ENGINEERING AND SCIENCE

APRIL/1958

Faculty Portraits . . . page 15

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Picture of a man trying to wreck a train

Railroad trains have been clocked at speeds as high as 111 miles an hour. Most trains on open stretches run on a schedule that exceeds 60 miles per hour. Isn't it remarkable, when you think of it, that nobody ever wonders whether the *wheels* will hold up? For many years we have made this our concern so that it would never have to be yours.

To make sure that fast trains will also be safe trains, U. S. Steel research teams carry on a continuing study of railroad wheels at the U. S. Steel Research Center at Monroeville, Pa. Wheels of the type used in high-speed service are subjected to the toughest trials which can be administered on the world's largest inertia dynamometer. Here wheels are driven at speeds equivalent to 160 mph, with the dynamometer generating 68½ million foot-pounds of energy—enough to lift a 34,000-ton ocean liner one foot in the air. These tests show us the minor revisions in design which enable us to maintain the wide safety margin for the ever-increasing speed of operation. Today's wheels would provide complete safety at train speeds which are, as of now, impossible to attain.

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More of our story is told in the booklet, "Paths of Opportunity," which you can obtain by writing to United States Steel, Personnel Division, Room 1662, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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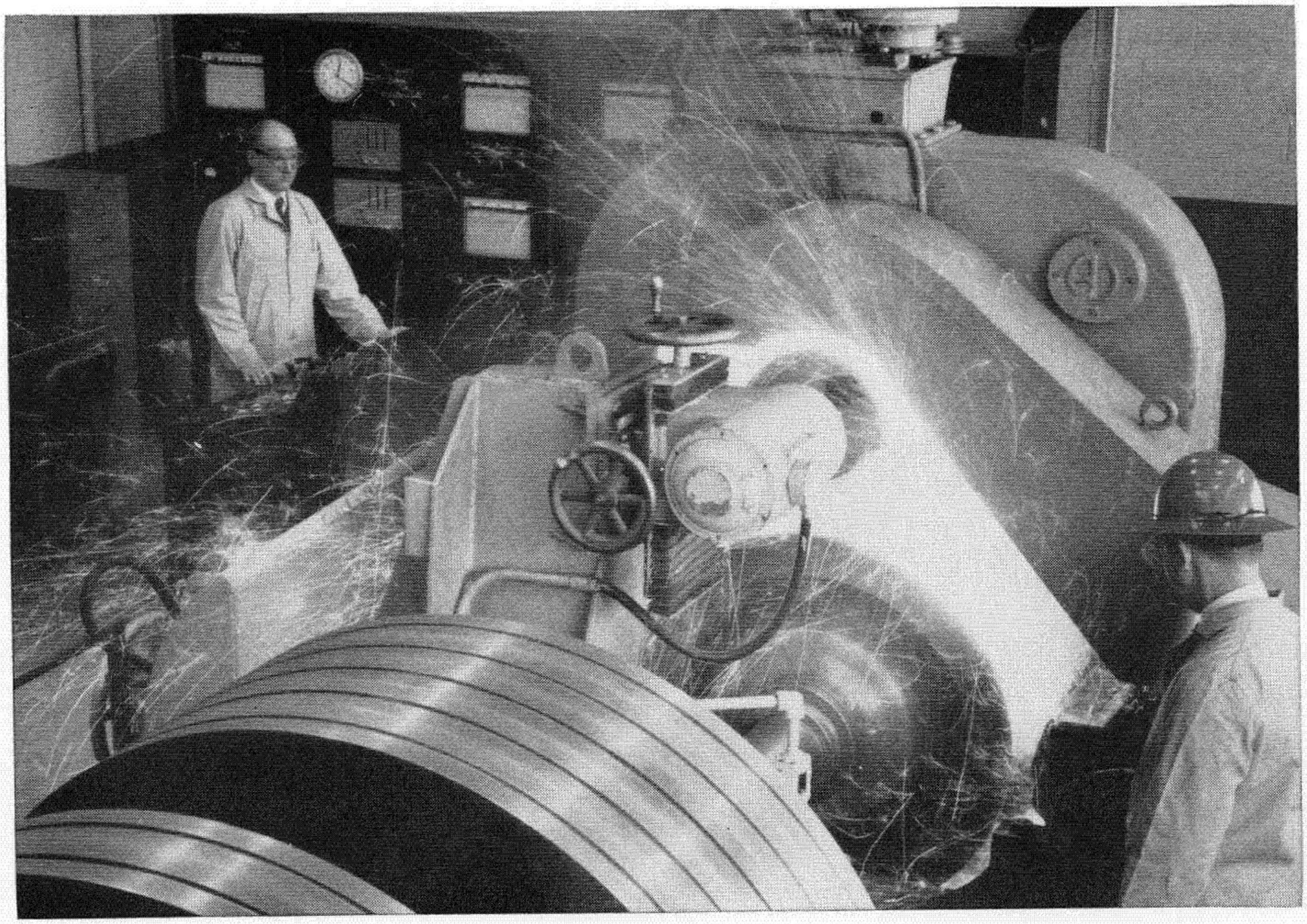

USS United States Steel

"They all agree..."

"Since the day we decided to get married, I've been doing a lot of thinking about our future. It's time I made a choice on a career. I've talked to the Dean of Engineering, most of my professors, and to some of the fellows who have graduated, and you know, they all said the same thing.

"They all agree that the aircraft and missile industry holds the best opportunities and the brightest future for an engineer these days. What they said makes sense, too, because developments in this field today really give a fellow an opportunity to make important contributions on vital projects.

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Unlimited opportunities, high salaries, company-paid benefits unheard of until a few years ago — these are only a few of the reasons why so many young engineers with a keen eye to the future are choosing the aircraft industry.

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BUILDERS OF THE FIRST INTERCONTINENTAL GUIDED MISSILE

ENGINEERING AND SCIENCE

IN THIS ISSUE

ON OUR COVER—a portrait of Linus Pauling, chairman of Caltech's division of chemistry and chemical engineering, taken by Tom and Muriel Harvey. The picture heralds another collection of faculty portraits by the Harveys, on pages 15-20 of this issue. This is the fourth group of these portraits we have run. If you'd like to check back on the others, see *E&S* for December, 1957; May, 1957; and December, 1956.

"THE CHALLENGE OF THE SPACE AGE," a worthy successor to President DuBridge's "Challenge of Sputnik" (*E&S*—February, 1958), has been adapted from Dr. DuBridge's keynote address at the Western Space Age Conference, sponsored by the Los Angeles Chamber of Commerce and held in L.A. on March 20-22.

ROBERT L. SINSHEIMER, who wrote "A Search for Simplicity" on page 21, is professor of biophysics at Caltech. A graduate of MIT, where he received his PhD in biophysics in 1948, he was on the faculty of Iowa State College from 1949 until 1957, when he came to Caltech.

PICTURE CREDITS

Cover, pps. 15-20 — Harvey

p. 30 — Graphic Arts

APRIL, 1958 VOLUME XXI NUMBER 7

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Books

Puzzle-Math

by George Gamow
and Marvin Stern

The Viking Press, N.Y. $2.50

A couple of years ago George Gamow, professor of physics at the University of Colorado, and author of a series of deservedly popular science books *(The Birth and Death of the Sun, Biography of the Earth, One, Two, Three . . Infinity,* and *The Creation of the Universe)* spent a summer in San Diego as a consultant to Convair.

In this position Dr. Gamow had to confer a good deal with Marvin Stern, technical assistant to the vice president of Convair. The two men had offices on different floors, so they became heavy users of the elevators, and they soon noticed a curious thing: Whenever one of them started out for the other's office, the first elevator that came by was almost always going in the wrong direction.

Direct action

Now, maybe this *wasn't* a particularly original observation; it must have occurred to *everybody* at some time or other. The difference is that, where most people just indulge in a little swearing and then forget the whole thing, Gamow and Stern have *done* something about it; they have written a book.

In the course of solving the elevator problem (it's in the book, on page 59) the two men discovered that they had a mutual weakness for mathematical puzzles—and this book is the result.

There are some 30-odd brain-twisters here, presented in the form of short stories. (Dr. Gamow, of course, could be counted on not to present *anything* in school textbook style.) This technique manages to trap those people who are still nervous in the presence of mathematics by involving them in the *problems* rather than in sets of figures.

Puzzle addicts can count on this book for several long, sleepless nights. It is dedicated to a famous addict — "Theodore von Karman, who likes puzzles."

Fantasia Mathematica

edited by Clifton Fadiman

Simon & Schuster, N.Y. $4.95

In his introduction to this anthology, Mr. Fadiman claims that the stories and oddments he presents here are not suitable for mathematicians, "who will be bored by their naiveté." Even non-mathematicians may not learn much mathematics from them, Mr. Fadiman says, "but they may lead readers like myself, curious but unlearned, to create a better image of a few mathematical ideas."

Odd numbers

The book is divided into three sections. The first (called "Odd Numbers" because the material is drawn from writers not usually associated with the field of mathematics) includes short stories by Karel Capek and Aldous Huxley, mathematical snippets from novels by Arthur Koestler, James Branch Cabell and H. G. Wells, and even one of Plato's Socratic dialogues.

The second section of the book ("Imaginaries") consists of 16 short stories. Most of these come from the science-fiction field, but there is also one of William Hazlett Upson's Alexander Botts stories from the *Saturday Evening Post,* and the late Russell Maloney's *New Yorker* classic about the man who decided to test the mathematical cliché that six chimpanzees, pounding six typewriters at random, would eventually write all the books in the British Museum.

The book ends with a miscellany of poems, paragraphs and jokes. All in all, it's a graceful collection, a beguiling book—even for mathematicians.

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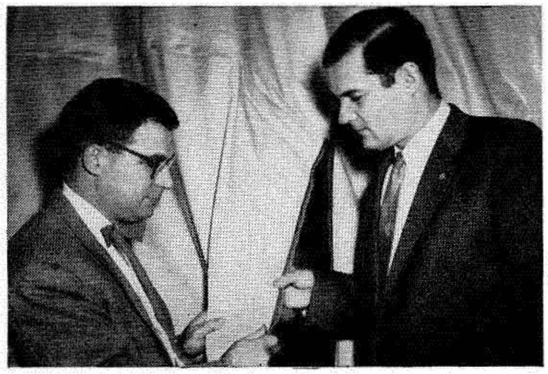
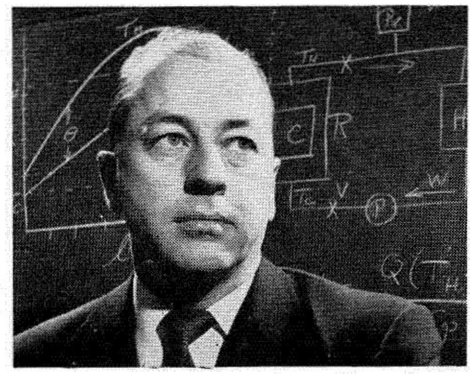
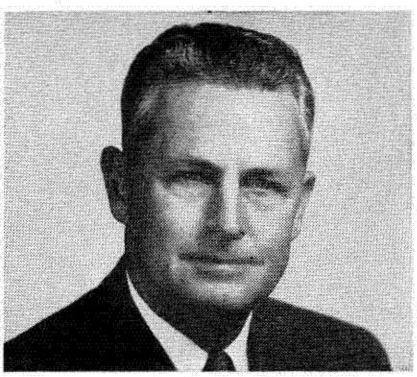
AIMS TORPEDOES. C. H. Jones (Northwestern—EE) is Assistant Department Manager of electronics and nuclear physics department. He recently invented a new device for underwater acoustics applications. While at Westinghouse he has supervised varied research projects on color TV, antennas, micro waves, radar and sonar.



BATTLEFIELD RADAR. J. W. Currie (U. S. Naval Academy—EE) and C. J. Miller (Virginia Polytech—EE) check fabric of the huge Westinghouse paraballoon, which they developed with the help of Cornell Aeronautical Laboratories. This lollypop-shaped device, more than 30 feet high when inflated, makes possible for the first time a lightweight, mobile radar antenna which can be set up near the front lines to support ground troops in battle.



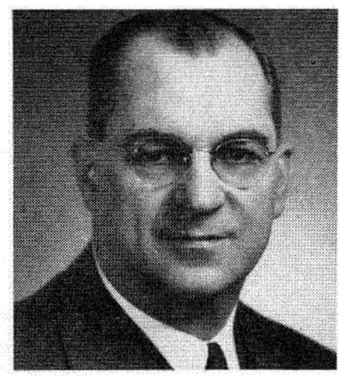
ATOMIC FLEET ENGINEER. P. N. Ross (Harvard—EE) is assistant manager of Large Ship Reactor Project for Westinghouse. He joined the company as a graduate student, rose rapidly in nuclear work. Mr. Ross played a key role in development of USS Nautilus, the first atomic submarine.



HEADED NEMA. J. H. Jewell (Pratt Institute—ME) headed National Electrical Manufacturers Association in 1954-55. He is Westinghouse vice president in charge of marketing.

TURBINE EXPERT. C. C. Franck Sr. (Johns Hopkins—MME) is consulting engineer in Westinghouse Steam Division. His research helped develop the Normandy invasion fleet. He is an internationally-known authority on steam turbines.

