular activities that a person can pursue in the United States today are those of the military, the university administrator, and the scientist and technologist. Although the combination of all three of these in my own history may leave me with a good deal to explain, I'll do that on some other occasion and confine these comments principally to a discussion of science and technology.

Why are science and technology the subject of special controversy today? Why do so many react to them and their practitioners with fear, anger, or—more mildly—merely disdain?

The first reason, I think, is that people tend to look at new problems which science and technology have not solved, or may even have helped to create, rather than looking also at the old and sometimes overwhelming problems which they *have* solved. It is the old attitude of "What have you done for me *lately*?" And I suppose that attitude is not entirely amiss. Professionals in any area ought to be prepared to answer it. But the question, of course, is prompted by people's forgetting that, for example, biologists and doctors are faced now with the problem of solving the degenerative diseases of the old, mostly because they have done so much in the past to reduce and nearly eliminate the acute physical diseases of the young. Those diseases are now the exception rather than the principal causes of suffering and death that they used to be.

People worry about the concentration of DDT throughout the biological cycle, and the poisoning of fish, small animals, and perhaps even man, that this concentration of DDT produces. And they *should* worry about this. On the other hand, the insect-carried diseases of man and of food crops have been virtually wiped out in many parts of the world because DDT has controlled those insects. Thus malaria, which until recently was the most common cause of death in the world (more people died of malaria than of heart disease or cancer or anything else) has been eliminated in many areas of the world. Now that's not necessarily a good reason to keep using DDT instead of finding new non-persistent insecticides, but it does show that DDT, like most technological advances, was introduced and developed for a humane purpose.

This case illustrates a major difficulty of technological advance. What solves the problem of one segment of the population does not necessarily help everyone. Indeed, we are well aware that it may create new problems. This situation is the more acute because we have not yet found a social and political mechanism to weigh and balance the positive against the negative effects of technological advance on the population as a whole, or on its segments. Nor have we found a way to balance off the positive effects on one segment against the negative effects on another segment and come to some over-all conclusion that is politically and socially acceptable.

Let me take another example. Our big cities, and sometimes our small cities, are plagued with air pollution. This is certainly a condition that must be changed, or life in them will become unlivable. But the technological advances that have helped create that problem are the same advances that gave us a mobility contrasting sharply with earlier times, when few men traveled as much as 50 miles from their birthplace during their entire lives. Today we know virtually no limits to travel—which may not be an unmixed blessing, but in any event it is one we are unlikely to forego—and the problems that have been created by this travel go with the benefits and can't easily be disentangled.

by Harold Brown

A second reason, I think, for the decline of science and technology in public esteem is that they have been oversold as a cure for all the ills of society and individual human beings. It is clear that scientific discovery and its applications in technology are limited in what they can do —limited by the resources of this planet, for example, and limited also by the nature of man. The scientific method solves by simplifying. But the simple truths one discovers through the scientific method can seldom be applied in any straightforward way to the complex ethical problems that face us all every day. And it is equally clear that the practical fruits of scientific discovery must be implemented by economic and political action.

In trying to explain current attitudes toward science we must also face a third factor. This is the fact that there is a strain of irrationality in man, a strain with a dark as well as a bright side. According to some modern anthropological theories, one can describe the dark side as the heritage of the aggressive instincts that were bred into our ancestors by the environment ten million years ago. Unfortunately, there has not been time for evolution to breed into us the changed behavior patterns so necessary now that we have come to possess enormously greater powers to destroy. And I suppose that a theologian might call this aggressive ancestral heritage original sin, Whatever you call it, this quality of man clearly does not welcome rational thought, let alone its embodiment in science and technology.

A fourth cause of the troubles of the engineer and scientist today—the current leveling out of support from government and private sources for science and for research and development—was inevitable for economic reasons, too. Expenditures, both the total for research and development and for basic scientific research in the universities, grew in the late 1950's at the rate of about 15 percent per year. This growth was triggered to a substantial extent by the launching of the Soviet Sputnik, which was only 13 years ago but seems so much longer ago than that. That event conveyed a correct signal to us but probably one that we saw in too simplistic terms. The signal was that no country that lags in scientific training and its technological applications is going to be in the forefront of wherever it is that our civilization is taking us.

During the early 1960's, government planners for science and engineering could identify continuing future requests for large and expensive programs that called for many more thousands of scientists and engineers each year than were then being trained. These planners also noted that expenditures for research and development were less than 2 percent of the gross national product, and that basic science consumed less than one-half percent of the GNP. What we forgot (and I say "we" because I was among those who made those projections) was that such technological projects, however much sense they made to their sponsors, would not automatically be funded in the face of competition from the needs and desires of other segments of the population.

Federal research and development expenditures amount to something between $17 and $18 billion per year. Total research and development expenditures in the United States are about $24 or $25 billion per year. The fact that such a figure is only about 2 percent of the current gross national product does not make it seem a small amount to the taxpayers and stockholders who have to provide that money. Neither does it seem small to the government officials and industrial managers who have to decide whether to spend funds on science and technology or on capital investment or, instead, on social welfare or on the solution of other urgent problems. And during the early 1960's—that period of hopeful planning—there was a failure on the part of the planners to communicate to the public either the long-term nature of the practical benefits that flow from science or of the benefits to the human spirit which accrue from knowing how nature functions.

The results of these public attitudes toward science and technology created a severe crisis as government funding began to lose momentum. In the mid-1960's the rate of annual increase dropped from about 15 percent to about 5 percent, and in the late 1960's, at about $18 billion per year, the annual federal funding for research and development leveled out. Meanwhile, price levels have continued to increase. This has resulted in a net shrinkage, by as much as 5 percent per year, of the actual program being carried out. In other words, the work being done goes down at the rate of about 5 percent per year even if the funding stays the same because prices

There has not been enough time for evolution to breed into us the changed behavior patterns necessary now that we have come to possess enormously greater powers to destroy.

go up by about 5 percent per year. This happens both in technological development and in the basic research carried on in the universities. To be more specific about basic research, the federal obligations for academic science, which is another word for the same thing, increased by less than 2 percent from 1967 to 1969, standing in 1969 at about $2.3 billion.

I believe that the future public funding of academic science can be fully justified at a level which is at least a constant percentage of the GNP. This would mean, over an extended period an increase of something like 4 percent per year in constant dollars. In current dollars that would mean perhaps 7 or 8 percent depending upon what inflation rate you think will have to be added to the 4 percent. In other words, if the economy levels out so that inflation is reduced to just a few percent per year, then if the real GNP increases by 4 percent per year, it is not unreasonable for the funding of basic science to increase at a rate (in decreasing-value dollars) of 7 percent per year. But whatever the inflation rate, a reasonable projection would be to have the funding of basic science roughly a constant percentage of the gross national product.

In the late 1960's the change in the attitude of the federal government toward funding of basic research was paralleled by a shift in the interest of the large private foundations, which had done so much through their seeding efforts, ranging from support of astronomy and nuclear physics to that of biology and medicine. Those seeding efforts still yield fruit in such diverse areas as the control of thermonuclear power and the creation of the "green revolution" which could double agricultural yields in some parts of Asia. But many of the foundations have turned their interests and their funds to proposals which hold out some hope of rapidly ameliorating urgent situations in such areas as race relations, poverty, and elementary school education—problems which, if we fail to solve them, may indeed destroy us as a society and as a nation. Some industrial organizations have followed the same road to some degree. It is too early to tell how successful these activities will be or even how successful they have been in the past five years. What is clear is that there has been in the past five years a substantial diversion of funds from the support of basic science to such approaches.

The leveling or decrease of support, accompanied by continued cost inflation, has put severe pressure on academic programs—damaging pressure that goes beyond the positive encouragement of greater efficiencies.

Even with increased efficiencies, static or decreased funding and increasing costs have resulted in the deferral or elimination of critically important new programs, and I can give some examples at Caltech. For example, it means for us several years' delay in valuable new research programs, among which is work in behavioral biology to study why organisms, and people, behave as they do for both genetic and environmental reasons. And we are just now in a position to begin to launch an exciting new program to bring together social science and engineering to examine and help find solutions in such problem areas as population growth, the use of technology for economic development, and environmental quality.

There is no doubt that we're going to do these things anyway. But they will be done later because of the difficulty in finding funds. And by delaying their accomplishments we risk a great deal, because the problems to whose long-range solution these will ultimately contribute very substantially are, in fact, becoming more acute all the time.

Also badly hit are the new opportunities in the fundamental studies of the behavior of matter—both in its very largest aspect as represented by radio astronomy which tells us about the distant galaxies, and its smallest aspect as represented by nuclear and particle physics. And the same is true for studies of matter in its medium-size aggregates, studies of things like the catalysis of chemical reactions, which might enable us to control biological and chemical processes.

Now, doubting that science and technology are worthy of the very substantial monetary costs required, government agencies, Congress, and private donors as well are apparently establishing a pattern of reduced support. I believe they should think again. Why? Perhaps the title of this paper, "Faith or Good Works—the Justification of Science and Technology," contains a hint. During the 16th century, and tracing back of course to earlier scriptural writings, theologians argued about how men could achieve salvation. The conflicting doctrines were those of justification (which means salvation) by faith and justification by good works. Science and technology can be compared to these two paths. The pure scientist seeks knowledge for its own sake. And the effort to understand the universe, including the nature of life and of thought, is the essence of the intellectual effort of the past few centuries. In practice, the work of the technologist is often similar, but it is done with a specific goal in mind—the control of nature and the solution of human problems.

One justification of the value of a high level of support for science is the link between it and technology. This link is clearly revealed by a backward look. Every modern comfort (or pleasurable vice, depending upon how you look at it)—television, rapid transportation, all the material benefits which go by the name standard of living, and the very easy access to education, to art, to music, and to literature—all of these depend on the technology which has evolved over the past few hundred years, actually most of it during the past one hundred years.

Each one of these technological advances depends on discoveries in fundamental science. Some of those discoveries took place a few years before their technological application, some 10 years before, some 50 years before. Some of the scientific discoveries (e.g., nuclear fission) were immediately seen by their discoverers to have far-reaching technological potential. Others (e.g., the Mendelian laws of heredity) languished unknown for decades before they were applied. But over time, the use through technology of scientific advances returns an enormous payoff to society.

The second justification of the value of a high level of science and technology—and of equal validity—is the enrichment of the human mind and spirit by science. Scientists and engineers are not often adept at conveying to the public the value of this function. But it is in fact vital to modern man to have a consistent, logical, believable picture of nature. Man evolved and is still evolving from the life process. Life itself grew from the planetary surface by a marvelous, one might almost say miraculous, combination of elements combining in increasingly complex molecular forms. This planet itself was created by the cosmological processes which began when our universe began. Our knowledge of such matters is still fragmentary; it would be a rash man who would say that we would ever know exactly what happened and exactly what laws govern what is and what will be. But even working on these problems conveys a sense of man's belonging in the universe, a sense which modern man seems to have lost—a loss which has resulted in a deep impoverishment of spirit.