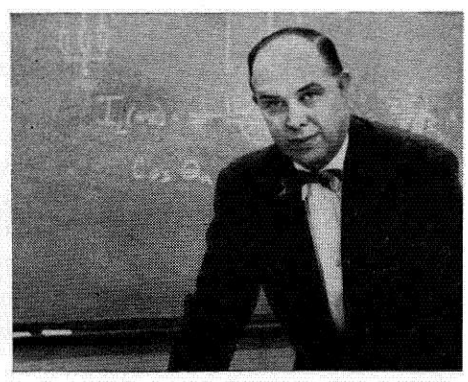
UTILITY "DOCTOR." As head of the Westinghouse Electric Utility Engineering Section, J. K. Dillard (Georgia Tech.—EE) helps diagnose ills and treat problems of 220 electric utilities across the nation. AC calculating board in background is largest computer of its kind in industry.



AIEE PRESIDENT. A. C. Montieth (Queen's University, Kingston, Ontario) was 1954-55 president of AIEE. He is vice president in charge of all Westinghouse apparatus products divisions.

WINS LAMME MEDAL OF AIEE The Lamme Medal, one of the nation's top honors in electrical engineering. was won in 1955 by Dr. Clinton R. Hanna, (Purdue—EE) associate director of Westinghouse Research Laboratories. Left to right: Dr. John A. Hutcheson, (North Dakota—EE), Westinghouse vice president in charge of engineering; Dr. Hanna; and M. D. Hooven, AIEE head. Seven other Westinghouse engineers have won the Lamme Medal and 11 others the AIEE's Edison Medal.

MOST EFFICIENT POWER STATION. J. W. Batchelor (Purdue—EE), head of Westinghouse Turbine Generator Engineering Dept., looks over the equipment which he helped to develop at Kyger Creek (Ohio) power station. The Federal Power Commission labelled this the most efficient station in the nation for 1955. Four Westinghouse turbine generators, each rated at 217,260 kilowatts, are there.



MODERN-DAY PIONEER. Dr. R. A. Ramey, Jr. (U. of Cincinnati—EE), is a pioneer in magnetic amplifiers. Joining Westinghouse in 1952 as a section engineering manager, he is now manager, new products department. He also had an important part in guiding the development of Cypak, the Westinghouse industrial control unit that thinks, decides and remembers.

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FIRST WITH THE FUTURE

The Challenge of the Space Age

Separating the sense from the nonsense about space travel

by L. A. DuBridge

Within the past few months the space age has dawned. Many people of varying degrees of competence have ventured to peer into the future and make predictions as to where we are going. Needless to say, these predictions do not all agree with one another—and yet, to some extent, to visualize the challenges of the space age we must make a choice as to which of these predictions we are going to believe.

Now who am I to try to make such a choice? I am not a rocket technologist or a space engineer. But the problem of calculating approximate satellite orbits in space is a simple problem in classical physics! The theory was all worked out by Kepler and Newton nearly 300 years ago—and no quantum mechanics or relativity or meson theory or similar erudite subjects are necessary to understand the elements of the problem.

This is a very fortunate situation. We will probably be spending a lot of money on space technology in the coming years, and it is comforting to know that we need not be at the mercy of a lot of so-called experts. If someone makes a statement about some phenomenon having to do with space travel, we can get the nearest high school or college physics teacher to tell us whether the statement is right or not. It may take an expert engineer to tell us how much some of these things are going to cost, but there do not need to be any mysteries about how things behave once they get into space.

First, I suppose everyone realizes that the earth's gravitational field does not stop at the top of the atmosphere 100 or so miles up. Rather, it extends for hundreds of thousands, even millions of miles into space, falling off in intensity inversely as the square of the distance from the earth's center. Even if we get away from the earth's field we are still in the field of the sun, which extends out a very long way indeed.

From these simple facts there follows at once a very important conclusion: There is no such thing possible as a *stationary* object in space. Everything in space is moving. An object stationary with respect to the earth, for example, would promptly fall into the earth, pulled by gravity. The only objects which can stay in space are moving objects—specifically, objects moving in such a way that the gravitational force on them is, on the average, balanced by a centrifugal reaction. Under these conditions a permanent path or orbit may be established about the attracting center—and such an orbit is always an ellipse or, in special cases, a circle, which is one kind of an ellipse. Stationary "space platforms" are a Buck Rogers myth.

There is also a precise relation between the period of the orbit—that is, the time required to travel once around it—and its average height above the earth, or more precisely, its major axis. Thus, for an orbit only 200 miles above the earth the period is always about 92 minutes; for an orbit averaging 1,000 miles above the surface, the period is 118 minutes. At about 20,000 miles the period is 24 hours; and of course at the distance of the moon, 240,000 miles, the period is the moon's period, 28 days.

The farther you are away from the earth, the slower is the speed required for a stable orbit, and the longer it takes to traverse it.

If, for example, you wish to establish an object in a very elliptical orbit which goes out as far as the moon and back, the period in that orbit (an ellipse whose major axis is about 240,000 miles) turns out to be very nearly 10 days—5 days out and 5 days back.

It has now been established that modern rocket technology has advanced to the point where it is possible to project into stable orbits about the earth objects of substantial weight—say, in the near future, up to 1,000 pounds or so. With a somewhat smaller payload the orbit could be sufficiently elliptical to reach to the vicinity of the moon.

A scientist cannot help but be excited by this prospect. Every now and then new advances in technology give science a new tool for research. The earth satellite is a tool *par excellence*. It opens up wholly new areas of scientific exploration—and America has a great opportunity to grasp these opportunities promptly and boldly.

Promising explorations

Just what scientific explorations are most promising?

To the layman who wants us to establish a colony on the moon next month, the experiments I have in mind may seem a bit less than bold. But, in contrast to some of the more fabulous schemes now being discussed, the ones I propose have the virtue of being both feasible and useful.

First, from the vantage point of an earth satellite we can learn a great deal about our own earth. We can learn more about its exact shape and size and the distances between important points. We can learn more about its gravitational anomalies, which are important in many types of geophysical explorations. Of even more practical value, we can learn more about the weather. The great meteorological patterns of storms and air currents which are so difficult to see from the surface will become much more understandable when we have observations from above the atmosphere.

The earth's magnetic field—its nature, variations and origin—also constitutes a scientific puzzle which observations a few hundred or a few thousand miles out into space will certainly help solve. To what extent is the field connected with electric currents in the ionosphere? What is the precise nature and extent of the ionosphere itself? How will radio waves behave when bounced off the top of the ionosphere? What happens as they pass through it? To what extent and in what way is the ionosphere affected by radiations from the sun—by solar flares and other eruptions, for example? Can these effects be related to radio propagation on the earth?—to the weather?—to high altitude jet stream winds?

Again, a whole book could be written about what the astronomers would like to do with a telescope which is above the atmosphere and which could see the heavens for the first time unaffected by the disturbances, the distortions, the absorption and the stray radiations of our blanket of air. The problems of stabilizing a telescope on a satellite in order to get good pictures are not easy. And the problems of transmitting pictures of good quality back to earth, presumably through some type of radiophoto technique, are even more difficult.

But these are problems which can be solved in time, and there is much to be done even with relatively crude techniques. Man has never been able to measure directly the ultraviolet light from the sun, for example, since it is all absorbed at very high levels in the atmosphere. Even crude pictures of the sun taken in ultraviolet light would be of great interest, and would help us understand some of the complex processes going on in sunspots and solar flares.

And then there are the cosmic ray problems, such as those being examined in the first U.S. satellites, Explorers I and II. The effects which primary cosmic rays produce in our atmosphere are so complex that these secondary phenomena delayed for 20 years our understanding of the true nature of the primary cosmic rays themselves. To observe these primaries for the first time on a continuous basis, completely unencumbered by the multiplicity of secondary phenomena which occur when they strike the air, will advance enormously our knowledge of their nature and origin—and this may help us unravel some of the deep puzzles about the origin and evolution of the universe, of our galaxy and our solar system.

I have said that experiments and observations such as these and many more are technically feasible. Many of them are feasible right now with satellites weighing only from 50 to a few hundred pounds. But there are a number of technical difficulties which will be with us for a long time. One, of course, is the unreliability of the rockets which launch these objects. These rockets are bound to be big and expensive devices, and it is important that we do not lose half of our experiments through technical failures of the rockets themselves. It will be some time before even a 50 percent overall reliability can be achieved, I am told. And 90 percent is still in the future.

Providing an energy source

An even more troublesome problem is that of providing an energy source to power the various satellite experiments and to transmit the intelligence by radio back to earth. Thanks to the development of extremely sensitive receiving techniques, we can use radio signals from a satellite transmitted with a power of only 1/100 of a watt—provided the distance from the earth does not exceed a few hundred miles. Even the 20-pound payload of Explorer I has enough batteries to power such a transmitter for two months or so. But the Explorer I satellite itself will stay in orbit for many years—and it is exasperating to have all those valuable instruments, gotten up there at such great expense, remain completely useless all that time. And as we project objects farther out into space and put more complex equipment aboard, we will need not only longer life, but also much more power.

To detect a radio transmitter which is near the moon, for example, may require a power not of .01 watt but of 10 watts—1,000 times as much. We don't need to transmit signals all the time; we can develop more efficient batteries; we can put more batteries in the larger vehicles and use solar batteries. But the fact remains that the limit to how much information we can obtain from scientific satellites will be set primarily by the strength of the energy source they can carry along. Even solar batteries cannot provide large amounts of power in moderate-size units—and, of course, they cease to operate when the satellite enters the earth's shadow.

If the problem of energy sources looks pretty difficult for satellites requiring only a couple of watts for a few weeks, think of the colossal problems facing us when we try to plan more extensive and complex space expeditions. The great hero of the space age will be the man who invents an extremely compact device for storing quite large amounts of energy. None is now in sight.

So far I have said nothing about satellites which carry human beings. The reason is simple. For most scientific explorations in space the presence of man involves quite unwarranted complications and expense not justified by what he can contribute to the success of the venture. True, a man makes a pretty good servo system; he could keep a telescope pointed at the right star, for instance. He could also supply a little bit of energy—by turning a crank connected with a dynamo to charge up a battery, possibly. But in return for this he demands a colossal price. He not only requires that we take along air and water and food and other things to keep him alive and comfortable, *but he also requires fantastically expensive* provisions to bring him back alive.

Man against instruments

No set of *instruments* demands such a ridiculously expensive luxury. Instruments are content to coast around in space, unused and unattended for years, and then to come back to earth, if at all, in a fiery cataclysm. But not a man! He wants to get back to earth, and he wants to get back not only unburnt but essentially unjarred as well.

I assure you this is not easy, and we are a long way from having the facilities to do it in any practical way. Consider a satellite vehicle rotating in an orbit some 200 to 400 miles above the earth. Its speed will have to be in the neighborhood of 18,000 miles per hour, or 5 miles per second. Suppose this vehicle is large enough to carry a man, and the man now wants to return to earth. How does he do it? Obviously, jumping out of the vehicle with a parachute and an oxygen tank won't do it. There is no air to affect the parachute, so our man would become another satellite floating alive around the earth at 18,000 miles per hour—alive, that is, until his oxygen gave out.

No—he'd better stay in his vehicle. He will then find he needs a sizable rocket motor and a good deal of unused fuel so he can reduce his speed and lower himself gently into the atmosphere, where his parachute may be used. This is no mean trick, and it will require a large amount of rocket propellant—all of which will have had to be a part of the payload with which he was launched in the first place. So the initial payload will have to be, not a few hundred pounds, but many thousand pounds—and, of course, the size of our launching rocket has increased proportionately.

But let us interrupt our discussion of the scientific uses of space satellites at this point and ask what other uses such vehicles have. We think at once of possible military uses and then of the use for space travel, or space adventure. Whether the human being is of any use for scientific observations or not, human beings are going to insist someday on taking journeys out into space. The spirit of human adventure cannot be suppressed, no matter what it costs. Granted adequate resources and adequate time for technological development of the necessary equipment, men can certainly be projected into orbits around the earth someday, and eventually into orbits which go far from the earth. There is nothing about space travel which man can't stand—except perhaps the expense. Provided he is housed in a suitable container supplied with oxygen, water, food, and suitable temperature controls, there is nothing in space that will hurt him. On long journeys he is more likely to die of boredom than anything else.

Landing on the moon

But when we talk about landing a man on the moon or Mars or some other planet, and then getting him off again and back home safely, we are talking about a new order of magnitude of difficulty and cost. To land safely on the moon will take the same sort of rocket equipment that would be required to lower him back to the earth. The gravitational force on the moon is smaller, so that will help, but also there is no atmosphere on the moon to support a parachute. Hence the entire vehicle will have to be lowered gently to the moon's surface using the rocket blast alone—like the landing of a vertical-take-off jet plane. Then there will have to be enough fuel for the vehicle to take off again, get projected into an earth-bound orbit, and there will still have to be enough fuel left over to lower the vehicle gently into the earth's atmosphere.

During all this time the man has had no access to any supplies of oxygen, water, food and energy other than what he carried with him on take-off. And the entire round-trip in the best orbits for the purpose would consume not less than 10 days. I will leave it to some rocket experts to calculate what payload would have to be lifted from the earth for such a journey—and how many millions of pounds of initial thrust it would take to do it. There is nothing impossible about it, you understand. It will just take a lot of money and a long time. Whether it is worth it or not depends on our concept of the values to be achieved.