The teaching of science, to the technical and nontechnical alike, needs to stress these factors. To have such concepts taught from a base of experience and understanding requires that the teachers be researchers as well, in the forefront of research. To teach the engineers, physicians, and other professionals who apply science for the good of society, we need physicists, chemists, biologists, geologists, and other pure scientists who are professionally outstanding, and that means we need to support their research.

The development and continuing growth of science and technology in southern California require special discussion. In a very real way, I think, the difference between southern California in 1920 and southern California in 1970 can be explained by the interaction of two things. The first is sunshine and the attraction it has for people. The second is science and the applications it has in engineering and technology. One may ask whether southern California is better in 1970 than it was in 1920. Certainly it is more crowded and more polluted. For some fraction of those who lived here in 1920 there was a graciousness and spaciousness that modern developments have not been able to reproduce. But it was so for only a small fraction of a very much smaller number of people. Without science and technology, how many of us would be able to live in what is still one of the more pleasant parts of the world?

The aircraft industry was equally a product of good flying weather and of the genius of the applied mathematician and aerodynamicist Theodore von Karman, whose students have spread far and wide as aircraft engineers and managers. The entertainment industry was brought partly by sunshine, but it has grown and flourished through the technological advances of sound and of television. The electronics industry is a product, pure and simple, of basic science converted quickly into technological application. Even tourism, attracted by the climate and scenery, is made feasible by rapid air transport. And the importation of electric power and water into the Los Angeles Basin in the 1920's, which made urban life possible here, was a product of the early flowering of technology. Specifically it was largely based on the work of the early engineers of the institution that was just then changing its name from the Throop Polytechnic Institute to the California Institute of Technology.

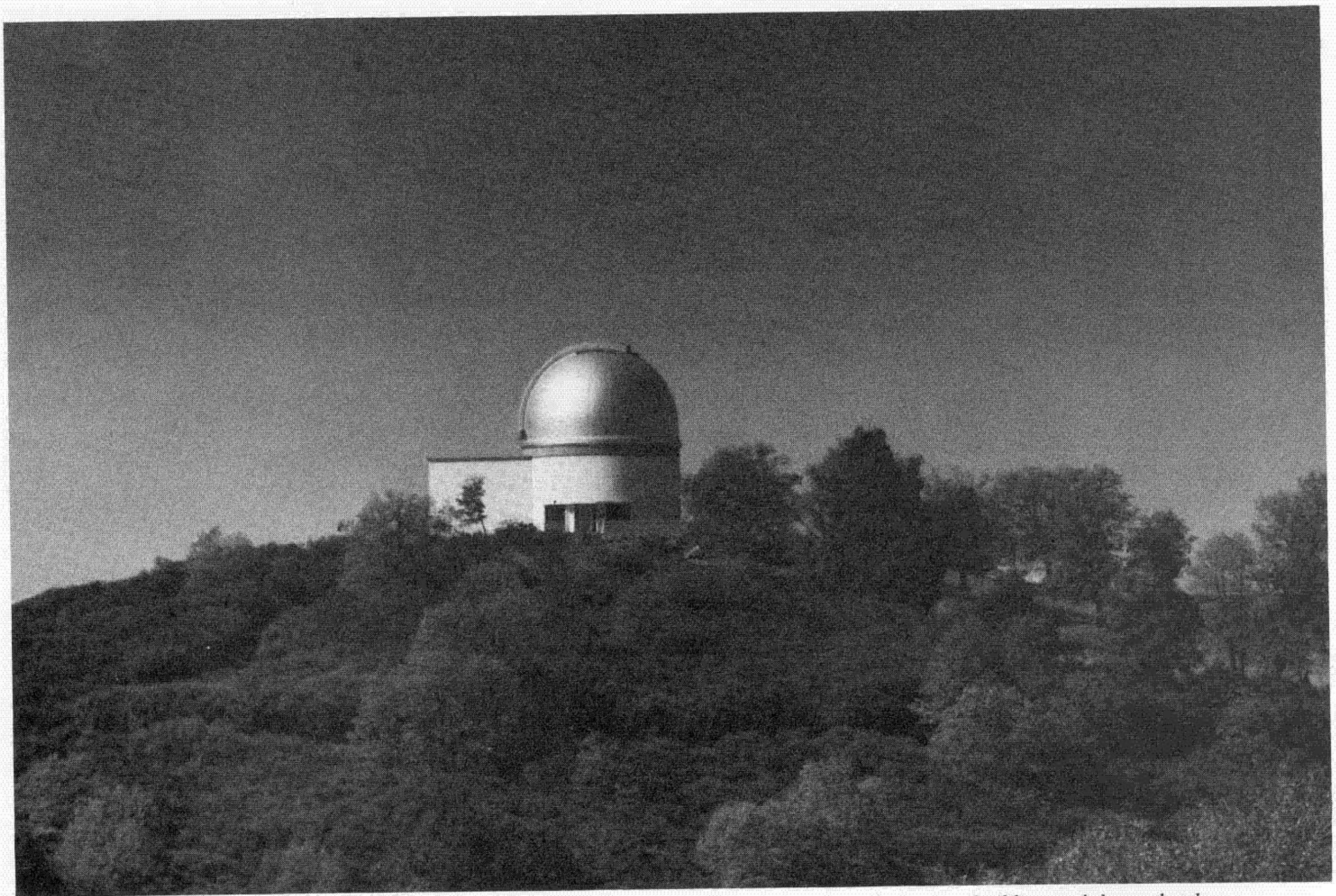
What the future holds is hard to say. I doubt that all of it is bright. We must concentrate more on the quality of life, on environment. We may be able, by understanding not only how man came to be but how he thinks —through the study of behavioral biology—to damp down some of his more aggressive and dangerous characteristics. It is foolish to think that science and technology can by themselves solve these problems. But solutions of our social or environmental problems will not and cannot be forthcoming without new technological applications, using science and technology to the utmost to create new things and methods and to increase our productivity. Nor can we solve those problems without a better understanding of man and the universe, an understanding in which basic science plays a fundamental role.

Science and technology have forged the high wire, material and intellectual upon which our society balances. It is hard to predict where we are going or whether we will be happier when we get there. But one thing is sure: This is no time to cut the wire.

A New Telescope at Palomar

A new 60-inch telescope representing unique advances in electronic and optical design was dedicated at Palomar Observatory on October 23. The first major addition to the observatory in some 22 years, the new telescope joins the 200-inch Hale and 48-inch Schmidt telescopes at Palomar Mountain. The three Palomar telescopes, together with the 100-inch and 60-inch telescopes at Mt. Wilson, comprise the Hale Observatories, now operated jointly by Caltech and the Carnegie Institution of Washington.

The new instrument fills a critical need at the Hale Observatories for a telescope of moderate size in a



The Mayer Observatory, a three-story building and dome that houses the new 60-inch telescope, is located on Palomar Mountain a little less than half a mile from the 200-inch facility.

location remote from city lights. Aside from the 200-inch, the only other telescopes at Palomar capable of photometric observations have been of 20 inches diameter or less. The light-gathering power of these instruments falls far short of that required for a major portion of the observations conducted. The 48-inch Schmidt at Palomar is restricted to photographic observations and is not equipped for spectral measurements. Telescopes of moderate size—100 inches and 60 inches—are available at Mt. Wilson, but the lights from the Los Angeles Basin seriously hamper those observations that require a dark sky. As a result, the 200-inch was often being used in experiments where its great light-gathering capability wasn't really needed. Finally, observing time on the four existing Hale Observatories telescopes was in such demand that requests for their use exceeded available time by 50 percent or more.

One of the first major telescopes to operate with a computer, the new 60-inch combines the maneuverability of a short tube together with the higher magnifications normally associated only with a long focal length. It can detect objects as faint as 22½ magnitude (as compared with a limit of 23rd magnitude for the 200-inch Hale).

The source of the higher performance capacity is an unusual optical system of six mirrors and a corrector lens. The system permits effective focal lengths of 525 inches and 1,800 inches at the two operating focuses of the telescope—the Cassegrain and the coudé—even though the actual length of the tube is only 150 inches.

Much of the photometric and photographic work will be done at the Cassegrain focus, while spectrometry will be done at the coudé. By means of a simple mechanical procedure, the observer can change mirrors and select the desired focal length.

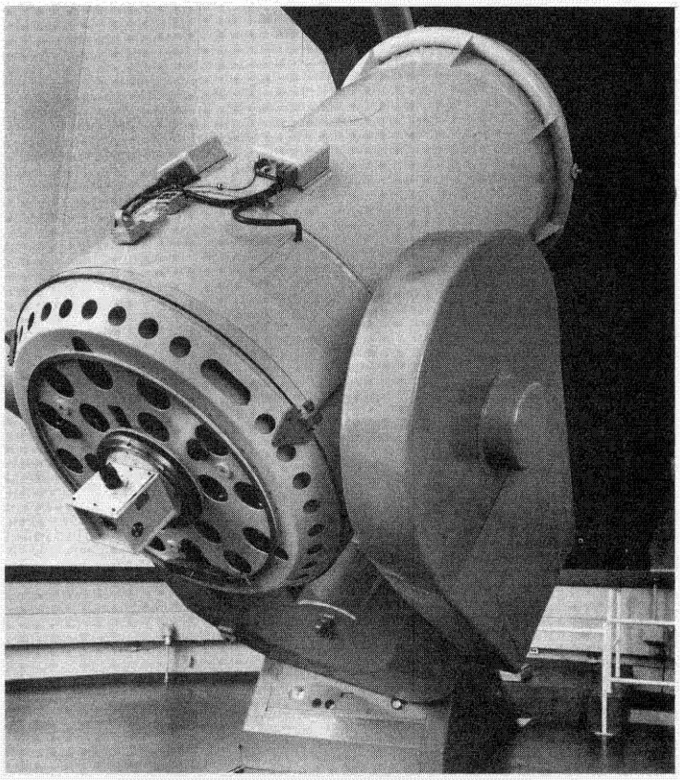
Weighing 19½ tons, the new telescope occupies a three-story circular observatory building adjacent to the 200-inch telescope facility. The new building also contains an observing space; an extended coudé room (where light can be spectroscopically analyzed); a combination office, library, and photographic plate assessment room; dark rooms for developing plates; and a galley, elevator, and service facilities. The dome is insulated to minimize temperature changes, and work rooms below the observation floor are air-conditioned.

Planning for the new instrument began in 1962. Over-all design and construction were supervised by Bruce Rule, chief engineer of the Hale Observatories. Construction, which took place largely in the central shops at Caltech, began four years ago when the Corning Glass Works of Bradford, Pennsylvania, cast a mirror blank of fused silica 61 inches in diameter. The 2,000-pound mirror disk is 10½ inches thick on the outside by 9 inches on the inside. A hole 18 inches in diameter through the center allows the magnified image of stars and galaxies to reach the Cassegrain focus.