Clearly, a man landing on the moon and coming back could bring valuable scientific information, such as samples of the moon's surface (if he didn't get roasted or frozen while on the moon's surface, which boils water in the daytime and freezes carbon dioxide into dry ice at night). His visual and photographic observations would be of great scientific interest. I think, however, that most responsible scientists (not counting the Space Cadets) would feel that we could collect plenty of scientific data about the moon during the next few years by cheaper methods.

What about the military value of space travel?

Obviously, military *ballistic missiles* which will hit accurately any point on the earth from bases in the United States, with payloads of 1,500 pounds or more, are very important military weapons. Nothing should impede our efforts to develop and manufacture them and continue to try to make them cheaper, more reliable and more effective. That, in itself, is a big job which will take a lot of talent and money during the coming years. That is the challenging job which American industry and American technology must not lose sight of.

Obviously, also, the rocket techniques which will carry sizable warheads on trajectories of 5,000 miles or so on earth are also automatically adequate, with but moderate changes, to launch earth satellites of a few hundred pounds weight, more or less, into orbits around the earth—and even out to the moon or beyond.

Military satellites

What military value will such satellites have?

First, they will make fine reconnaissance vehicles. With suitable optical and telemetering equipment, they will provide interesting pictures of most of the earth's surface every few days, if the orbit is properly chosen. Let's hope we can load enough batteries aboard so we won't have to send up a new vehicle every two weeks or so because the old one's batteries have run down.

Second, our military satellite will be good for weather observations—and military men always seem to be interested in the weather.

That, as far as I can see, is about the end of the story on the military value of earth satellites. Probably some communication techniques will be worked out; possibly someone can figure a way to use satellites for radar antennæ. But as weapon delivery systems they are clearly not very interesting. You can't drop a bomb from a satellite; it just won't drop! And to project a bomb to earth accurately is most difficult. You may not have to treat the bomb quite so gently as a man, but you do have to land it at exactly the right place. Besides, the ballistic missiles we already have, which started all the excitement in the first place, are quite adequate weapon carriers—a lot more accurate, cheaper, more reliable, more flexible, and more instantly available for use than any satellite could be.

Thus, the military value of developing very large rockets (of a million pounds thrust or more) solely for the purpose of launching very large satellites would appear to be very small in the immediately foreseeable future.

What about a military base on the moon?

There have been some extraordinary statements made on this question in recent months. Here is a typical one from a Sunday newspaper supplement, in an article by a Washington correspondent: "A base on the moon with elaborate equipment and highly-trained men *(What are the men breathing, I wonder?)* would be an observation post surpassing anything military strategists have dreamed of in history." *(I am not familiar with military strategists' dreams—but I do know that from the moon only one side of the earth faces you at a time, and for a good fraction of each month that face will be in total darkness. Much of it will probably be covered by clouds anyway—and anyone who thinks he can see manmade objects from 240,000 miles away is a bit optimistic.)*

But the quote goes on: "It (the base on the moon) could launch weapons of great destruction *(the very same weapons we've got right here on earth now, I'll bet you)* with terrible accuracy *(terrible is right)* on any target on earth. It could also be done without the slightest fear of retaliation. *(Retaliation against what? Nobody on the moon could stop the enemy from wiping out New York, Washington and Los Angeles.)* For us, reaching the moon first is a defense necessity."

That's what the man said! It is my firm opinion that this is utter nonsense. It is nonsense for many reasons. I will mention only three:

1. Why transport a hydrogen warhead, together with all men and equipment for establishing and maintaining a base, 240,000 miles to the moon, just to shoot it 240,000 miles back to earth, when the target is only 5,000 miles away in the first place. I can think of no gain that is worth the colossal cost.

2. If you did launch a bomb from the moon to a target on the earth, using, of course, an orbit that required the minimum amount of fuel, the warhead would take five days to reach the earth. The war might be over by then! An ICBM can reach any target on earth in 20 minutes.

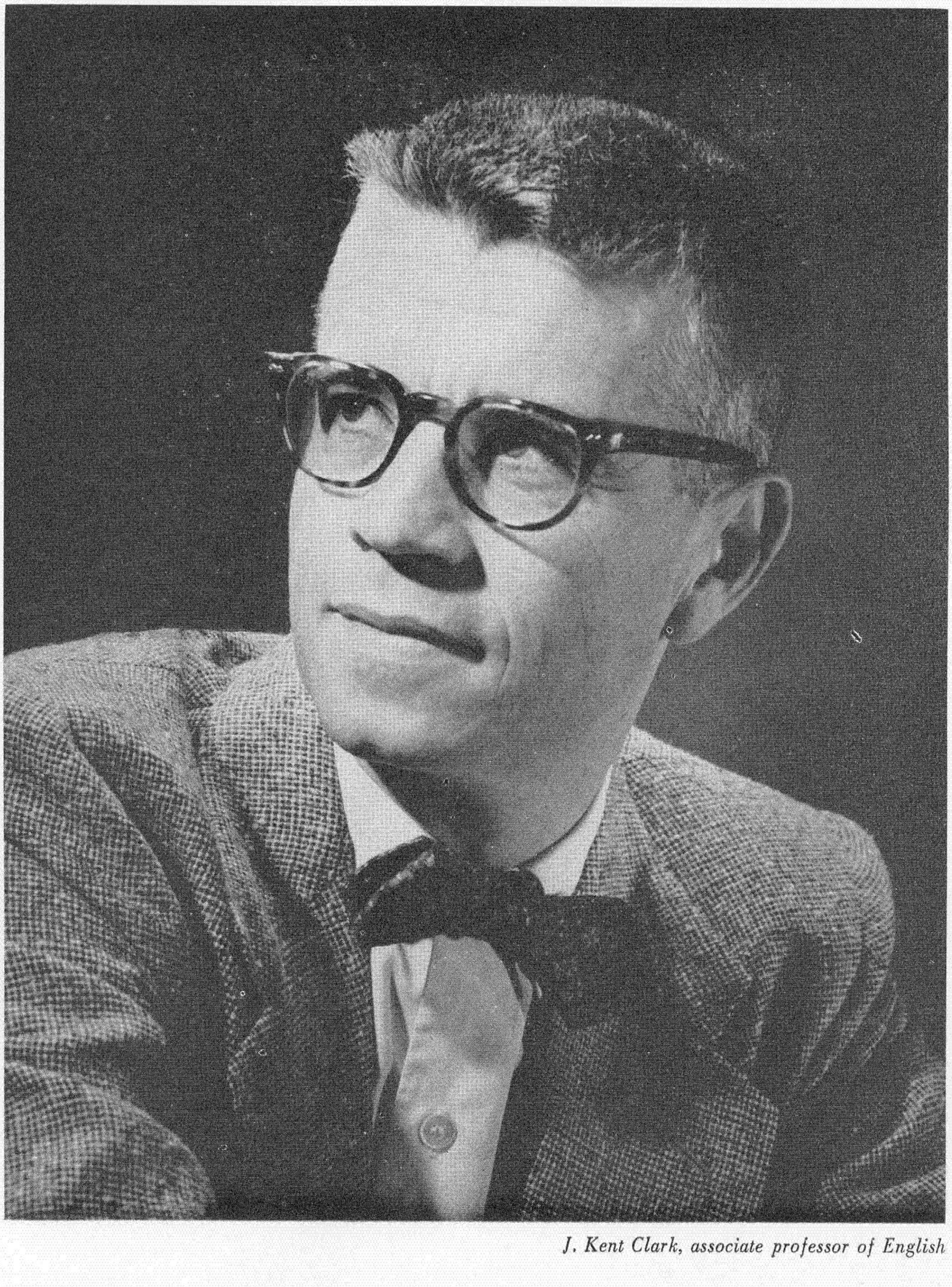
3. As to retaliation, if we have rockets good enough to land men and equipment on the moon, the enemy will surely have rockets good enough to put a hydrogen bomb (a much smaller payload) at the same spot. Either people will land on the moon for peaceful purposes by mutual agreement—or else we will surely launch the nuclear war here on earth which we are all trying to avoid. I'll willingly fight a war to keep the Communists off our shores—but I am not interested in getting blown up to decide who shall have a military base on the moon.

The challenge

As I see it then, the challenge of the space age is whether we use the great new technologies of space travel for peaceful and scientific purposes—conducting a bold and exciting program of research and exploration—or will we be led into wild programs of Buck Rogers stunts and pseudo-military expeditions? The decision is going to be made soon, and it is high time that the best people in America—including the best people in industry—do some good hard thinking about it.

IV. A Portfolio of Faculty Portraits

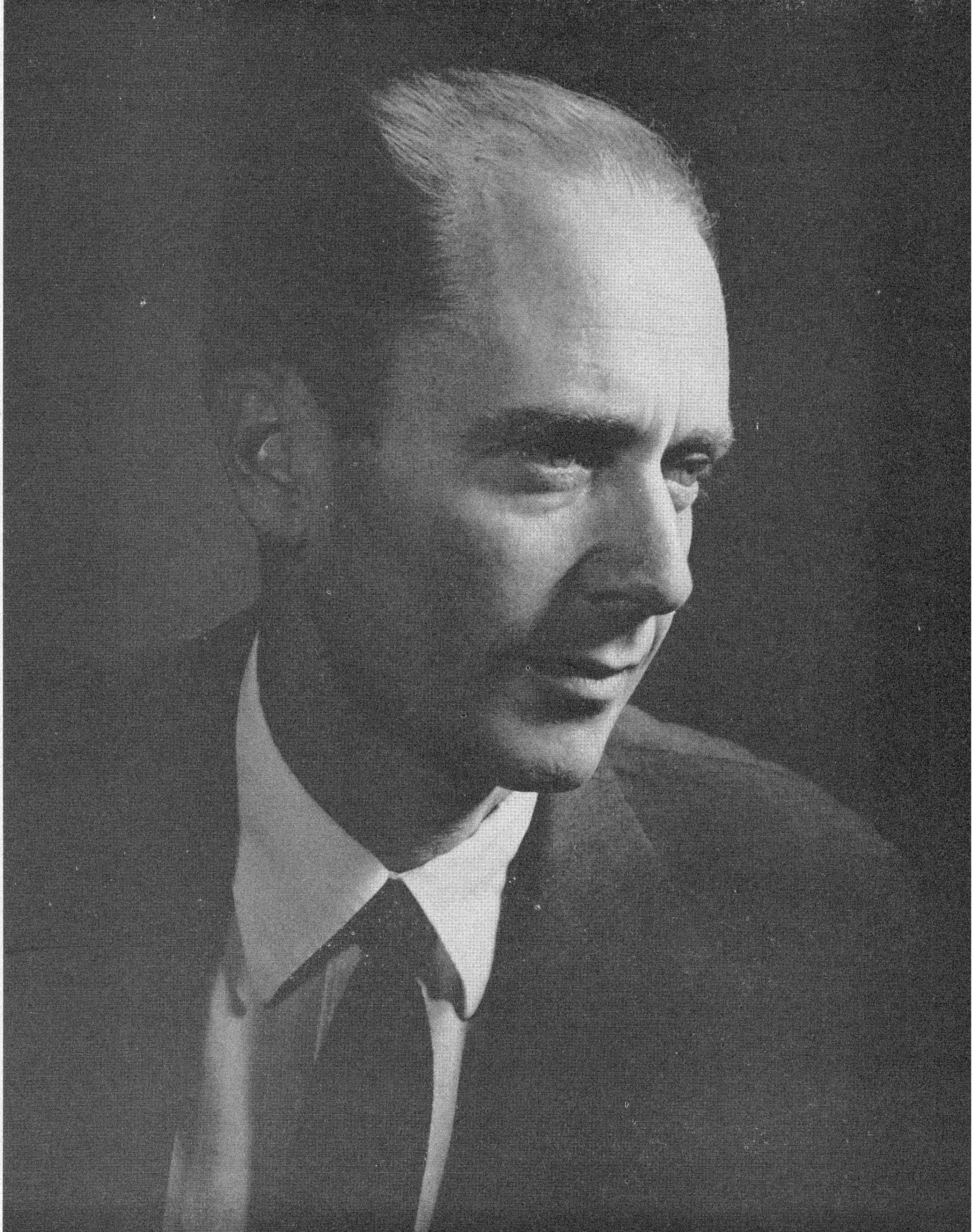
by Harvey



J. Kent Clark, associate professor of English

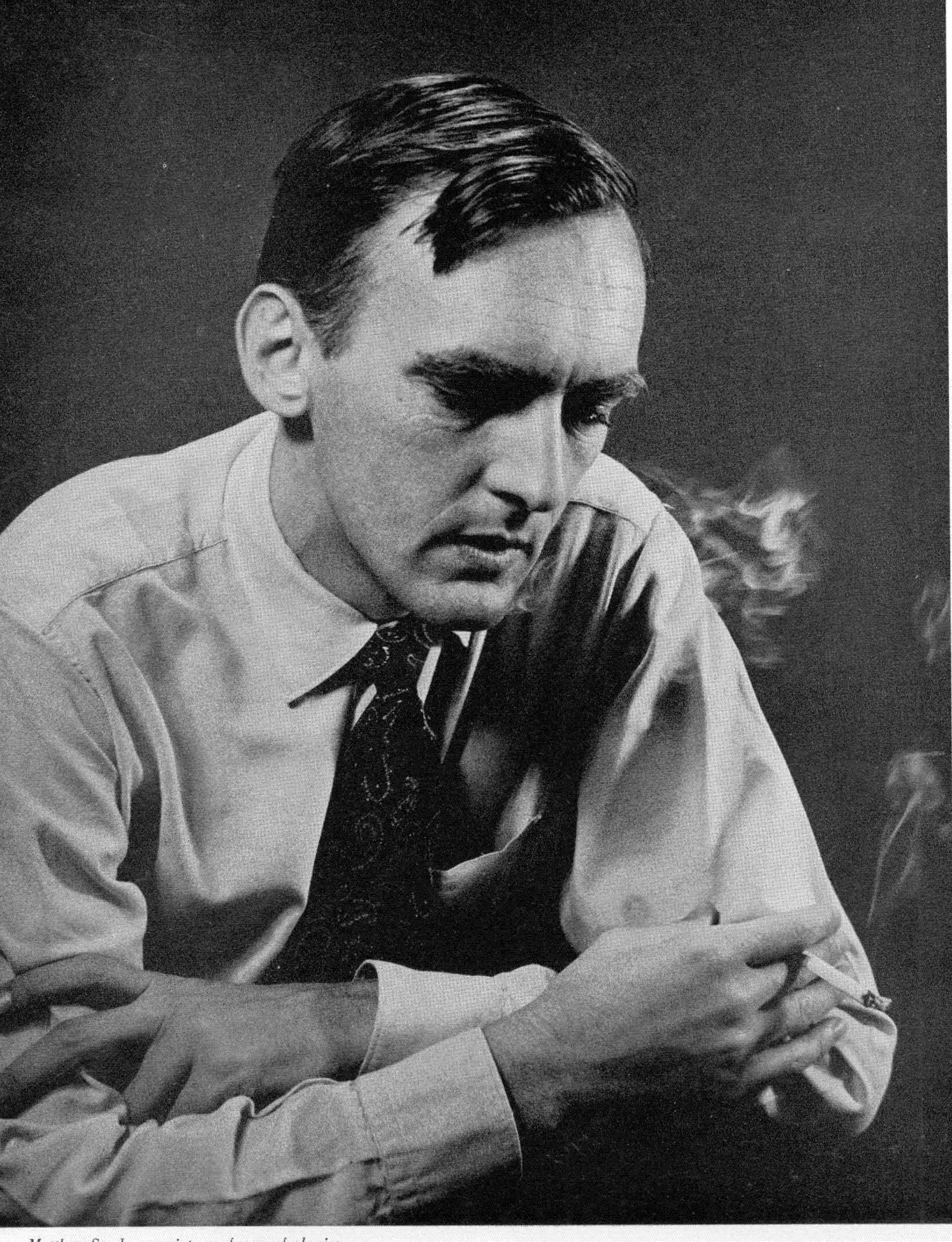
Ernest E. Sechler, professor of aeronautics

Frits W. Went, professor of plant physiology



Norman Davidson, professor of chemistry

Robert F. Bacher, chairman of the division of physics, mathematics and astronomy



Matthew Sands, associate professor of physics

A Search for Simplicity

Biophysicists search for the smallest known virus that can give a clue to the hereditary pattern of the gene

by Robert L. Sinsheimer

On most campuses the gulf between physics and biology is so vast and deep that an onlooker might assume that one group was composed of matter and the other of anti-matter, so that annihilation would be the fate of anyone who attempted to bridge the gulf. Having resided in a physics department for eight years, I know physicists are not as different as all that, and this lack of contact between these areas is, to my view, a pity, for biologists have certainly much to learn from physics that will be of the greatest value in the solution of their problems.

I am not so sure that the converse is valid; I am not sure that biology can contribute much to physics in a fundamental sense, although it can certainly offer the stimulation of an entrancing field, with wide scope and opportunity for the ingenious application of physical principles and concepts and techniques.

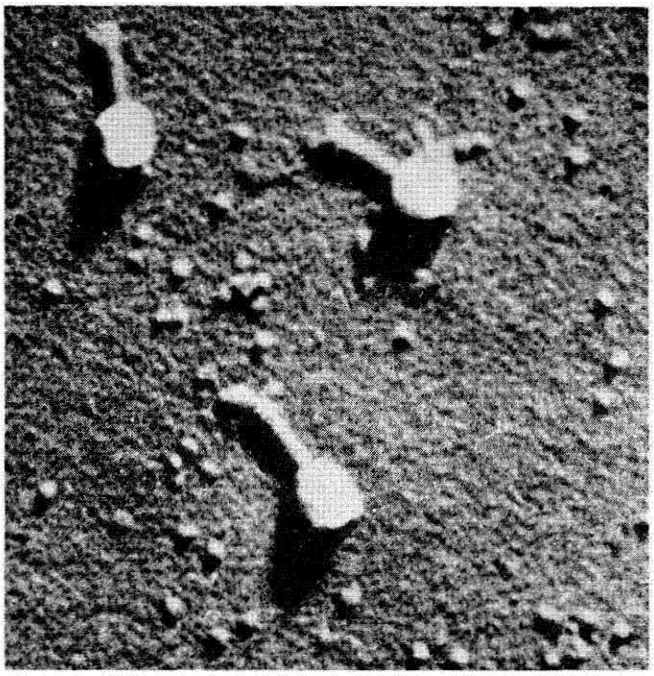
Actually, of course, an increasing number of people do work in the tenuous area between biology and physics, and some of these people even go so far as to call themselves biophysicists. Physics is the study of the properties of matter and energy. Biology is the science of life in its myriad manifestations. One of the most important areas of modern biology can be loosely called molecular biology. Molecular biology might be defined as the attempt to achieve an understanding of some of the remarkable phenomena of living organisms in terms of the structures and the physical and chemical interactions of their components—that is, in terms of the structures and reactions of the molecules, the macromolecules, the particles, which are found in living matter in an orderly and often highly organized pattern.

If the people who are engaged in this activity tend to derive their concepts, their techniques, and their mode of approach from physics, they are likely to consider themselves as falling into a loose category called biophysicists. If, conversely, they tend to draw their concepts and techniques and mode of approach from chemistry, they are likely to consider themselves biochemists.

Actually, very few of the people in this field are so narrow as to restrict themselves to the use of a purely physical or a purely chemical approach. In general, the biological phenomenon—be it photosynthesis or gene duplication, muscle contraction or nerve conduction—is the source of inspiration, and the scientist seeks to attack the problem with whatever means he can devise—be they biological, chemical or physical in nature. But I think it is clear that if a man's background is in physics and mathematics he is more likely to choose a quantitative physical approach than a qualitative chemical one, at least if he can devise one to answer the problems at hand.

Operationally, biophysics can be best defined in terms of the activities of those people who consider themselves to be working in the field. And so perhaps I can best give you a glimpse of a small area of the field by briefly describing the more recent activities of a self-designated biophysics laboratory at Caltech.

The broad biological problem with which I have been vitally intrigued for some time is represented by the word gene. More specifically, I am interested in the problems of the structure of the gene, the manner of its action, and the mode of its replication. Now genes are, formally speaking, simply units of heredity, and initially the idea of a gene was a purely abstract conception. It is a biological observation that a plan—a pattern of heredity—is passed from each generation to the next generation. Each organism, each of us, develops from a single cell which, at the time, possesses within itself a plan that leads, in due course, to the development of the mature individual. And each individual retains many



Tadpole-shaped T2 virus particles. Magnification is about 100,000 diameters. Smaller objects are extraneous material. The T2 virus is a representative of the most extensively studied class of bacterial viruses.

copies of that plan which he may pass on to his descendants.

One of the first triumphs of genetics was to show that this plan is unitary in character. It is made up of discrete entities or factors called genes. When stocks are crossed equal numbers of genes from each stock are pooled—in a precise way, to be sure. When a mutation—a change in the hereditary plan—is observed, it is found most often to be the result of a modification of one of these units.

To a physical scientist it usually seems almost self-evident that there must be some physical object, some structural entity, corresponding to each gene. To a biologist, more accustomed to thinking in terms of dynamic interacting systems, this has not been so obvious. Lest we be smug, let us remember that the discreteness of nature, the existence of atoms, was debated for many decades. In any case, it has only been relatively recently that techniques have been available to make the issue of the nature of the gene anything other than an ideological debate.

For this discussion I am going to assume that there is a discrete structure corresponding to the unit of heredity. To learn, then, the physical basis of these units of heredity, to learn how they are copied at every cell division, to learn how they direct the activities of the cells, of the embryo, of the whole organism as it develops and the hereditary plan unfolds—this is the broad problem. It is clearly a central problem in biology and it is one that has attracted many workers from varied disciplines.

As stated, the problem seems deceptively simple. In truth, it is extraordinarily complex and, with our present limited vision, difficult of access. There are many conceivable approaches to the problem, and how any individual will approach it is certainly a function of his background, his knowledge, and his intuition.

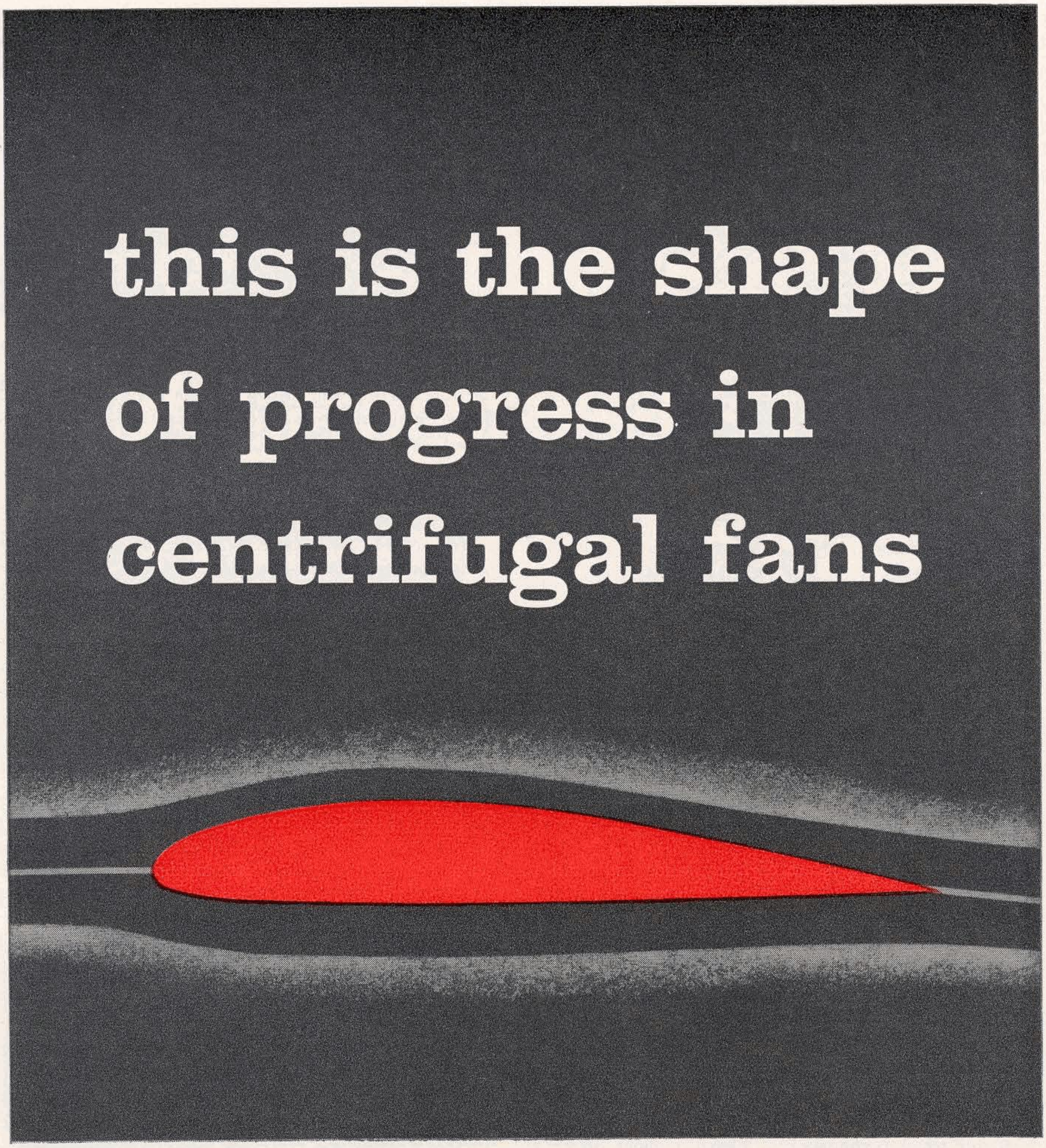
Physicists and people of like mind prefer to work with simple isolated systems, with arrangements in which as many variables as possible are controlled, or else are at least surely ignorable. They also, and with good reason, prefer systems that are amenable to quantitative analysis. Now, one may question whether even in principle (technical difficulties aside) a gene can ever function in an isolated system. For instance, one may ask whether its function might require a sort of feedback from the result of its function, but we are not ready for such questions yet. Surely, at present, a gene can only find expression in a living organism. But in a search for simplicity one can take certain plausible steps. One can first of all look for an organism which is both qualitatively and quantitatively of a minimum complexity—an organism for which the hereditary plan might therefore be of a minimum complexity. If one takes this approach and looks about for the simplest (or more accurately, the smallest) object that can cause, in an accurate way, its own duplication—that carries a plan of heredity which is at least believed to be unitary in character and which is mutable in the usual way—one's attention is soon drawn to the viruses.