Optician Floyd Day of the Hale Observatories optical shop took two months to grind several pounds off the sides to achieve the desired mirror configuration and disk shape. After that, two years were spent in polishing to achieve the desired precision of the front surface.

Ira Bowen, former director of the Mt. Wilson and Palomar Observatories, designed the six-mirror optical system in the Ritchey-Chretien form—a type of design that eliminates the distortion of images near the outer edge of the field.

Total cost of the new telescope, facilities, and support equipment was about $1 million. A grant of $590,000 from the National Science Foundation covered costs of materials and construction of the telescope itself, and the Oscar G. Mayer family of Madison, Wisconsin, contributed $373,000 for the observatory building. A grant of $125,000 from NASA supported preliminary design studies and paid for the mirror blank.

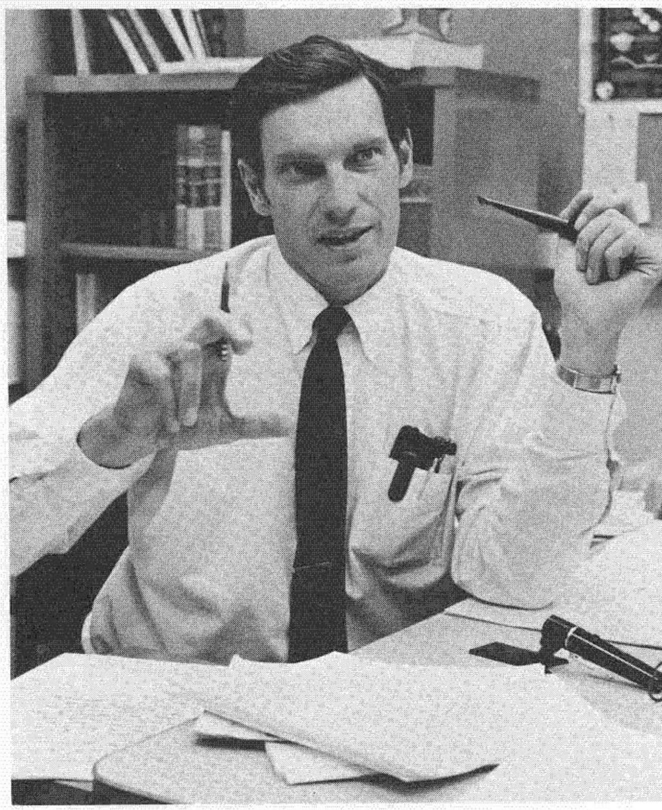


Looking for all the world like a stubby cannon aimed at the stars, the new 60-inch telescope stands ready for use. The observer uses a chair that is placed to permit him to make direct observations by looking into the black, circular eyepiece which extends from the box mounted at the base of the tube.

AUTOMATED ASTRONOMY

Computerization Comes to Palomar

by Edwin Dennison



Edwin Dennison—staff member of the Hale Observatories and head of its astroelectronics laboratory.

About two and a half years ago the astroelectronics laboratory of the Hale Observatories began working on a computer system to handle data and to control telescopes at Palomar and Mt. Wilson. Previous experience with photometric observations had shown us that by using an automated system an astronomer could observe many more stars per night than he had been able to observe before. The main boost in efficiency came from automatic recording and instantaneous data display—a major improvement over earlier systems, which required time-consuming manual calculations to convert sensor data into meaningful information.

However, these early automated systems were hard-wired, which is to say the logic reflecting a given control strategy was permanently wired into the basic system hardware. Because of this it was extremely difficult to modify the system to accommodate new observing requirements.

We therefore started developing a computerized data system. This would greatly increase the flexibility of the system, permitting the variety of command functions to be limited only by the availability of sufficient core storage and of computer software written to perform the specific function. Building the system around a digital computer also meant that we could add new observing instruments and data collection devices without having to modify the hardware already constructed. All we would have to do was write the software—the instructions that tell the computer what to do with the data being fed into it.

The first Hale Observatories telescope to be automated was the new 60-inch at Palomar. The system by which it operates is one of the first to include both telescope control and data acquisition functions. We are also building a similar system for the 200-inch Hale telescope, and we hope to start one for the 60-inch at Mt. Wilson soon.

One of the basic ground rules we established before we began the actual design was that the control procedures must be simple and directly related to the observing operation. There are times at night when even the best observer becomes fatigued, and we certainly didn't want to require him to become a skilled computer operator just to operate the system. Further, the number of devices that confront an observer will undoubtedly increase with time, and it could easily develop that no one person could handle all the control functions efficiently.

We looked at a number of possible hardware configurations, including timesharing (sharing a large computer with other users), but we decided on a dedicated computer —one located and set up to operate exclusively with this telescope. This would allow us to avoid depending on a central installation, which of course would not be able to guarantee being operational 24 hours a day. In addition, this approach made it possible for us to avoid the problems of data transmission from a remote site to a central computer.

We finally selected a Raytheon 703 minicomputer—a machine we judged to be ideally suited to our special astronomical applications. This computer has a convenient instruction set, and the manufacturer-supplied software is well developed and complete. Core memory size is 8,000 words—more than adequate to handle our current core storage requirements. Standard peripheral devices include an input keyboard, TV monitors, a teletype printer, and a paper-tape punch. In addition, we developed a generalized input/output expander circuit so we could attach our own special sensors and actuators via a single cable that runs serially through each. We can expand to over 200 such devices, and we can issue up to 256 commands to each one.

The observer communicates with the computer primarily through the keyboard and TV monitors. Commands—e.g., data acquisition time or telescope tracking rates—are entered via the keyboard and verified by alphanumeric displays on the monitors. Data acquired by the telescope and received by the computer are also displayed on the monitors as well as recorded in storage or printed out.

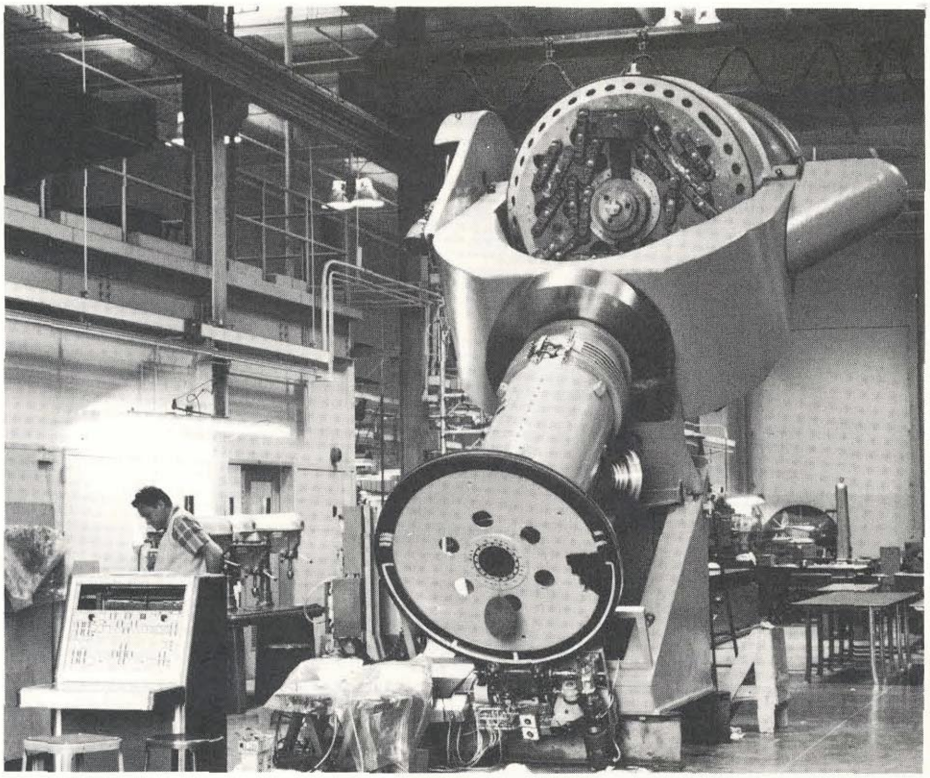
The system is controlled through panels at the observer's and night assistant's stations. One panel enables the night assistant to select the various control program options that are available. A second panel contains buttons to start, stop, or suspend the data collection process. It also permits the recording cycle to be suppressed when the data is considered to be of no value.

Because accurate time is fundamental for most astronomical observations, the system includes a clock which operates as an independent unit. It has an independent display and separate power source that remain on when the rest of the system is turned off. It can also be run from standby batteries if power interruptions prove to be frequent. The computer consults the clock to read sidereal time (which is time based on the earth's rotation with respect to the stars) and civil time (which is time based on the earth's rotation with respect to the sun).

Merely by automating the data recording and display functions, we have improved by a factor of two the speed with which an observer can make photometric observations. The significance of improvements such as this in telescope utilization efficiency becomes immediate and obvious when we remind ourselves of the magnitude of investment represented by these instruments: Total construction and installation costs on the 60-inch telescope came to some $1 million.

Another major step will come when we have preprogrammed stellar coordinate corrections, which will free the observer from the traditional, time-consuming methods of calculating coordinates to locate an object in the sky. I expect this improvement to produce an additional 10 percent saving in observation time. This saving alone will pay for the entire computing system, which cost a little over $100,000.

But even beyond the dollar savings, we have really only begun to scratch the surface in providing astronomers with the enormous flexibility of the modern digital computer. Right now, observers are still getting acquainted with the possibilities of the system. As they become more familiar with its capabilities, they will identify new observation requirements—to which we will respond by developing new control devices, data gathering devices, and computer software.



In early 1969 the telescope was assembled, without optics and data acquisition devices, in the central engineering shops on the Caltech campus. After completion of the control system tests, it was disassembled and shipped to Palomar.

The Modes of Science

by George S. Hammond

Scientists face an unprecedented task—finding within a single generation a reorientation that has previously been spread over several generations.

For many of us at Caltech, science really is a way of life. We enjoy the privilege of defining problems in our own way and are stimulated by solving them according to rules that we have largely devised ourselves. It is really delightful, because the game is fun, and the results have often had value that can be shared with the society as a whole. Twenty-two years ago, I began my first faculty appointment at Iowa State College with a good deal of enthusiasm and some trepidation. The intervening years have certainly been the most productive period of scientific learning to have yet been recorded in the history of man, and I am truly grateful for my good fortune in having been a scientist during that time.

It is trite, but true, to say that we live in a troubled society. Although our troubles may not be the greatest faced by our nation, scientists do face problems that I, at least, did not anticipate two decades ago. Financial support of science and of science education built up rapidly, but it has dwindled at an alarming rate during the past three years; the public has turned from overadulation to suspicion of science; and we are particularly vulnerable to the wave of anti-intellectualism that has swept through the western world. I have always been fascinated by change. This probably is the reason that my interest in chemistry has been strongly focused on chemical reactions; but at this time I have an almost obsessive interest in the changes that are occurring in science.