Parasitic genes

It must be said right away that viruses lack many of the attributes of life. They must, in a sense, sponge on their host for preformed parts, for catalysts, for energy. But viruses do have the remarkable power to reorganize the synthetic machinery of the host and use it to bring about their own specific replication. They seem to represent in a stripped-down form just that portion of the living organism which is central to our problem of the gene. A virus, in this sense, represents an organized set of independent—and parasitic—genes.

Viruses are known to prey upon nearly all living species, and here again, in a search for simplicity one is led to concentrate upon the bacterial viruses, the bacteriophages. The simplicity here may be a little deceptive, but at least the host, the bacterium, is a single-celled, undifferentiated creature that may be grown in a precisely defined environment under quantitatively reproducible conditions.

Further, the bacterial virus particles may be quantitatively assayed by methods of great delicacy. It is easily possible to detect single virus particles. Thus one has means to detect in the range of 10^{-15} to 10^{-17} grams of virus, dependent upon the particular virus. Yet it is quite feasible to prepare 10^{15} particles. These features have been, and remain, a basic advantage that has permitted bacterial virus work to far out-distance work on other viruses. Bacterial virus work is quantitative and the conditions of bacterial virus growth can be readily and quantitatively varied.



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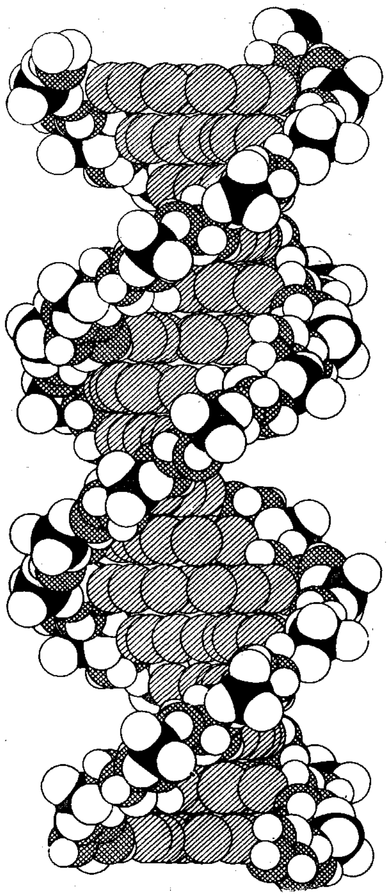


Molecular model of the two-chain helical structure for DNA proposed by Watson and Crick. DNA is believed to carry hereditary information in the sequences of its four or five component building blocks.

Now, bacterial viruses are of many kinds and qualities. All of them are particles with structure and with some degree of functional organization. A bacterial virus that has been easily the most intensively studied goes by the name of T2.

This virus (shown on p. 22) is about 600 angstroms across and 800 A long, in the head; it has a tail which is about 1000 A long, and has a particle weight of about 250 million. It has, thus, about 1/2000 of the mass of its host bacterium. Structurally, this particle is composed of an outer sheath which is protein in nature, and an inner core which is composed of a small number (of the order of 10) of large macromolecules of a substance called nucleic acid. Each of these nucleic acid macromolecules is of the order of 13 or 14 million in molecular weight. The sheath is differentiated into the head, the tail, and an organ of attachment at the tip of the tail which is the means by which the particle attaches to its host bacterium.

If a suspension of these particles is mixed with a suspension of susceptible bacteria, the particles, in Brownian motion, collide with and attach to the outer membrane of the bacteria by the tail.

At this moment the fate of the bacterium is sealed. About 20 minutes later the infected bacterium will burst, and as it does, some 200 virus particles just like the one that initiated infection will be spewed out. This is a really dramatic result. It was first discovered here at Caltech 20 years ago by Emory L. Ellis and Max Delbruck. In the ensuing two decades, a great many ingenious experiments have been performed to find out what goes on inside the host cell in those 20 minutes.

The more salient results of these investigations have told us that in the first minute or so, in some manner, a hole is produced in the bacterial wall at the site of attachment and the nucleic acid core of the virus is, so to speak, injected into the bacterium. The protein sheath has done its work; it can now actually be dispensed with. The injected nucleic acid brings about, first, its own replication (the production of more virus nucleic acid); then the development of new protein coats; and, finally, the assembly of the mature virus particles that are released when the cell bursts, or lyses.

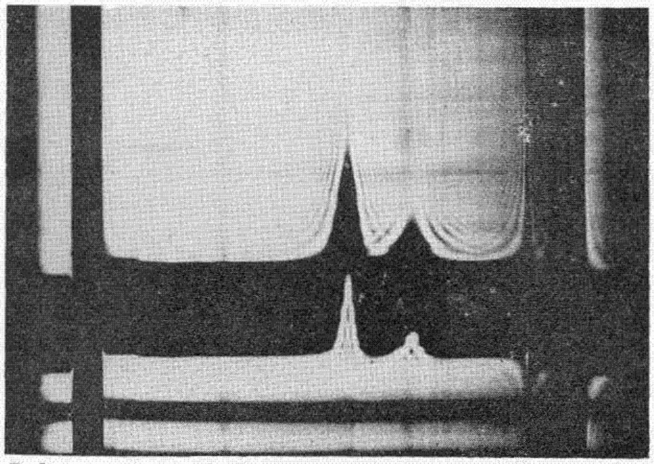
The hereditary plan

Now, these virus particles have definite hereditary traits that are passed on to their progeny. They may or may not attack certain host bacteria; the time of lysis may vary from strain to strain; they may differ in temperature resistance, in resistance to radiation, in their chemical composition, in their antigenic nature. Viruses mutate to new characters; viruses can also be mated by infecting the same cell with several particles; if these have different characters, recombinant types with new assortments of the parental characters are found, indicating the unitary nature of the hereditary pattern. So, these viruses have a hereditary plan that determines both the nucleic acid and the protein component of the progeny. Yet, effectively, only the nucleic acid enters the cell; so, logically, it must carry the hereditary plan. It seemingly must, here at least, be the bearer of genes.

There is not time here to buttress this conclusion, to cite all of the other evidence, direct and indirect, that is available from other organisms to confirm the view that these macromolecules we call nucleic acids are the hereditary factors. For viruses, the evidence seems conclusive.

If the nucleic acid carries the hereditary pattern, in what symbols, in what code, is it written? Here we enter what is at present a realm of pure speculation. Seemingly, the pattern must be expressed in the structure of the nucleic acid molecules. Fortunately, we believe we know the general form of the structure of these macromolecules.

The nucleic acid found in bacteriophages such as T2 consists of two helical chains (shown above) wound about each other and linked to each other by weak but specific bonds. Each chain is a linear sequence of monomeric units called nucleotides, of which there are usually only four or five kinds. For want of a better thought, it is presumed that the information, the hereditary pattern, must reside in the sequence of these four or five kinds of nucleotides along the chain.



Sedimentation velocity pattern of a partially purified ∅X174 virus preparation. Sedimentation is from right to left in the analytical ultracentrifuge. The faster-movin peak on the left is the virus. The slower-moving peak on the right represents incomplete virus particles.

While very plausible, there is no experimental evidence for this hypothesis. To go further—to test this hypothesis, to decipher this code—it is clear that we will have to learn the structure of these macromolecules in much greater detail.

Now, in the T2 virus there are some 8 or 10 of these macromolecules, each composed of a double strand containing some 20,000 nucleotides per strand. There is good reason to believe that the 8 or 10 strands are each different and each important. As an hereditary pattern this is still a rather complex object to hope to analyse in detail. A mutation, for instance, *might* (I emphasize *might*) involve a change in only one nucleotide. This would be one part in 400,000.

We have sought, therefore, to find a virus with an even simpler (again I really mean smaller) hereditary pattern. We have looked among the bacterial viruses, for the reasons already mentioned, for the smallest we could find, and we have sought to isolate and study it.

The exotic ϕX174

The virus to which we have in this way been drawn has the somewhat exotic name of ∅X174, and we have been devoting the better part of a year to learning how to grow it, how to isolate and purify it, and to establishing its size and some features of its structure.

Many of the technical problems encountered in this work are not very pertinent here. The biological problems associated with growing large quantities of the virus had to be solved, and the chemical problems of isolating relatively purified virus from the crude lysate while preserving the viability of the particles, caused us some pause. But, in time, we produced a highly purified preparation which we then examined in the analytical ultracentrifuge—a device which enables us to measure the rates of sedimentation in a strong centrifugal field of the component or components of a suspension.

Our preparation at this stage had two major macromolecular components, one of which had about $1\frac{1}{2}$ times the sedimentation rate of the other in the centrifugal field (as shown at the left). By the use of a partition cell—that is, a centrifugal cell with a porous plate across its middle—and then by making assays of the virus titer remaining above the partition after various times of centrifugation, it was possible to correlate the virus infectivity with the more rapidly sedimenting component. The slow component was not infective.

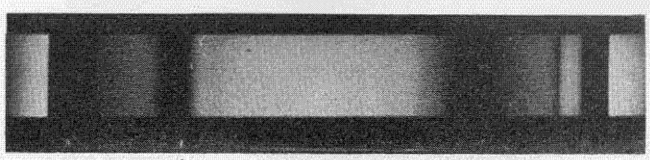
Seeking pure virus

To obtain pure virus, it was now necessary to separate these two components. This proved extraordinarily difficult to do. The slower component displayed essentially identical properties to those of the faster moving component in regard to all of the readily available chemical methods of fractionation. Indeed, this is not surprising, as we are now quite sure that the slow component is related to the virus; it is, in fact, an incomplete virus—the protein shell, lacking most of the internal nucleic acid.

Small amounts of pure virus could be obtained by straight differential centrifugation, but this was a Pyrrhic method involving great losses of material. Fortunately, at this stage, the newly developed method of density gradient centrifugation—developed here at Caltech by Jerome Vinograd, research associate in chemistry, and Matthew Meselson, research fellow in chemistry—came to our rescue. In this technique a dense salt solution is spun at high speed until a stable density gradient is established in the solution. Because of the centrifugal field, the salt tends to move centrifugally, but the resultant concentration gradient sets up a centripetal diffusion flow and at equilibrium a density gradient will exist from the inner to the outer radius of the cell. This is quite analogous to the density gradient in the atmosphere.

If particles are suspended in this stratified salt solution they will, of course, seek their own density. Because of diffusion, however, the particles will not all come to exactly that level corresponding to their density, but will form a band about this level. It may be shown that the width of this band is inversely related to the molecular weight of the particle.

Fortunately—as is shown below—it turned out that the



Density gradient sedimentation of a partially purified ∅X174 virus preparation in the analytical ultracentrifuge. Density increases from right to left. The dark band A indicates, by absorption of the ultraviolet light, the position of the virus particle. The dark band B indicates the position of the less-dense incomplete virus particles.

two centrifugal components of our preparation had different densities. The virus has a density of 1.40 and forms a band near the outer edge of the cell (the band may be detected by the ultraviolet absorption of the particles), while the slower sedimenting component has a density of 1.32 and forms a band near the *inner* edge of the cell. These bands are now spacially separated and the two components can be obtained physically separate.

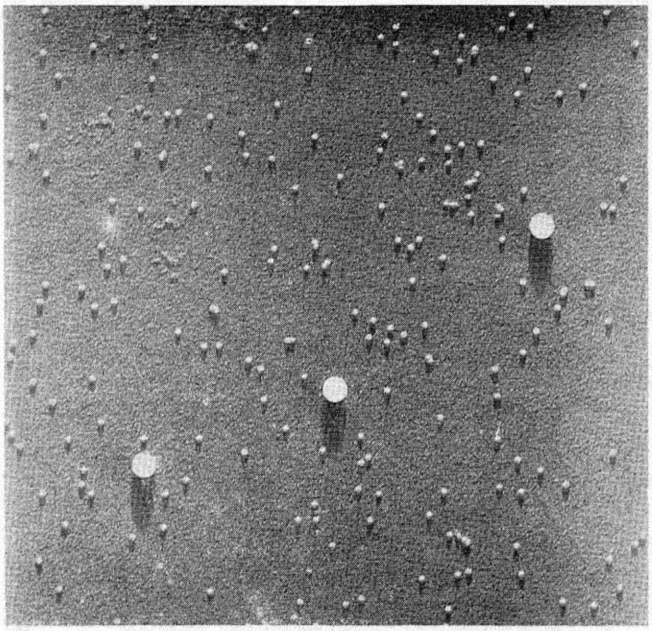
Incomplete virus

We may note that the lighter band is broader than the virus band, indicating a lower particle weight. This is in accord with the idea that it is an incomplete virus.

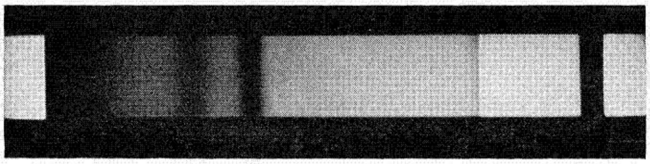
Having obtained a pure virus preparation, the particle weight of the virus could now be determined by another physical technique—that of light scattering. If a suspension of particles is illuminated by a parallel, monochromatic beam of light, of wave-length 10 or more times greater than the dimensions of the particle, the amount of light scattered at 90° to the beam will depend only upon the number of particles and their effective refractive index. The latter can be measured in a separate experiment, so a measure of the number of particles present in a given suspension can be obtained from a scattering experiment. If the mass of virus present in the suspension is known, then the mass per unit particle is readily calculated.

The particle weight of this virus (which is pictured below), calculated from the light scattering data, is only 6.2×10^6. This is about 1/40th of the weight of the T2 virus.

As was expected, this virus has nucleic acid; chemically it can be shown to be about 25 percent by weight



Electron micrograph of ∅X174 virus particles. The three large spheres are polystyrene latex of known diameter. Magnification is about 23,000X.



A B

Density gradient sedimentation of a mixture of DNA from ∅X174 and T2. Density increases from right to left. The dark band A indicates the position of the DNA of ∅X174, while the dark band B indicates the position of the less-dense DNA from the T2 virus.

of nucleic acid. The important possibility then arises that this nucleic acid is present as a single molecule of weight 25 percent of 6.2×10^6 or 1.6×10^6. To test this, the nucleic acid was extracted from the virus and its molecular weight determined by light scattering. The molecular weight of the nucleic acid is found to be 1.8×10^6. Thus the virus has but one molecule of nucleic acid, only 5500 nucleotides. The nucleic acid content is thus 1.5 percent of that of the T2 virus previously discussed.

A surprising feature

It often happens in physics that when the scale of a particular phenomenon is changed by an order of magnitude or two, new features appear and, somewhat to our surprise, this may have happened in this instance. In the density gradient sedimentation picture above, two bands (A and B) appear. One is produced by DNA from the ∅X virus. The other is produced by the addition of some nucleic acid of the T2 virus. The latter band is clearly narrower than the band produced by the ∅X nucleic acid, indicating it is bigger in molecular weight, but also this band is displaced. The nucleic acid from ∅X is significantly denser than that from the T2 virus. Since all the nucleic acids previously studied—from bacteria, from salmon sperm, from calf thymus glands—have been almost exactly the same density as that of the nucleic acid from T2 virus, there seems to be something unique about the nucleic acid from the small ∅X virus.

It must be said that we have never had a nucleic acid of this low a molecular weight, and it is possible that this altered density is an artifact resulting from the action of our isolation procedure upon such a singularly small nucleic acid. There is, however, supporting radiobiological evidence for the view that this nucleic acid is in some way unusual even when inside the virus.

Here the prologue ends. We have established the size of this virus and the unimolecular nature of its nucleic acid. The virus is almost two orders of magnitude less complex than the previously studied T2. I feel our search for simplicity has been successful and can stop here. We can, and have, isolated mutants of this virus; we can almost surely create other mutants when needed. It is time to begin to examine the structure and the functions of these particles in the most intensive way.

THE PRODUCTS OF THE MIND

The world we live in is in large part the product of the scientific thought and accomplishment of the past, translated into engineering achievements. Whether we continue to go forward depends on whether the scientific curiosity, the imagination, the careful thought, and the logical analysis of the past, upon which today's technical achievements were built, can exist and flourish in the environment of the new world.

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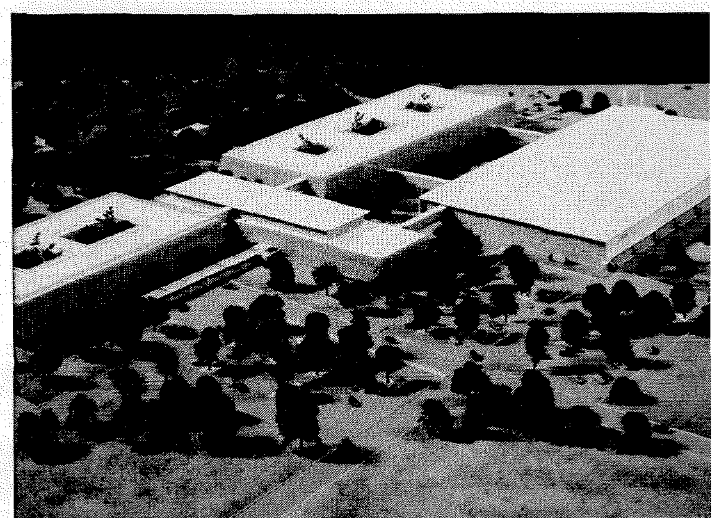
Sidney L. Simon

Dr. Sidney L. Simon
Assistant to the President

Dr. Sidney L. Simon



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The Month at Caltech

Radhakrishnan

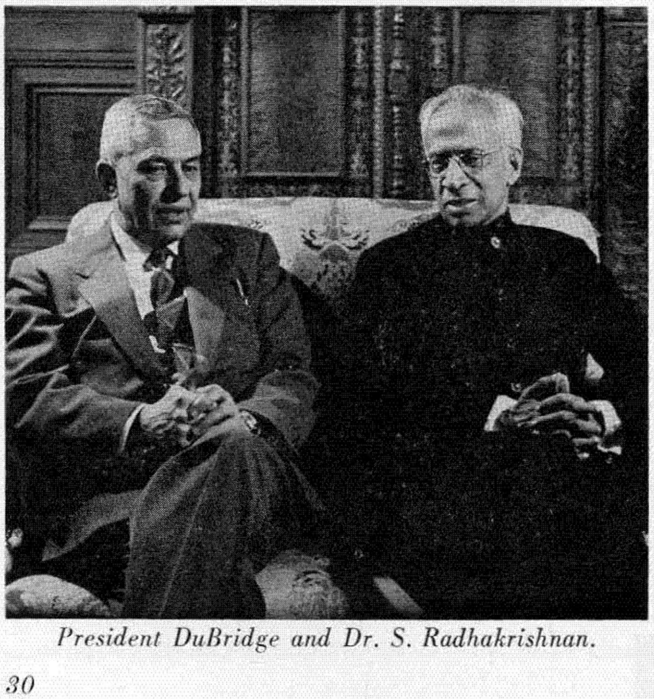
Dr. Sarvepalli Radhakrishnan, vice president of India, came to the Caltech campus on April 2 for a three-day visit. As the third visitor in the Caltech YMCA's Leaders program, Dr. Radhakrishnan spent most of his time in informal meetings with students, but he also gave formal talks on "Science and Religion," on "India's Foreign Policy," and on "Indian Philosophy and Religion."

One of India's leading statesmen, Dr. Radhakrishnan is also known as one of India's foremost modern philosophers. From 1909 to 1948 he held various academic posts in India, and served as guest lecturer at such universities as Oxford, Chicago, Yale, Harvard, Michigan and Cornell. He was knighted by George V in 1931 and in 1939 he was the first Indian to be elected to Fellowship in the British Academy. He holds honorary doctorates from the universities of Oxford, Cambridge, Columbia, Rome, London and McGill.

In 1946 Dr. Radhakrishnan was the leader of the Indian delegation to the newly-formed UNESCO. He became vice chairman of the organization in 1948, and chairman in 1949. In that same year he was appointed India's first ambassador to the Soviet Union. He resigned the position in 1952 to become the Congress Party candidate for vice president of India.

Lauritsen's Award

Charles C. Lauritsen, professor of physics, has received the second annual Captain Robert Dexter Conrad Award, established by the Office of Naval Research. The award is named for the late Captain Conrad, first head of the ONR's planning division, and the primary architect of the Navy's basic research program. It is given for outstanding technical and scientific achievements in research and development for the Navy. The first award went to Alan T. Waterman, director of the National Science Foundation.



President DuBridge and Dr. S. Radhakrishnan.

As a member, and vice chairman, of Division A of the National Defense Research Committee, Dr. Lauritsen made a major contribution to the proximity fuse program. And, as research director of a group at Caltech, he contributed so much to the Navy's rocket program that he became known among most experts in the field as the "father of Navy rocket power."

After the war, the Caltech group became the nucleus of the Naval Ordnance Test Station at China Lake, California. Dr. Lauritsen served as first chairman of the NOTS Advisory Committee and has continued his committee membership, except during 1956 and 1957.

Dr. Lauritsen also helped formulate the plans which led to the establishment of the Office of Naval Research. In close association with Captain Conrad, he was influential in originating the concept and philosophy of operation of the Navy's contract research program.

Trustee

Whitley C. Collins, president and chief executive officer of Northrop Aircraft, Inc., has been elected a member of the Caltech board of trustees. Born in Des Moines, Iowa, in 1898, he was graduated from the Wharton School of Banking and Finance at the University of Pennsylvania in 1921. From 1921 to 1929 he worked in the new business department of the Continental Illinois National Bank and Trust in Chicago. After two years with the Lockheed Aircraft Company, as vice president and general manager, he became credit manager of the Security First National Bank in Los Angeles in 1931. He has been president of Northrop since 1954.

Roscoe F. Sanford

Roscoe F. Sanford, an astronomer at the Mount Wilson Observatory for almost 32 years, died on April 7. A graduate of the University of Minnesota, he received his PhD from the University of California in 1917. He was a member of the Lick Observatory in Santiago, Chile, from 1911 to 1915, and in 1918 he joined the staff at Mount Wilson, continuing his investigations with the 60- and 100-inch telescopes until his retirement in 1949. His photographs of the spectra of "cool red carbon" stars are accepted as the best ever made in his field.

The Red and the Black

— *or who's got the moral fiber?*

Life ran an interesting article last month—a comparison between high-school education in the United States and Russia. The cover was split to show a representative of each system: Johnny, a handsome, clean-cut, all-American, but unfortunately quite stupid youth; and Igor, a sneaky-looking lad, with mustache and leer—good commissar material for the next generation (just as Johnny will probably be a good congressional candidate).

The article first follows Typical John through a typical day at his typical American high school. After a wastefully large breakfast, he pauses only to read *L'il Abner* (his favorite), then leaps into his hot rod for a quick dash to the home of his latest teen-age queen. She's the cute-blonde, tight-Bermuda-shorts type—not too cheap-looking though, so she's probably a student leader (first to memorize the Pledge of Allegiance, etc.)

Once at Central High, John plunges into a hectic routine of degenerate fun. History, geometry, English—he's equally ignorant of all of them. He browbeats the teacher with witty comments on his ignorance, and the class laughs with him. But his real hour to shine comes during Club Period. Handsome and gregarious Johnny is president of a Hi-Y, Key Club, Service Club, and probably a secret fraternity, too. He mismanages all of them, but he's such a neat guy nobody cares.

After school John spends 100 percent of his time pursuing more teen-age queens, using the seductive charms of rock n' roll music, Pepsi-Cola, and miniature golf. (If he lives in New York City, he may take time off now and then for a rumble with the rival Hi-Y.) The conclusion is unavoidable: Johnny is a worthless wastrel; America's moral fiber is disintegrating.

Igor's daily pattern forms a Spartan contrast. Every cold Moscow morning he trudges several miles through the snow to a gray stone building, the local learning factory. There he spends long hours absorbing world history (revised Russian edition), foreign languages (especially English), and—most menacing of all—math and science.

One picture shows him sitting at a long bench, with several other drably-uniformed boys and girls. The teacher is a mannish-looking woman, the type that even Johnny would think twice about browbeating. On the walls are voltmeters, Leyden jars, and other such exotica. Igor has his hand in the air and an anti-American gleam in his eye. Perhaps he's on the verge of another breakthrough for Russian science.

Igor belongs to only one club—the Young Communist League. Until recently Igor has had no time for women. Someone, however, has pointed out the necessity of carrying on the Russian race, so now he is quite often seeing one of the uniformed girls. Perhaps, if he's really a mad romantic at heart, he's building an electroscope to give her next Khrushchev's day.

Igor gets his big kicks, though, another way. Every evening he plays a game of chess with his buddy from the next tenement. Of course he usually wins. Moral of the story: Unless America gets serious about its high-school educational system, Igor and his friends will be taking over soon.

Bunk! Many of the people who come to Caltech, for instance, tend more to Igor than Johnny. And one of the most important things the school tries to do is break these people out of their isolation. I don't see how an engineer, mathematician, or scientist can be of much value to the community without an understanding of people. Our present high school system does a splendid job of providing this understanding. It's a case of understand or wither. Quite a few wither, but more understand.