In a sense I believe that we have learned too rapidly for our own comfort. During the 20-year period 1950-1970, we accumulated more scientific knowledge than all mankind acquired during the previous century from 1850 to 1950. I believe that we have passed through an era during my own working lifetime, and this is not an entirely comfortable feeling. There have been no changes in our concepts of what science is all about even remotely comparable to those that occurred between 1850 and 1950. When we ask why, we get a variety of answers—with none being very reassuring.

Some say that science has matured, that its form is fixed, and that we will see only progressive development within the form that is already established. If this is true, the prospect is sobering. We would conclude that scientific discovery will roll on over a relatively smooth path. If the machine has in fact been created in nearly final form, all we will need to do is continue to feed in fuel in the form of new scientists, and oil the works with a reasonable level of financial support. This picture would indicate that the needs of science in human resources are for competence much more than creative genius. During the past three decades we have made a very successful pitch to the young, intended to attract many of the most gifted to science. If the field is really mature, perhaps this approach should be changed. In fact, there is already considerable evidence that some of the most imaginative students are rejecting science because they believe its form is cast in concrete.

Personally, I disagree with this analysis and wish to suggest an alternate point of view. When I look at us and the universe around us, I see much more that I do not understand than I understand. Science is, according to my dictionary, systematic understanding of the physical world. If so, my own observation tells me that science must be far from finished. I further believe that we may have a problem in science at this time because too much of our attention is centered on what we know fairly well and too little on things about which we know very little. This would be a logical consequence of our incredible achievements during the era that has just passed.
My friend Burton Klein, a Caltech economist, maintains that we have a problem because we are still caught up in the scientific philosophy of the 19th century. I believe that our problem arises from the heritage of the first half of the 20th century. Most of the thinking about the structure and goals of science is too heavily dominated by people, such as myself, who were active and knew, or thought we knew, what science was all about in 1950.
In a sense, we are in the same position that we would have experienced if Kekulé and Faraday, reigning scientific figures in 1850, had still occupied important scientific thrones in 1950.

If my analysis is even reasonably accurate, scientists of the world now face an entirely unprecedented task. We must find within a single generation a kind of self-renewal and reorientation that has previously been spread over several generations. The prospect is frightening, because we all must share some fear that detailed scrutiny of what is new and what is old might relegate our own finest works to historical museums. Furthermore, the creative young people who enter science must face the challenge of defining the new wave of science for themselves, since those of us who teach are so inextricably involved in what has now become history. Although I have really disqualified myself as a reliable prophet, I still cannot resist throwing my guesses about the future into the mill.

We can find clues of many kinds. If we look at the voluminous current scientific literature, we find depressingly repetitive patterns in the results reported. The work is new and both methods and answers are elegant, but the answers in many cases are not astonishingly different from those published five or ten years ago. The same criticism can be justifiably leveled at much current industrial research and development. For example, synthetic fibers are a tremendously important product of chemical technology. However, dozens of new fibers have been produced during the past decade. Very few have had a major commercial impact because they are not really much better than pre-1960 fibers.

Another symptom is found in the kinds of new challenges now being presented to scientists, and our reactions to them. The demand for new technology to preserve and improve the quality of our environment becomes increasingly loud. Many scientists are eager to respond, partly as a relief from nagging worry as to whether or not their traditional activities have adequate innovative character. I like this move and am pleased that Caltech will take a part in it by establishment of a laboratory for environmental studies. However, the studies we have made in the past year in preparation for setting up this laboratory have shown that we are not particularly well prepared to solve the problems of the environment, which turn out to be terribly complicated. We have to face the fact that technological solutions will be of variable utility depending on what occurs in the socioeconomic area. This somewhat humiliating discovery has real pedagogic value. The fact is that scientists, and even engineers, are ill prepared to deal with the complexity of real systems. I believe that our poor state of preparation for the complex is partly the result of a lopsided value system that has arisen in science during the past half century.

I think there are two complementary modes of science, the analytical and the synthetic. In analytical science, we divide things into smaller and smaller parts and study the small elements in great detail. In synthetic science, we try to construct useful models for thinking about complicated systems containing many elementary parts.

George Hammond, an outstanding scientist in the field of photochemistry, is chairman of the division of chemistry and chemical engineering and Arthur Amos Noyes Professor of Chemistry at the Institute. He is deeply concerned about the philosophy of education in general and curriculum revision in the field of chemistry in particular, and is in demand as a speaker on this subject both in this country and abroad. Convinced that the traditional subdivisions of chemistry are inappropriate for modern research, he has put many of his ideas into practice by designing and teaching new freshman and sophomore courses in chemistry at Caltech. "The Modes of Science" was originally presented as a talk in the Caltech Lecture Series, at Beckman Auditorium on October 19.

An extreme example of analytical science is particle physics, and the biologists are surely doing science in the analytical mode when they narrow their focus to the subcellular level and discover molecular biology. On the other hand, astrophysicists seem inevitably constrained to work in the synthetic mode since there is no good way of tearing apart things in remote regions of the universe.

The most important scientific advances during the past 50 years have come from analytical science, and most scientists have worked in this mode or aspired to do so. Many of our most widely useful concepts—for example, quantum mechanics—could only have arisen as a consequence of the analytical approach to the study of matter. Unfortunately, the success of the analytical mode has led many scientists to the view that the reductionist approach *is* science and that no other mode exists. This has led in turn to unfortunate distortion of the scientific value system.

People have for years been raised in the scientific subculture to believe that systems of any significant complexity are dirty and unfit for proper scientific scrutiny. This even carries over to distortions of our language. Obviously a prerequisite for modeling any complicated system must be a description of the system; yet the term "descriptive" has come to be used in a pejorative way. In my own field, it has become a fashionable put-down to refer to a man's work as "descriptive." The term usually conveys subtle implications such as "lacking in true intellectual content" and "having no lasting value." While it is true that descriptive science can easily degenerate to encyclopedic accumulation of uncorrelated observations, I fail to see how we are going to make great progress in understanding the universe unless we take the time to describe it.

Another scientific bad habit is the tendency to apply entirely different criteria to mathematical descriptions and those given in any other language. Mathematics provides a vehicle for two rather different kinds of expression. First, some concepts having far-reaching value can be set down far more conveniently in mathematical form than in natural languages. Second, mathematics provides a precise way of expressing relationships between parts of a system. Each function is valuable in its own way, but we have come to regard almost any equation as automatically involving the best of both. Consequently, we frequently lose the most valuable components of observation by trying to force the description into mathematical form prematurely. This desire can even have a perversive effect on the way in which observations are made since an investigator may eschew any measurement that he cannot fit to someone's mathematical treatment. This acquired characteristic of modern scientists is partly responsible for our disinclination to undertake serious study of the complexities of the real universe.

An insidious mystique has evolved in science—the feeling that ultimately the analytical mode will tell us all about everything. The fanciful folklore about the relationships within science illustrates the point. We blithely chatter about chemistry finding a basis in particle physics and biology finding its roots in chemistry. There is no doubt whatsoever that the more complex sciences have derived invaluable inspiration from the reduced sciences. However, to parlay this into the conclusion that, if we wait long enough, all the elementary components will fall together like the pieces in a jigsaw puzzle is vastly deceptive.

I do not think that we will ever arrive at a total description of a living cell based upon integration of rate equations for the thousands of chemical processes going on within the cell. This conclusion is not based upon mystical notions concerning the physical process that we call life, but arises simply from consideration of the characteristics of complex systems. First, accurate identification and description of all the reactions in a living cell will take a long time and require an accounting system that may even strain the capacity of large computers. Even more important is the fact that in the living system the reactions do not operate independently but are coupled to each other. The rate at which one process occurs is strongly dependent on the rates of many others. In order to describe any such system, we will have to take account of an enormously complicated set of interactions. In the light of these considerations, I am convinced that theoretical models for living cells will always be just that—cell models. They will be incomplete as total descriptions of the chemical systems. However, good models for the cell will surely be strongly influenced by partial knowledge of the chemical activity within the cell.

There is really nothing new in this view. The interactions among the fields of science have always been a kind of bootstrap operation. If there is any legitimate ground for delineating the various fields of science and engineering, it is to be found in certain intellectual units useful in the various fields. In high energy physics the unit is a particle; in chemistry, the molecule; in biology, the cell; in psychology, the individual; and in sociology, the population. Disciplinary description in these terms is rather shallow, but may be helpful in understanding relationships and distinguishing between synthetic and analytical science. For example, the branch of theoretical chemistry devoted to molecular quantum mechanics is really an example of science operating in the synthetic mode. The best practitioners are developing valuable new models for molecules. They use many ideas and techniques, including concepts borrowed from particle physics. However, the notion that they are "analyzing" molecules in terms of elementary particles is quite deceptive. Yet many people in the field are so imbued with the value system of analytical science that they

An insidious mystique has evolved in science—the feeling that ultimately the analytical mode will tell us all about everything.

pretend they are doing analysis rather than synthesis. In short, they claim an objective that would be rather silly and fruitless, thereby hiding the real genius of their work.

The models for complex systems put together by synthetic methods will never be permanently fixed. To work effectively with models without jeopardizing our future, we must continuously work to distinguish between our conceptual models and reality. The models we can describe and examine in infinite detail whereas total physical reality will never be described by the mind of man. This seems to be one of the most solid theoretical conclusions that one can reach, simply because the number of elementary components in the brain is far less than the number of components in the universe. The necessary incompleteness and changeability of the models in synthetic science conflict with more than current values of science. They seem in conflict with that precept of our culture which drives us to seek definitive and final answers to everything. The notion that we can find *the* solution to any problem has probably been a powerful stimulus for development of analytical science but now stands in the way of full exploitation of our analytical success in building our synthetic capabilities.

People, including scientists, are funny. The challenge of really very complicated problems, such as preservation of the environment, has considerable appeal, and many scientists will surely be working in these areas in the future. I admire their enthusiasm and dedication and believe that they will make valuable contributions. However, it is always interesting to see people who are afraid to walk—but eager to run. Chemists who have been haughty in their attitude toward systems of moderate complexity in chemistry now rush to try their hands at the study of some of the most complicated systems available. Included are those who have long expressed utter contempt for the shallowness of social studies. I don't know how it will work out. Certainly some of us will learn appropriate humility, and I also expect that our real accomplishments in fields such as environmental studies will be significant.

Along with the big leap, we will probably undertake less glamorous but highly instructive forays into synthetic science. We should be able to learn a great deal about scientific systems analysis by moving out from areas where we have learned most from analytical study. A modest example from the work of my own research group is our attempt to use our knowledge of photochemistry as a tool in modeling the much more complicated chemical changes induced by high energy radiation such as gamma rays. As I indicated earlier, I believe that a tremendous opportunity exists to create useful models for living cells based upon the concept that a cell is a complex chemical machine. In recent years, there has been a good deal of interesting work in the field of properties of materials, their strength and hardness, how they fracture, and so on. Attempts have been made to relate these macroscopic properties to chemical structure. Although the field is in its infancy, I think it will develop rapidly in the near future. Surely, if the minds of men can construct imaginative and believable models for the history and current development of the universe, we can also formulate workable theories about the relationship between behavior of materials and the molecules in them.

If we are led to initiate a new era characterized by reemphasis of the synthetic mode of science, we have much to learn from a group of engineers who are trying to develop the field of systems analysis. For example, I anticipate that within a few years there will appear a group of people doing chemical science and calling themselves "systems chemists." Some of the classicists from the bygone era of 1950 to 1970 will undoubtedly attempt to denigrate the new activity by calling it "only engineering." Nor will even this kind of patrician conservatism be new; I can still recall a few people who bewailed the demise of real scholarship when the study of Greek was all but abandoned in the public schools.

It is no accident that my own examples are taken from the interfaces of chemical science with biology and engineering. When one reaches out, he reaches from wherever he happens to be, and I am in chemistry. I also want to say that Caltech is a remarkably good place for such speculative excursions. We are not immune from the kind of insularity that is characteristic of established disciplines, but we are small enough that a chemist can at least find the people working with complex systems if he hunts.

I have shared with you some of my own views as to the current problems within science. In some ways this seems risky because my doubts may be thrown back at me by those whose disenchantment with science takes a destructive turn; and there are many people who want to destroy science, or at least punish the scientists for their arrogance without concern for the consequences. I believe that science is still a baby, with great potential for further growth. I am disturbed to look at the baby and find it somewhat dirty. However, as the father of five, this is not an entirely new experience to me. Obviously, the baby needs washing. I fervently hope that we will not end up throwing the baby out with the bath water.

Counselors at Large

Being a campus counselor requires having a genuine liking for young people—whether they're agreeable and neat or barefoot, bearded, and bellicose.

When Caltech's psychologist Kenneth Eells retired in 1969, he was succeeded by Ian Hunter, who soon became as overburdened in the job as Eells had been. Last June Nancy Beakel was hired as a second psychologist and immediately found herself as busy as Hunter. Is this a manifestation of Parkinson's law? Not really. The fact is, Caltech's counselors not only dispense therapy, they also elect to be a part of campus life. This, it turns out, is an innovative way of working. In their relations with other colleges and universities, Drs. Hunter and Beakel both find that many campus psychologists are still so medical-center oriented that students don't see them unless a problem has already developed, and generally the medical center is alien territory at best.

Both Ian and Nancy see their task as two-fold: They must not only practice therapy but also do what they can to help students improve their ability to relate to other people.

Five days a week they keep regular counseling hours at Caltech's Young Health Center. They both come in, ready for their first session, at 9:00 a.m. Nancy has a good half hour drive from the Beakels' home in Sherman Oaks. Ian lives only ten minutes away from campus with his wife, Jan, and small son, Bruce.

Monday through Friday they each devote about 15 of the traditional 50-minute therapy hours to individual therapy with students who come regularly. In these cases the average counseling span is from six weeks to two months—generally until the specific problem bothering the student is pretty well in hand or the counselor feels he has done all he can. Occasionally they may see a student on a long-term basis if they feel they can be particularly helpful.

Who sees which student depends on who has the time—at the time—although students are always asked if they have a preference.

The biggest complaint that brings students to Ian's and Nancy's offices is pressure, which they say every Caltech student feels to some degree. The next most common problem is any number of variations on the inability to make friends, loneliness, and depression.

After their mornings of counseling—with the ten-minute breaks used mostly to return phone calls—lunch hour is generally a catch-as-catch-can affair. They may use the time to see a client if the need is urgent. They each manage to drop into a student house at lunchtime about once a week. This is probably easier for Ian than for Nancy, since many of the residents still accept a man's presence with a little more equanimity than a woman's. With Nancy, some students tend to act as if she isn't there at all, or she gets a "Who's *that* dame?" look. Nancy usually goes through the lunch line, sits down at any vacant place at a table, and starts asking questions until she can get a conversation going.

Several times a week Ian tangles into the noon basketball game at the gymnasium—a long-standing

mix of faculty and graduate students for the most part. On other days he may play touch football or get in a few games of tennis. He can cram this mini sports program in by skipping lunch, and since he continually battles the weight problem, he looks on a missed meal as a skirmish won.

After lunch, from 1:00 to 2:00 p.m. is the emergency hour for people who need help on short notice. If there is no emergency counseling, the psychologists will see somebody they haven't managed to work in at any other hour. They also try to keep the hour from 2:00 to 3:00 fairly open, and here they average two or three students a week who want to talk about dropping a course, or a leave of absence, or trouble with grades. Many of these are sent over by faculty members who have recognized

Nancy Beakel *lived in New York City for five years after getting a fine arts degree from the University of Texas, and worked as a classical repertory actress. She specialized in Shakespeare and Shaw, and met her husband, Walter, when he directed her in Shaw's play* Misalliance. *When they moved to Hollywood after her husband became a theatrical agent, Nancy enrolled at UCLA, took a year of undergraduate courses, and then went on to get her PhD in clinical psychology.*

Ian Hunter *is a graduate of Occidental College and took his PhD at the University of Oregon. He served a clinical internship at the Suicide Prevention Center in Los Angeles, and held a postdoctoral fellowship at the Langley-Porter Neuropsychiatric Institute and the Mt. Zion Psychiatric Clinic in San Francisco before joining the faculty at UCLA. He taught courses in psychology there and also supervised the clinical training of graduate students.*

a student in potential difficulty. Often such matters can be handled in a single session or on a "Come-see-me-again-if-things-get-rough" basis.

The psychologists keep records on whom they see and when, but the records are purposely kept sparse because of the confidential nature of the matters they deal with.

The greatest frustration for both Ian and Nancy is the lack of time. They simply cannot see as many students for as long as they would like. When it's financially possible, they refer clients to outside therapists. But any way they face it, they have to juggle too many students and too few hours.

"Each of the girls at Caltech has to make her own adjustment to her roles as a woman and as a scientist," says Nancy Beakel. "I hope we can help them identify some of their alternatives."

They have managed to give themselves some leeway by starting two therapy groups. One is held on Tuesdays from 3:00 to 5:00 in the Health Center conference room, and is for students either of them has seen briefly and feels would do well in a group. Some can't go the group route. The student who can't make friends is often so terrified by a group-therapy situation but he can't make use of it. Nancy and Ian are careful about putting students into groups, because they know that an individual has to be ready for this kind of experience—has to have some ability for give and take, and be willing to take some risks.

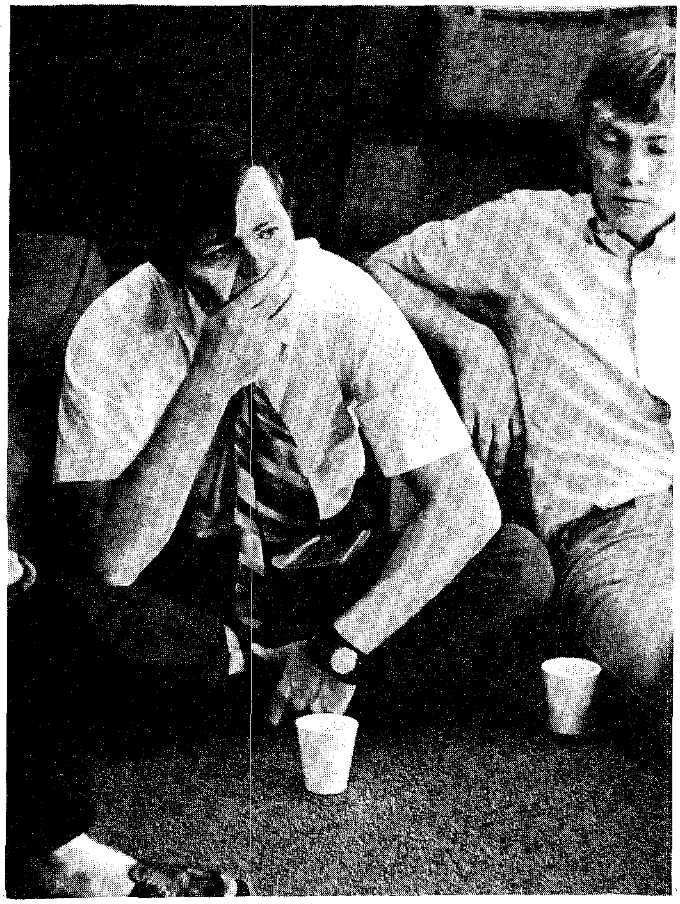
Their second group meets on Wednesdays in a clubroom in Winnett Center, and is a walk-in type. This focuses on specific problems and is a way a student can hear from others how they handled a similar situation. It may have to do with trouble in a specific course; or not being able to finish a paper; or having trouble talking to a certain professor; or possibly a student doesn't feel comfortable with members of his research group. And then there's always the chance of finding out how and why the other students may feel more comfortable in the presence of girls.

On afternoons when they aren't "grouping" they try to have a staff meeting—sometimes with Dr. Daniel Siegel (the Institute psychiatrist) or with Dr. Louis Breger, who is visiting professor of psychology this term.

These get-togethers are a comforting—and necessary—thing since they both acknewledge that they tend to pick up low moods from their clients. "Nancy and I can shore each other up and remind ourselves that these things do happen," Ian explains.

They try to keep time for a lot of meetings, many with the Caltech YMCA in activities planning. They meet as consultants every Tuesday evening from 5:00 to 6:30 with the student leaders of the Y's various encounter groups. With the YMCA personnel Nancy is now planning a seminar which will bring noted women scientists to the campus for informal discussions of their careers and philosophies. Both are working on plans for a Y-sponsored weekend in the mountains—and they will go along on the weekend as well.

Nancy recently led a group at a Fleming House encounter-group weekend. In this case, her husband came along and led a group himself. As a former repertory actor and director, he is just as interested as Nancy in getting people to realize their own potential, and he does his own version of therapy in the volunteer Student Development Center in Los Angeles. This is a center where school dropouts learn to put more value on their own worth. Beakel has the youngsters doing all kinds of classic theater, the idea (which seems to work) being that getting into a role not only unblocks tensions, but also brings heightened personal confidence to the student as well. It is possible that Walter Beakel will start an acting class on the Caltech campus this winter.



"Alienation, distrust, fear of disclosure, withdrawal, and loneliness are common to people in our society," declares Ian Hunter. "We'd like to help reverse some of that."

Ian and Nancy's campus activities take up many more hours than their counseling. If there are any other free-time chinks in their days, there are countless ways to fill them. Ian is collaborating with Richard Dean, professor of mathematics, on new teaching techniques for the latter's courses, and tries to get to a Dean class when he can. Nancy is turning her dissertation on intrafamilial communication patterns into a publishable research paper, and is working on a speech she will give at the December dinner of the Friends of the Caltech Y.