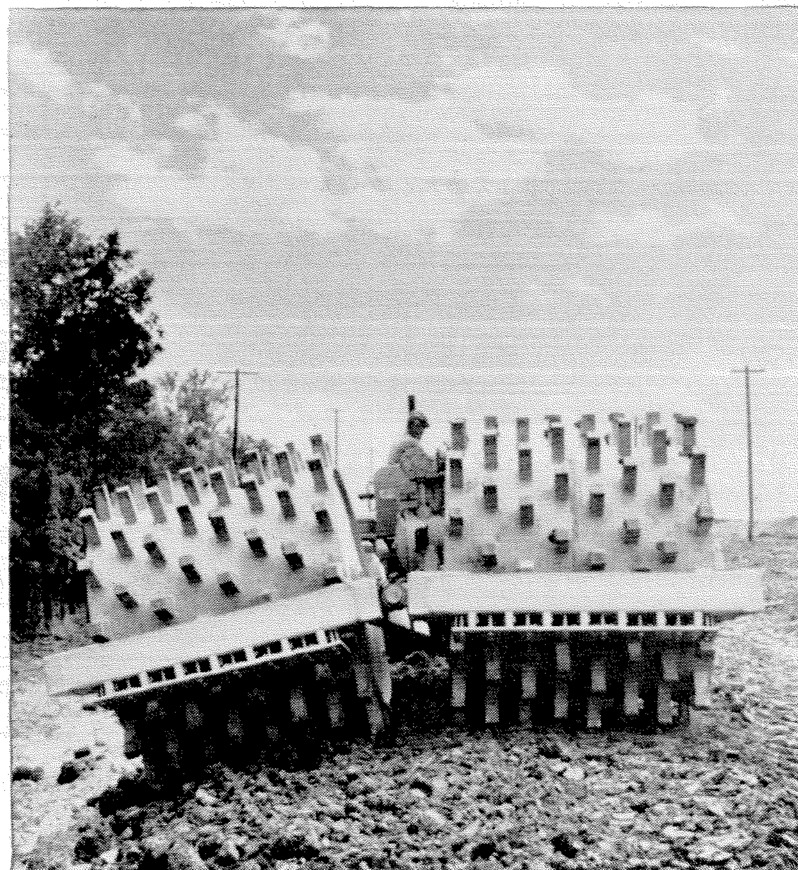
Secondly: In the high schools I've seen (public schools, middleclass neighborhoods) the students have been more serious about their schoolwork than was apparent to the casual observer. (And I think *Life's* observer was pretty casual.) I can't believe that everyone in the Russian schools is an Igor, either. If they were, the U.S.S.R. would have cracked in half the first time somebody laughed at it.

Thirdly, and most important, I do believe our high schools are more fun than Russia's. Good. Any system that provides four enjoyable years for nearly everyone is well worth saving. Why should we be *ashamed* of the fact that our schools are more fun? This is real democracy. Not only a vote and a voice for everyone, but an enjoyable life, too. I say let Johnny keep his hot rod. He'll have plenty of time for the serious life.

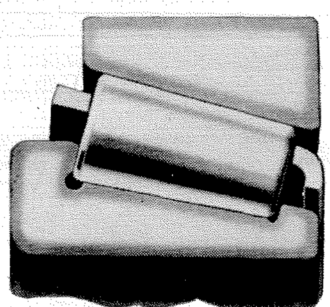
—*Brad Efron '60*

Tear out this page for **YOUR BEARING NOTEBOOK...**

How to take 22½ ton impacts on drum axle

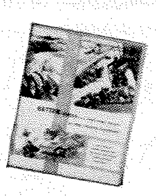


The designers who built this giant tamping roller had to contend with impacts as high as 1450 psi on the drum axle. To take these terrific loads, designers mounted the drum axle on Timken® tapered roller bearings. Timken bearings are case-carburized to produce hard, wear-resistant surfaces over tough, shock-resistant cores. Their full-line contact between rollers and races gives them extra load-carrying capacity. And because they practically eliminate friction, they help heavy construction machinery start and roll more easily.



Slice a Timken bearing in half and see why it takes shocks

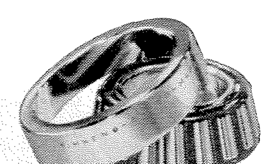
The picture at left shows what you'd see if you cut through a Timken bearing: hard, wear-resistant surfaces and tough, shock-resistant cores.



Want to learn more about job opportunities? Timken bearings help make better machines—machines that enrich our lives. It's what the Timken Company calls Better-ness. If you'd like a career helping to create the machines that create Better-ness, write for: "BETTER-ness and your career *at the Timken Company*". The Timken Roller Bearing Company, Canton 6, Ohio.

TIMKEN *TAPERED ROLLER BEARINGS*

TRADE-MARK REG. U. S. PAT. OFF.



NOT JUST A BALL NOT JUST A ROLLER THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL AND THRUST LOADS OR ANY COMBINATION

Personals

1928

Arnold O. Beckman, PhD, president of Beckman Instruments, Inc., in Fullerton, California, has been appointed to a National Advisory Committee on Radiation in Washington, D.C. The committee works on the development of adequate safeguards against the hazards of radiation.

Alfred C. Nestle, chemist at Texaco's Bellaire laboratories, is co-patentee of a recently issued patent entitled "Lost Circulation." He has also been awarded three patents which deal with oil and gas wells, drilling and completion. Al has been with Texaco since 1928.

1930

Walter D. Wilkinson is senior metallurgist at the Argonne National Laboratory and is assigned to teaching reactor metallurgy at the International School of Nuclear Science and Engineering.

Nathan D. Whitman, Jr., MS '32, construction engineer, was president of the L.A. section of the American Society of Civil Engineers last year.

1931

George F. Wislicenus, MS, PhD '34, is now professor of aeronautical engineering and director of the Garfield Thomas Water Tunnel at Penn State University.

1938

Edmond F. Shanahan has announced the formation of a law partnership with Vernon D. Beehler in Los Angeles. Under the firm name of Beehler and Shanahan, they will specialize in patent, trademark, copyright and unfair competition causes.

1939

Charles H. Townes, PhD, professor of physics at Columbia University, has been named winner of the 1957 Research Corporation Award for his outstanding work in microwave spectroscopy. A former member of the technical staff of the Bell Telephone Laboratories, he gained international recognition a few years ago for his development of an "atomic clock."

1940

Keith E. Anderson has resigned as regional drainage and groundwater engineer for the Bureau of Reclamation and opened offices as a consultant in engineering and geology at Boise, Idaho.

Mark M. Mills, PhD '48, deputy director of the University of California's radiation laboratory at Livermore, was killed in a helicopter crash at Eniwetok Atoll on April 7. He was 40 years old.

On a mission related to the forthcoming atomic tests in the Pacific, the helicopter, with several other scientists aboard, was forced down by a rain squall off one of the islands. The other passengers escaped serious injury.

During World War II, Mark was a leader in developing solid rocket propellants at JPL. He joined the Livermore laboratory in 1953 as head of the theoretical physics and mathematics division. He became an associate director in 1956 and was recently named deputy director.

He leaves his wife, a daughter, Ann, and a son, Mark John. White House Press Secretary James Hagerty, who described Mark as "one of our top scientists," said that President Eisenhower had sent a personal message of sympathy to the family. And, in his message of condolence, Lewis Strauss, chairman of the AEC, said that Mark's work had "contributed materially to the defense of the United States and the free world."

Col. Norman L. Peterson, MS, has now assumed command of the USAF Air Weather Service. He has been deputy commander since August, 1954. Headquartered at Andrews AFB, the USAF Air Weather Service is the component of the Military Air Transport Service, charged with the provision of weather support to Air Force and Army units throughout the world. The Petersons have three children —Sandra, 18; Diana, 14; and Malcolm, 11.

1941

H. Guyford Stever, PhD, associate dean of engineering at MIT, has been named to head a special committee on space technology for the National Advisory Committee for Aeronautics. The committee will help to coordinate and bring into sharper focus the substantial and increasing effort of the NACA on problems of flight beyond the earth's atmosphere.

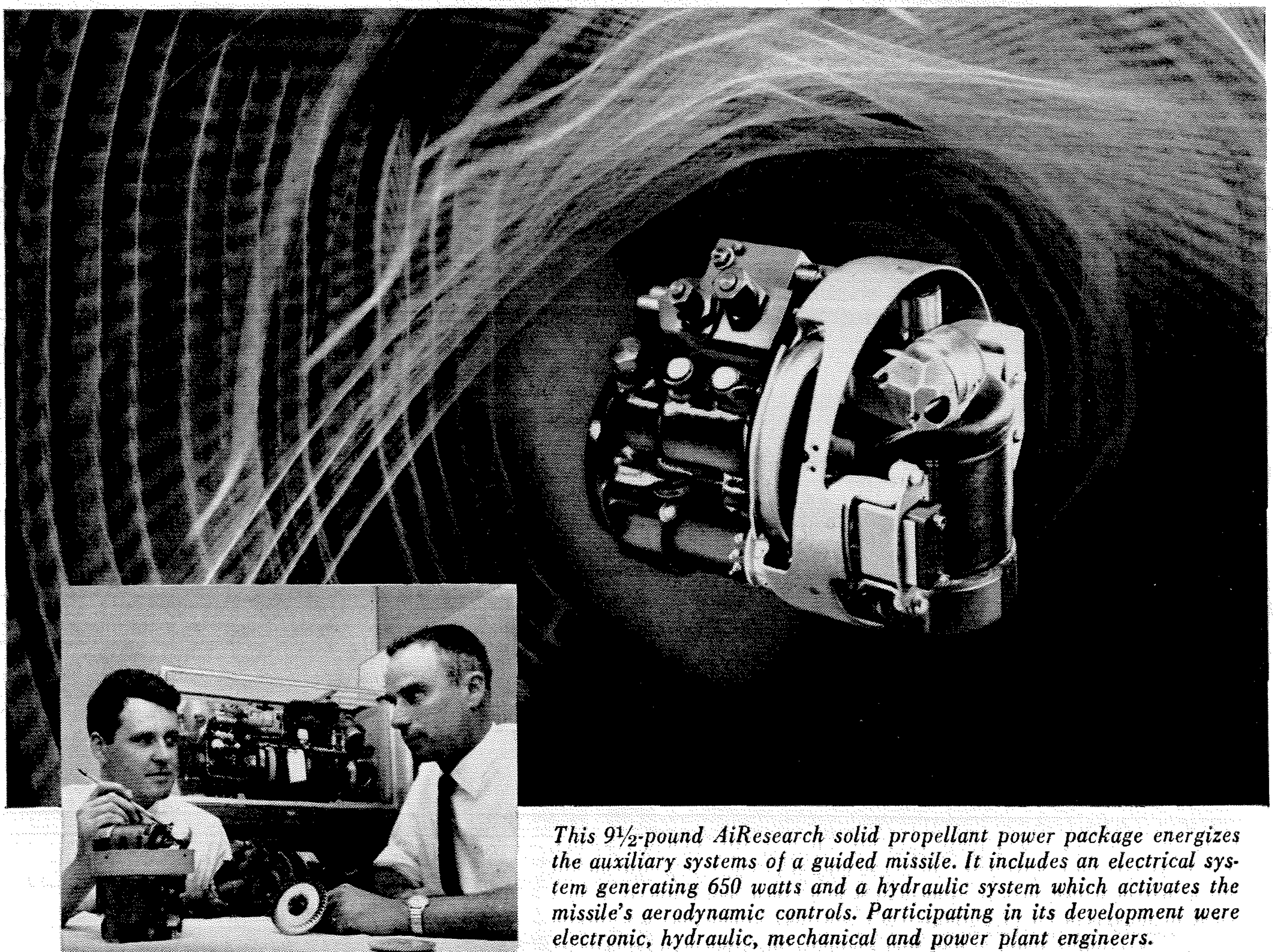
1942

Edward B. Lewis, PhD, MS '43, professor of biology at Caltech, has been named a member of a new National Advisory Committee on Radiation in Washington, D.C. The committee's activities for radiological health concern research, epidemiological studies, monitoring of milk, water and air, and technical assistance to states on radiation safety.

George P. Sutton, MS '43, was recently elected president of the American Rocket Society. George is chief of preliminary design for Rocketdyne and has also been selected to serve on a panel of the President's Committee for the Development of Scientists and Engineers. George reports that he has been happily married for almost three years. With their two daughters, the Suttons live in Woodland Hills.

William L. Rogers, manager of the Azusa plant of the Aerojet-General Corporation, celebrated his 15th year with the company

IF you're looking beyond tomorrow . . .



This 9½-pound AiResearch solid propellant power package energizes the auxiliary systems of a guided missile. It includes an electrical system generating 650 watts and a hydraulic system which activates the missile's aerodynamic controls. Participating in its development were electronic, hydraulic, mechanical and power plant engineers.

Your first position after graduation will determine the direction in which you will grow in engineering knowledge and ability.

Garrett offers engineering career opportunities which will expand for many years to come.

They include the following in the fields of aircraft, missiles and technological industry: system electronics; computers and flight instruments; gas turbine engines and turbine motors; prime engine development; cryogenic and nuclear systems; pneumatic valves; servo control units and air motors; industrial turbochargers; air conditioning and pressurization and heat transfer.

In addition to direct assignments, a 9-month orientation program is available to aid you in selecting your field of interest. This permits you to survey project, laboratory and administrative aspects of engineering at Garrett. With company financial assistance you can continue your education at outstanding universities within easy reach of your employment.

Project work is conducted by small groups where individual effort is more quickly recognized and opportunities for learning and advancement are enhanced. For full information write to Mr. G. D. Bradley.

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Personals . . . *continued*

in 1957—and also the 15th year of the founding of Aerojet.