On the two campus psychologists devolves much of the task of helping students build up an informed and rational attitude toward drugs. Last summer, after plowing through almost everything written on drugs, they gleaned the best of it—several hundred books and articles—and catalogued it all. The drug library for students is now housed in the Caltech YMCA.

Each will teach a course this year, which will take up three hours a week, plus preparation time. Ian will teach abnormal psychology in the winter quarter—as he did last year. Nancy will teach a course in social psychology in the spring. This will be on the behavior of groups, the effects of communications on people, the process by which people operate in large and small groups, how groups form, and why certain people pick others to associate with.

Even though they seem to stretch their professional activities to infinity, it is remarkable what people can cram into their lives when they like what they're doing. As a carry-over from his days at UCLA, Ian still has some clients in therapy out in the west end of Los Angeles, and he sees them one night a week at an office in Santa Monica.

They both work their families into their activities when they can. Jan Hunter is as well known as Ian to many students, because she comes with him to dinner in the houses and on some of the weekends the students plan. Walter and Nancy Beakel like to drop into the Athenaeum basement on a Friday night and talk to the graduate students who gather there for an end-of-the-week letdown.

Their preferences in relaxation during the few hours when they are private citizens are widely different. The Beakels are home people and like to buy things and decorate. The Hunters are inclined to clear out of town, if Ian's schedule permits. They go camping at the drop of a sleeping bag, for a weekend at the beach, or sailing.

Ian and Nancy look on themselves as humanistic psychologists, Ian describing the term as "finding out what people are really like and then adapting our society to fit people's needs." They feel that the people they see in therapy are victims of society's preformed, arbitrary notions of institutions and behavior; that some very normal parts of their natures have been suppressed.

"Every person we see eventually brings up his loneliness," Ian says, "and how far away from other people and from himself he feels. There are successful techniques that can bring him closer to other people, and Nancy and I hope we can make a little progress in showing Caltech students what these are."

—Janet Lansburgh

The Month at Caltech

Applied Physics—a new option

What is potentially one of the most far-reaching curriculum changes at Caltech in many years is now off the drawing board and beginning operations. An interdivisional program of study in applied physics for both undergraduates and graduates is being organized, largely in response to requests by students, for a course of study that is applicable to their interests and accurately labeled for what it is.

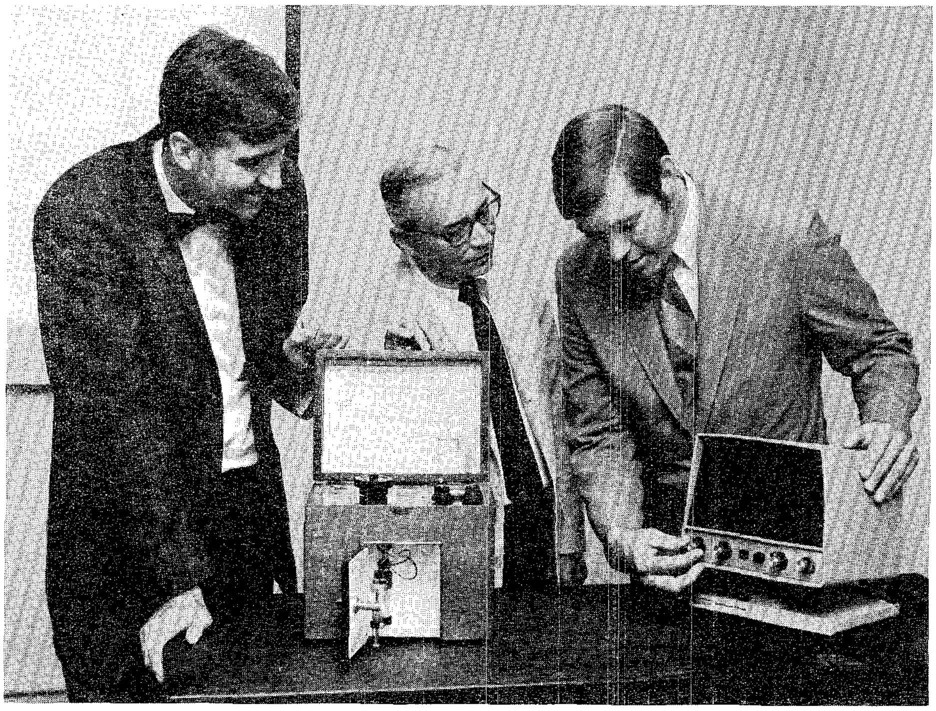
In March an ad hoc committee on applied physics (consisting of R. W. Gould, professor of electrical engineering and physics, as chairman; physicists Robert Christy, David Goodstein, Jon Mathews, and Ward Whaling; and Pol Duwez, Hans Liepmann, Milton Plesset, and Amnon Yariv from engineering and applied science) recommended the establishment of the program and stated four objectives:

1. To provide physics students who have a special interest in applications of engineering with a curriculum that has more emphasis on the behavior of matter in bulk (e.g., thermodynamics, statistical and fluid mechanics, quantum electronics, and plasma and solid state physics).
2. To provide engineering students whose interests include modern physics with a more thorough training in that field.
3. To provide the proper identification and coherence to a group of faculty and students in both engineering and physics whose special interests are in understanding the technological applications of physics.
4. To give justification and aim to the teaching of selected physics courses and thus strengthen the existing instructional program in those aspects of basic physics that are of great importance in extending current technology.

The next step in setting up the option was the appointment of an interdivisional committee for applied physics. Members represented a number of the options: Hans Liepmann from aeronautics; Floyd Humphrey, electrical engineering; Goodstein, low temperature physics; Plesset, engineering science; Thomas Lauritsen, particle physics; William Goddard, theoretical chemistry; and Charles Archambeau, geochemistry. Liepmann (as chairman), Humphrey, and Goodstein constitute an executive committee within the larger group.

Feeling that it was important to get under way as soon as possible, this committee took as its first task the piecing together of a program from existing courses. This was approved, with minor revisions, by the faculty board at its meeting on October 12. Administrative procedures will be worked out and new courses will be added as the needs and opportunities develop.

At present the applied physics committee is recruiting faculty members who are willing to cooperate in the new option and students who would like to switch to it. It is expected that the faculty and students may largely be drawn from the divisions of physics and of engineering and applied science at first, but the committee hopes that eventually there will be much broader participation.



Meter Passes Acid Test

As part of its 35th anniversary celebration this year, Beckman Instruments, Inc., of Fullerton, Calif., ran a nationwide contest to find the oldest Beckman product still in use. The winner turned out to be the Caltech chemistry laboratories, still happily using a 1936 pH meter developed by Arnold Beckman—once professor of chemistry and now chairman of the board of trustees at Caltech. Fred Anson, Caltech professor of analytical chemistry, left, and George Slingmeyer, senior administrative assistant in chemistry, center, accepted a new digital pH meter from Beckman's representative, but modestly refused an auxiliary prize—a free airplane trip to Fullerton.

Acting Chairman

Robert F. Huttenback, dean of students and professor of history, has been appointed acting chairman of the division of humanities and social sciences. A member of the Caltech faculty since 1958, Huttenback was master of student houses before his appointment last year as dean of students. He earned his AB and PhD degrees at UCLA and is an authority on British imperial history. He has done considerable research on the subject in England, India, and Africa, and last summer he studied the history of immigration policies in Australia.

Huttenback succeeds Hallett Smith, professor of English and chairman of the division for 21 years, who will now spend more time on teaching and research. An eminent scholar of Elizabethan literature, Smith has accepted a position as a senior research associate of the Huntington Library.

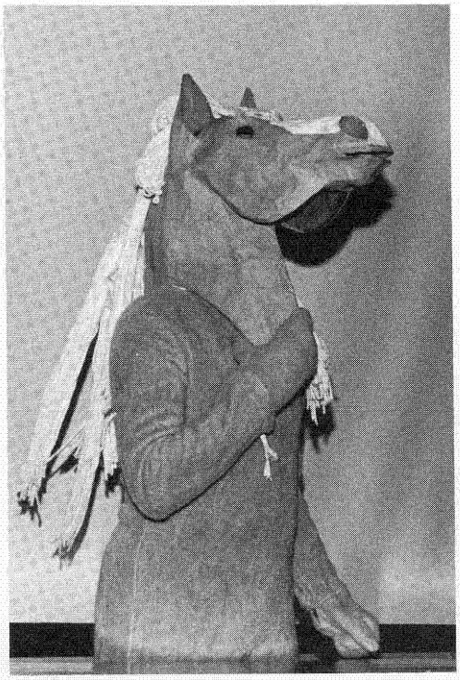
While a committee of faculty members, President Harold Brown, and Provost Robert Christy will continue their search for a permanent chairman for the division, Huttenback is moving ahead with the expansion of the programs of study in both the humanities and social sciences.

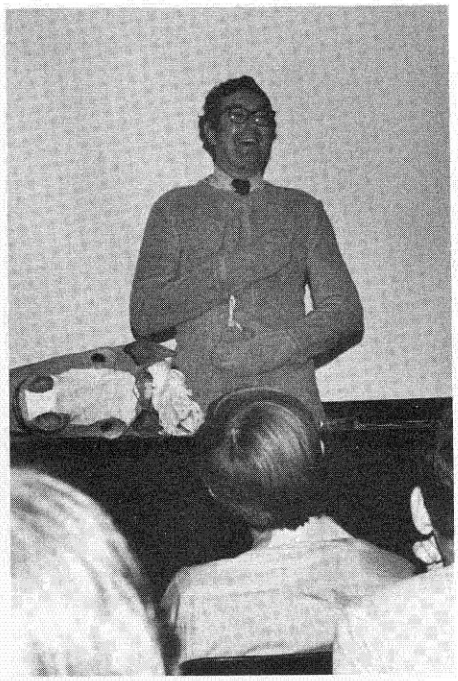
Exchange Program

Injecting diversity into the academic and social lives of Caltech students is of increasing concern to the faculty and administration of the Institute as well as to the students. While there are no easy solutions to this problem, an exchange program with Occidental College initiated this fall is a step in the direction of academic variety.

Students at each school may now take courses at the other and receive credit for them—up to the equivalent of one year of academic work. Caltech students probably won't be taking their math or science at Occidental, but they now have a wider range of humanities, arts, and social science electives to choose from. Participating in the program also makes it possible for the Institute to meet the diverse interests of its students without overloading its own faculty, facilities, or funds.

The agreement—worked out by an ad hoc committee on exchange programs consisting of Francis Buffington, chairman; Lyman Bonner; Kent Clark; Noel Corngold; S. A. Gabriel; R. A. Land; Gary Lorden; Peter Miller; Harvey Risch; and Hallett Smith—has been approved by both schools. It is based on two guarantees: First, no exchange of money will be involved; and second, each





Chemistry Harry-Gray-Style

When upperclassmen begin attending a freshman course, something is either wrong with the upperclassmen or right about the course. In any case Professor Harry Gray's freshman chemistry lectures are far from normal. His Monday lectures are serious, but his Thursday lectures are something else again—Chemistry Harry-Gray-style. He runs contests (rigged, of course) between staff and students; he has his beautiful young secretary perform demonstrations; he discards liquid nitrogen by throwing it across the room; and, for Halloween, he delivered the lecture dressed as a horse.

But all the demonstrations, contests, and secretaries in the world can't make a lecture course that popular; it takes a lecturer who will devote the time and understanding it takes to get along with his audience. His class knows that he is lecturing to 200 people, not 200 bodies, and Dr. Gray's relationship with the students goes far beyond the lecture. He is the most sought-after guest for dinner at the student houses. (Dining at Dabney House recently, he was not only the last to be served—when he lifted the lid of the tureen that was finally placed before him he found it contained his favorite dish, liquid nitrogen.)

About that horse—what would *you* do if your students had celebrated Halloween by filling your office with Hollywood-type cobwebs earlier that morning?

—Paul Levin, '72

institution will accept the admissions procedures of the home college as proof of the competence of the student.

Credit for the courses will be granted by the students' home school. A Caltech student who wants to participate needs the approval of his option, the division with courses most like the ones he proposes to take, and the registrar at the Institute. He must also be accepted by the instructor of the course he wants to take at Occidental. For reasons of draft status, health insurance, and veterans' benefits, the students are considered registered in their home institution for the total number of units being taken at both schools.

Graduate students are not excluded from the program, but it is expected that nearly all participants will be undergraduates. However, except in very unusual circumstances, it is not open to Caltech freshmen.

Eventually, the exchange program will probably be broadened to include other colleges, but Occidental was a natural first for several reasons: The academic terms of the two schools match; travel time between them is short; and Caltech and Occidental have a well-established academic relationship through the 3-2 plan, whereby students enrolled at Occidental (or any of several other liberal arts colleges) may follow a prescribed course there for three years, then transfer into the third year of the engineering option at the Institute for two years, and receive both an AB and a BS at the end of the five-year period.

New Professorship

The Clarence L. Johnson professorship in applied aerodynamics will be established at the Institute as the result of a gift to Caltech of $650,000. The gift, in the form of a trust, was made by Clarence L. Johnson and Althea Johnson.

Johnson, senior vice president and member of the board of directors of the Lockheed Aircraft Corp., is recognized as one of the world's leading designers of high performance aircraft.

Among the many honors he has earned is the Theodore von Karman award of the Air Force Association, named for the founder of Caltech's aerodynamics research program. Johnson has also received the Presidential Medal of Freedom, the National Medal of Science, the Lawrence Sperry award of the Institute of Aeronautical Sciences, and the Collier award for design of aircraft. He is a member of the National Academy of Engineering, the National Academy of Sciences, the Society of Automotive Engineers, and the Institute of Aeronautical Sciences.

Lauritsen Lecturer

Aage Bohr, Danish physicist, son of Nobel laureate Niels Bohr, and director of the Niels Bohr Institute at the University of Copenhagen, delivered the first C. C. Lauritsen Memorial Lecture at Caltech on October 29. The talk, "Concepts of Nuclear Structure," was the first of a series to be given each year in honor of Charles C. Lauritsen, professor emeritus of physics at Caltech and a faculty member from 1930 until his death in 1968. The lectureships are made possible by his friends and former students.

Bohr, who has had a long acquaintance with both Lauritsen and Caltech, began his talk with a short reminiscence about those associations:

"I should like to use the occasion to pay a warm tribute to what our group in Copenhagen owes to Charlie Lauritsen's support over the years. My father visited Caltech for the first time in 1933 at the exciting period when the newly established Kellogg Laboratory was initiating a series of major discoveries of new types of nuclear reactions, and he became deeply impressed with Charlie Lauritsen's genius as experimenter. There developed an intimate friendship between them and, in the following years, Charlie and Sigrid came on frequent visits to Copenhagen.

"My father was at the time occupied with the establishment of equipment for nuclear research at his Institute, and Charlie's advice and assistance was of the greatest value. Especially important was Charlie's initiative concerning the construction of an electrostatic accelerator and the arrangement whereby Tommy, who had been involved in the construction of such an accelerator in the Kellogg Laboratory, came to Copenhagen to make his valuable experience available. The Lauritsen family in this manner successfully launched the Niels Bohr Institute on a line of development that continues to be of basic significance for the nuclear research in Denmark. Moreover, the personal bonds between my father and Charlie Lauritsen grew into a tradition for cooperation between their two institutes. In Copenhagen, we have benefited from the stimulation provided by an illustrious series of visitors from Pasadena, and many of us have experienced the inspiration which a stay at Caltech offers.

"The cooperation has enriched the life of the Institute in Copenhagen in various respects. I found a copy of a letter from my father to Tommy from 1941, in which he acknowledges Tommy's 'energetic endeavours to refreshen the style of our conversations.' You may only fully appreciate what is referred to if you know Tommy's way of expressing himself in Danish."

Foreign Policy Seminar

Caltech and the Rand Corporation have joined in sponsoring a Southern California Arms Control and Foreign Policy Seminar. Established last month with a $285,000, three-year grant from the Ford Foundation, the seminar is designed to promote informed public discussion of the issues the United States will face in foreign policy and arms control in the 1970's.

The seminar has a workshop format in which senior members, with professional backgrounds, and younger participants can share their varied experiences and ideas. Participants have been invited from educational and research institutions and from industry, and they are now forming working groups that will develop research papers for seminar discussions and for publication. The results of intensive research on the selected problem areas will be combined during future discussions with debate on the possible goals of the United States.

Among the subjects being considered for examination are: U.S. commitments abroad, budget allocation and arms races, strategic arms control, and relations among Communist China, the Soviet Union, and the United States.

The idea for the seminar came from William Bader of the Ford Foundation and was further developed by leaders in industry and education—among them Caltech's president, Harold Brown, and David Elliot, Caltech professor of history and executive officer for the division of humanities and social sciences. Elliot is now co-chairman of the seminar along with Henry Rowen, president of Rand.

Letters

Missed Information

SIRS:

The listing of faculty and administrative changes at Caltech for 1970-71 was a most informative feature of your October issue. However, your list includes some *mis*information. Dr. Philip G. Saffman is indeed on leave of absence this year to the Massachusetts Institute of Technology, but he is professor of applied mathematics at Caltech—*not* professor of economics. And Peter Lissaman has indeed resigned to join Northrop Laboratories, but at Caltech he was assistant professor of aeronautics —*not* assistant professor of mathematics.

FACULTY OFFICE

He Ain't Seen Nothin Yet

DEAR SIRS:

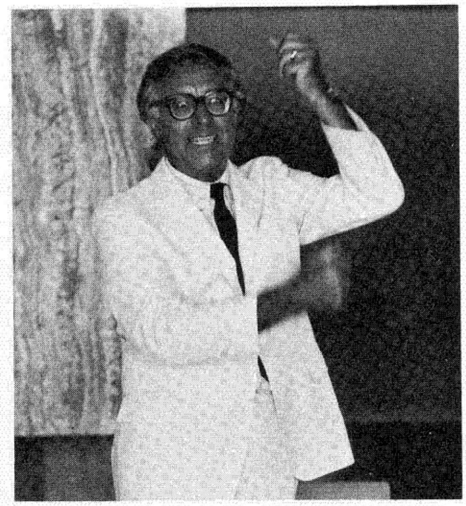
The photos illustrating my lecture/article in the current October *Engineering and Science* are some of the most hilarious I have ever seen. My wife and I fell on the floor and rolled when we saw them.

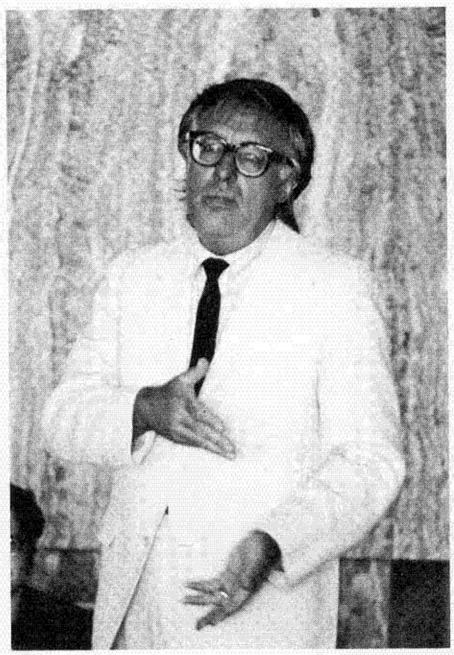
So, I would like to have extra copies of this issue to spread among friends, yes? Could you possibly send me an additional 12 copies?

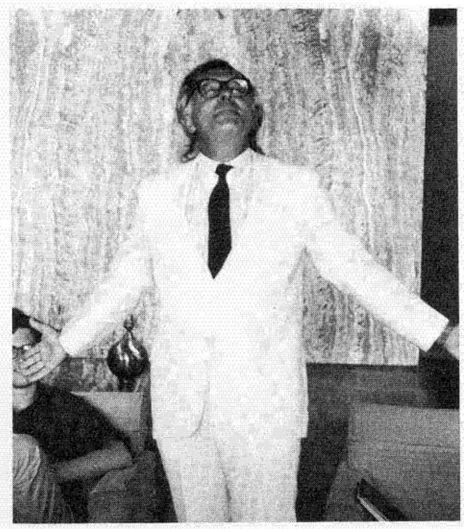
Many thanks. And my best to your photographer (Floyd Clark) who caught me in my conniption-fits.

RAY BRADBURY
Halloween Week, 1970!

Of course we're pleased that Mr. Bradbury liked the pictures we ran—but he should have seen some of the ones we didn't *run, like these.*







Statement of ownership, management, and circulation (Act of October 23, 1962; Section 4369, Title 39, United States Code)

1. Date of filing: Sept. 23, 1970.
2. Title of publication: Engineering and Science.
3. Frequency of issue: 7 issues per year.
4. Location of known office of publication: 1201 E. California Blvd., Pasadena, Calif. 91109.
5. Location of the headquarters of the publishers: 1201 E. California Blvd., Pasadena, Calif. 91109.
6. Names and addresses of publisher, editor, and managing editor: Publisher: California Institute of Technology, Alumni Association. Editor: Edward Hutchings Jr., 1201 E. California Blvd., Pasadena, Calif. 91109.
7. Owner: California Institute of Technology, Alumni Association, 1201 E. California Blvd., Pasadena, Calif. 91109.
8. Known bondholders, mortgagees, and other security holders: none.
9. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months.
10. Extent and nature of circulation:

	Average no. copies each issue during preceding 12 months	Actual number of copies of single issue published nearest to filing date
A. Total no. copies printed *(Net Press Run)*	8,928	8,750
B. Paid circulation		
1. Sales through dealers and carriers, street vendors and counter sales	20	20
2. Mail subscriptions	5,581	5,439
C. Total paid circulation	5,601	5,459
D. Free distribution *(including samples)* by mail, carrier or other means	2,457	2,131
E. Total distribution *(Sum of C and D)*	8,038	7,590
F. Office use, left-over, unaccounted, spoiled after printing	890	1,160
G. Total *(Sum of E & F—should equal net press run shown in A)*	8,928	8,750

I certify that the statements made by me are correct and complete.
—Edward Hutchings Jr.

"...I'm kind of a marriage counselor for the ocean..."

Vic Taylor is a corrosion specialist for International Nickel at its testing lab in North Carolina.

"...That old ocean doesn't like us sometimes. She rusts boats, eats away metals, destroys coatings... what we're trying to do is come up with alloys she can live with."

Inco's Francis L. LaQue Corrosion Laboratory, at Harbor Island, N.C., is testing materials needed for ocean engineering, desalination plants, water and sewage treatment facilities, bridges, boats, even houses. Testing not just nickel alloys, but 40,000 specimens of materials from many industries. Alloys, fabrics, coatings.

"...Remember how car bumpers used to corrode? Now it's a different story. And we're applying this knowledge to many industries. Making pollution control equipment, for instance, stand up longer than anyone thought possible."

Undreamed of advances are what Inco men are working for. Men who develop alloys, test them, search the world for more nickel. Nickel, the metal that makes other metals stronger, tougher, more corrosion resistant. Nickel, its contribution is quality.

INTERNATIONAL NICKEL

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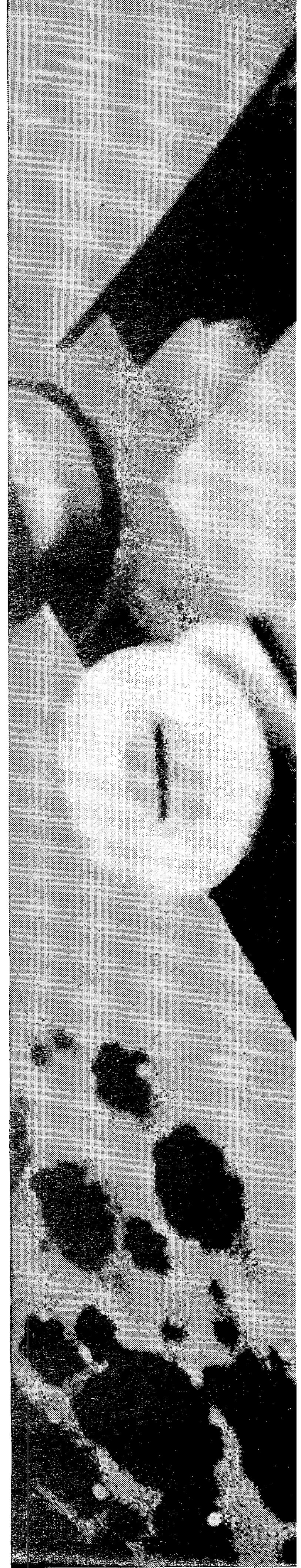
The International Nickel Company of Canada, Limited, Toronto, Ontario
International Nickel Limited, London, England

Vic holds a nickel-chrome plated automobile bumper which was tested in the corrosive seaside atmosphere.



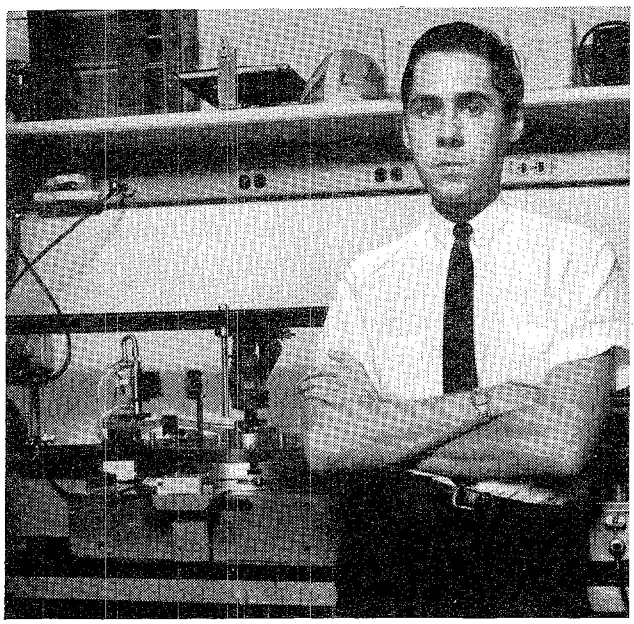
Photography by W. Eugene Smith.

"There's a little more freedom here to direct my own research than at most company labs."

Bob Pfahl, Western Electric

Thermal energy is his field. And since 1968, Bob Pfahl has been doing research and development in radiant heat transfer on the staff of Western Electric's Engineering Research Center.

Well-backgrounded, Bob holds three degrees from Cornell University—a bachelor's in mechanical engineering, and a master's and doctorate (received in 1965) in heat transfer.



"My job is self-motivating," said Bob. "I have to look ahead to see where I think research should be done."

And one such area was the design of heating equipment. Western Electric uses radiant heating in a variety of manufacturing processes because it's quick and inexpensive, and because it can be applied at a distance.

However, because of the limitations of existing reflectors, radiant heating has been limited to small areas. Bob has developed a reflector shape which uniformly distributes energy from a compact mercury arc lamp over larger circular areas.

"Many projects grow out of previous or existing work," Bob said. He explained that in order to calculate the reflector shape, he had to first design an instrument to measure reflectance of the reflector material.

"But we're well supported here at Western Electric," said Bob. "We have very fine lab equipment—and can obtain the equipment we need."

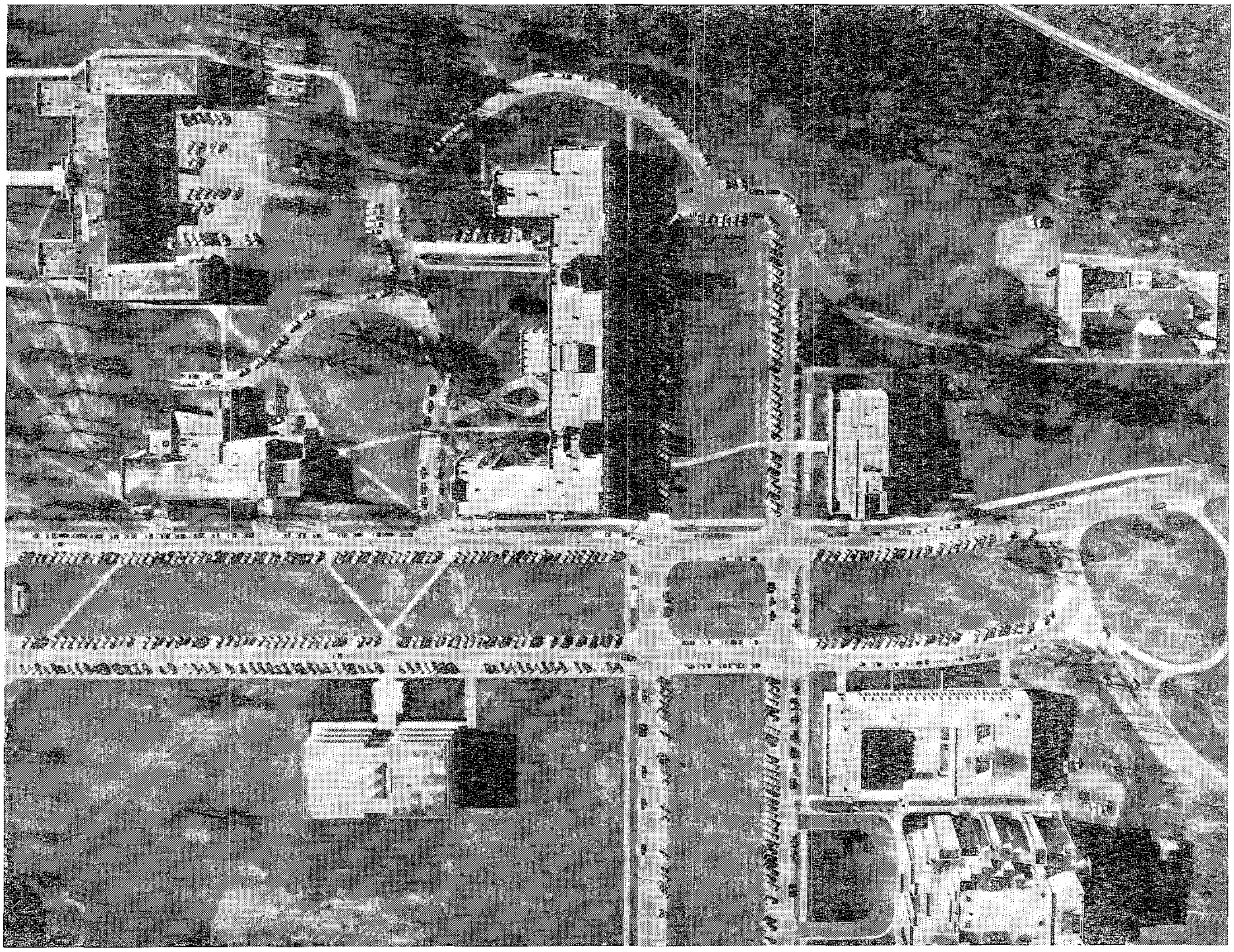
So Bob designed and built his "spectral bi-directional reflectometer." It provides data for a computer program he created that calculates reflector shape by numerically integrating a set of differential equations.

Bob is currently working on the development of an even newer type reflector which will distribute energy from line type filament lamps over a large rectangular area. An array of these reflectors will allow the uniform heating of almost any size workpiece.

"We're free to look around for our own projects," said Bob. "I like that—that's why I'm here."

Western Electric

An Equal Opportunity Employer



An engineer can cut crime as well as any cop. Maybe better.

Last year, murder was up 7%. Rape was up 17%. Robbery was up 14%.

It's getting to the point where a woman can't show her face on a dark street. And grown men are running scared. Sadly, crime has become a part of our everyday lives.

Where do we turn for help? To police, of course. But why not also to engineers?

Engineers at General Electric set out to develop a more efficient streetlight. And they came up with one of the most efficient crime fighters ever invented.

It's called the Lucalox® lamp. It puts twice as much light on a street as any other lamp without any extra operating cost. And wherever Lucalox has gone up, crime has gone down. By 50% or more in city after city.

But that's not all an engineer can do. He might design communications equipment that enables one patrolman to do the job of two. Or a complex of traffic monitors that puts twenty cops back on the beat. Or even a patrol car to do its special jobs in a better way.

It's sometimes hard for people to realize that engineers, with their technology, can solve social problems. But, in fact, some social problems can't be solved any other way.

So if you're an engineer who's bothered by social problems, you're in a unique position to help.

General Electric could use your help. We see more problems around us than we know how to solve. So what we need is more engineers.

GENERAL ELECTRIC

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