1943

Charles P. Strickland, Jr., has been named manager of the southwest district *for the York Corporation, subsidiary of* Borg-Warner. In his new assignment, he will supervise York activities in Louisiana, Texas, and portions of Alabama, Arkansas, Mississippi and New Mexico. The Stricklands live in Houston, Texas, and have three children — Anita, 11; Frederick, 3; and Charlene, 1.

Richard E. McWethy, who is in the insurance business in Aurora, Illinois, writes that "nothing new has happened except that I have acquired two horses to go along with the wife and three kids."

Alvin R. Eaton, MS, supervisor of the aerodynamics group of the applied physics laboratory of the Johns Hopkins University, received a Navy Meritorious Public Service Citation in December, for his work on the development of the Terrier guided missile.

1944

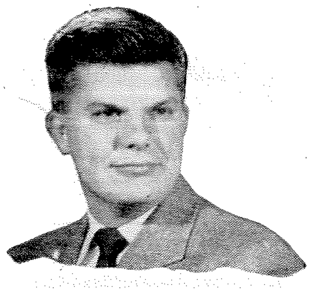
Eugene W. Bolster writes from Camino, California: "I'm the owner of 67 acres here. We have 17 acres planted with apple trees—and will have 33 more, this and the following spring. They're mostly Golden Delicious and some Red Delicious, Winesap and Rome Beauty. We decided the country life would be more fruitful (no pun intended) in all ways—so I sold my business interests, etc., and moved. Wonderful spot to raise the four children. It's only 50 miles from Lake Tahoe on Highway 50—good hunting, fishing, and lots of good honest work, with only the weather and one's common sense the limiting factors."

George M. Osgood writes that "after ten years with the General Electric Company's apparatus sales division in Schenectady, N.Y. *and Portland, Oregon, I left the* company in October, 1957, to set up my own business, the George M. Osgood Company. Our prime endeavor is the national sales of a new approach to specialized pumping rate control, 'the Flomatcher,' developed over the past seven years by a consulting engineering firm in Corvallis, Oregon. My wife, our two daughters, and son and I will still make our home in Portland. We continue to see a good deal of *Henry Judd* '44, *Dean Johnson* '45, and —until he moved to Walla Walla recently —*George Wilhelm* '45."

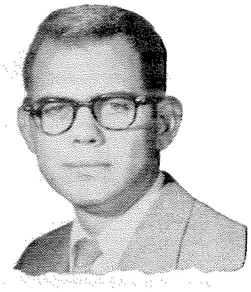
1945

Charles R. Cutler writes (from Washington, D.C.) that he was made a partner in his law firm — Kirkland, Fleming, Green, Martin and Ellis—on January 1. The Cutlers have three children—Tom, 6; Alan, 4; and Patricia, 1.

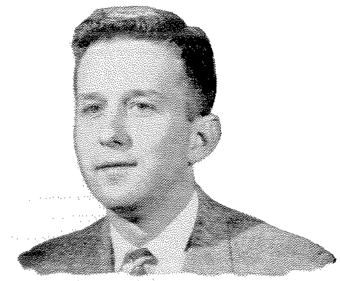
continued on page 40



Pump-turbine design is now the work . . . hydraulics, the field . . . of John Jandovitz, BSME graduate of College of City of New York, '52.



Water conditioning chemical, service, and equipment specialist in Houston is new assignment of Arthur Brunn, BS Chem. E., University of Tennessee, '56.

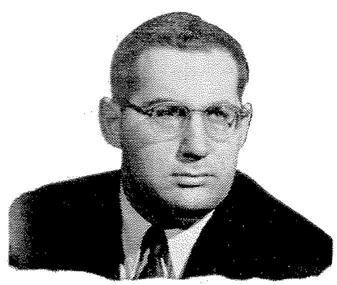


Field sales engineering of America's widest range of industrial products is choice of Roy Goodwill, BSME, Michigan State College, '54.

Recent Training Course Graduates

select wide choice of careers at Allis-Chalmers

Starting up a cement plant in Mexico after coordinating all work on it is latest job of John Gibson, BS Met. E., University of California, '54.



Nucleonics is chosen field of R. A. Hartfield, BME, Rensselaer Polytechnic Institute, '53. Currently he is working on design and development of new nuclear power plant.

THERE'S variety at Allis-Chalmers. Whether you're thinking in terms of types of industries, kinds of equipment, types of jobs, or fields of work, the diversification of Allis-Chalmers provides unsurpassed variety. For example:

Types of jobs	Industries	Equipment	Fields
Research	Agriculture	Tractors	Metallurgy
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Manufacturing	Chemical	Screens	Mechanical Design
Application	Construction	Earth Movers	High Voltage Phenomenon
Sales	Electric Power	Transformers	Stress Analysis
	Mining	Crushers	Nucleonics
	Nuclear Power	Reactors	Electronics
	Paper	Control	Hydraulics
	Petroleum	Pumps	Acoustics
		Motors	Thermodynamics
		Steam Turbines	

An outstanding training program, started in 1904, is designed to help you find the activity within these groupings for which you are best suited. Up to two years of theoretical and practical training are offered. Direct employment at Allis-Chalmers is available for those with sufficient background.

Learn more about Allis-Chalmers and its training program. Ask the A-C district office manager in your area or write Allis-Chalmers, Graduate Training Section, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

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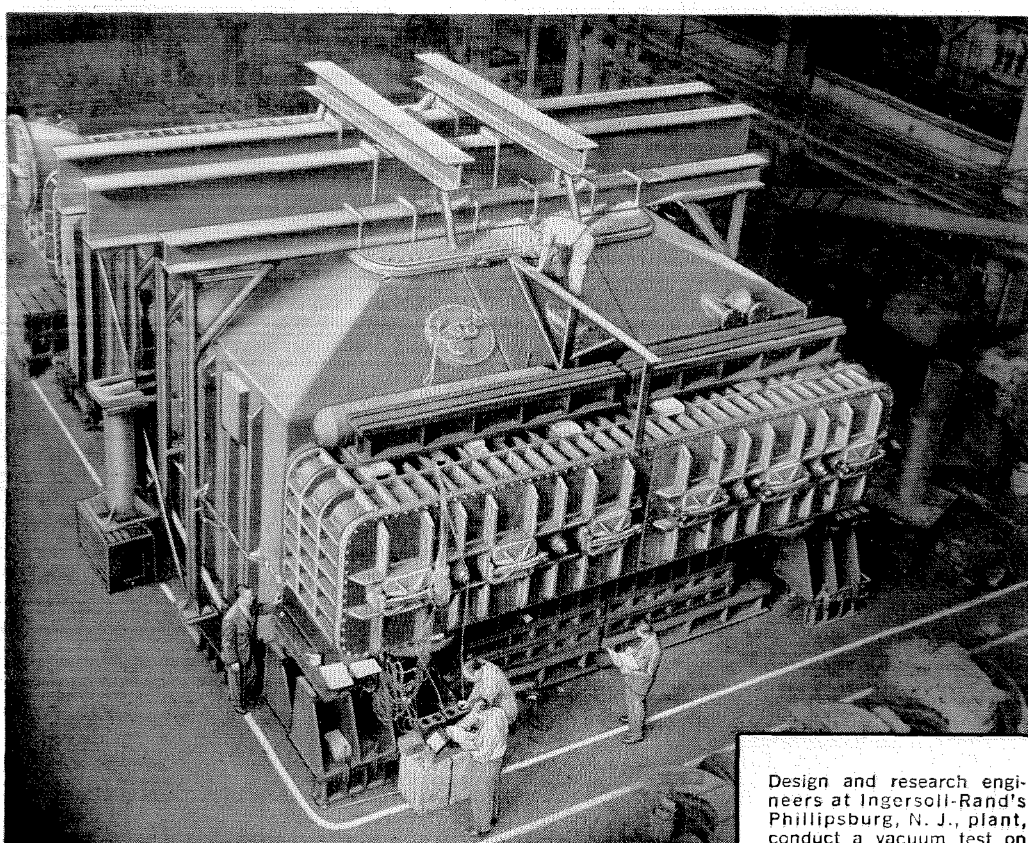
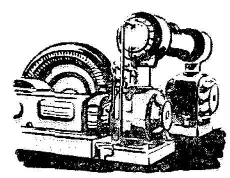
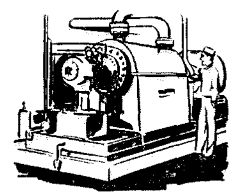


Design and research engineers at Ingersoll-Rand's Phillipsburg, N. J., plant, conduct a vacuum test on the shell of a large condenser, measuring millionth-of-an-inch stretches and deflections at 104 points, to check calculated stresses.

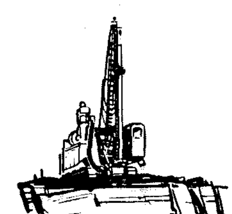
also means
LEADERSHIP
in



Compressors and Blowers

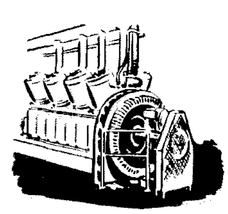


Centrifugal Pumps



Rock Drills

Air & Electric Tools



Diesel & Gas Engines

Here's What Condenser Engineering at Ingersoll-Rand can mean to you...

Steam condensation plays a vital role in every steam power plant, or wherever condensing steam turbines are used throughout industry. Linking the turbine exhaust to the steam generator, the condenser completes the steam-water cycle—conserves boiler-feed water and lowers the turbine exhaust pressure to improve efficiency. Although basically simple in construction and operation, the steam condenser is one of the most highly engineered of all I-R products – every unit designed for its specific application. Hence condenser engineering at Ingersoll-Rand offers exceptional opportunities for accomplishment.

Ingersoll-Rand is also a recognized leader in the design and manufacture of the specialized industrial equipment shown at the right – all requiring a high order of engineering.

If you are looking for a leadership career with long range job security and excellent opportunities for advancement, you'll find it at Ingersoll-Rand. For further details, contact your placement office, or write to Ingersoll-Rand, 11 Broadway, New York 4.

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1946

Richard M. Tunnell, MS, was promoted to the rank of Captain in February while serving as commanding officer of the Naval Air Test Facility at the Naval Air Station in Lakehurst, N.J. He came to Lakehurst in March, 1955, from the Bureau of Aeronautics in Washington, D.C., to establish the Naval Air Test Facility.

1947

David R. Opperman, formerly instructor in the college of engineering at the University of Illinois, is now assistant dean of the department.

Milton D. Van Dyke, MS, PhD '49, an aeronautical research scientist at the Ames Aeronautical Laboratory (National Advisory Committee for Aeronautics) at Moffat Field, California, recently reported on a new method of solving the so-called "blunt-body problem" critical in the design of ballistic missiles. His contribution to the technique is a mathematical process that can be handled by automatic computation machinery, which opens new possibilities for improving the design of missile nose cones. Milton has been with the NACA Ames Laboratory since 1943. The Van Dykes live in Los Altos and have two sons.

John P. Craven, MS, contract research administrator at the Navy's David Taylor Model Basin in Washington, was nominated for "special recognition" by the District of Columbia Council of Engineering and Architectural Societies during the 1958 Engineers and Architects Day Observance in February. John has been attending George Washington University Law School at night and is completing work for his LLB degree this spring.

1948

Tom Tracy, industrial sales manager for the Minneapolis-Honeywell Regulator Company in Los Angeles, and secretary for the Class of 1948, writes that "the class will hold its first reunion at the Annual Alumni Meeting at the Rodger Young Auditorium on June 11. Many members of the class have expressed interest in activities in addition to the June meeting so I'm planning a questionnaire to get an inventory of what pertinent things have happened in these ten years. If any of the class plan a trip to California—or want to get a regional reunion going—or if anyone has names of those who might not get the questionnaire—please write me at 1640 Amberwood Drive, South Pasadena, Calif. Or phone me at work (RA. 3-6611) or at home (SY. 9-3394)."

1952

Richard S. Winkler is now in Den Haag, Holland, working with Aramco as a design engineer, and expects to be abroad for five more years. He will be married to Andrea Mazel of Den Haag on June 21.

1954

John C. Day is now an applied science representative for IBM, specializing in the application of digital computers to scientific and engineering problems. John was formerly a lieutenant in the U.S. Air Force in El Centro. The Days live in Anaheim and have a two-year-old daughter.

Kenneth D. Johnson, PhD, is now staff assistant to the vice president of the Atlantic Research Corporation in Alexandria, Va. He was formerly vice president of the Albert L. Chaney Chemical Laboratory, Inc. in Glendale, Calif.

Manuel Morden, MS '55, structural designer for Ropp & Ropp, structural engineers in Los Angeles, announced the arrival of a son, Darryl Edward, on March 14.

James N. Pinkerton, graduate student at Harvard University in Cambridge, Mass., writes: "We have added three new members to our family—James, Jr., Agamemnon and Iphigenia; the latter two being white mice. These three are in addition to the dog, Geoffrey, whose arrival was announced in *E&S* in May, 1957."

1955

Lt. John L. Honsaker, U.S. Air Force, has been working on the "Perhapsatron" at Los Alamos for the past year. Next September, he'll be back at Caltech to work for his PhD in nuclear physics.

Lloyd E. Best, MS, geologist with the California Company in New Orleans, announced the birth of his first child, Glenn Hubbard, on December 20, 1957. Lloyd is now assigned to the geophysics section of the company, dealing with magnetic recording of seismic data.

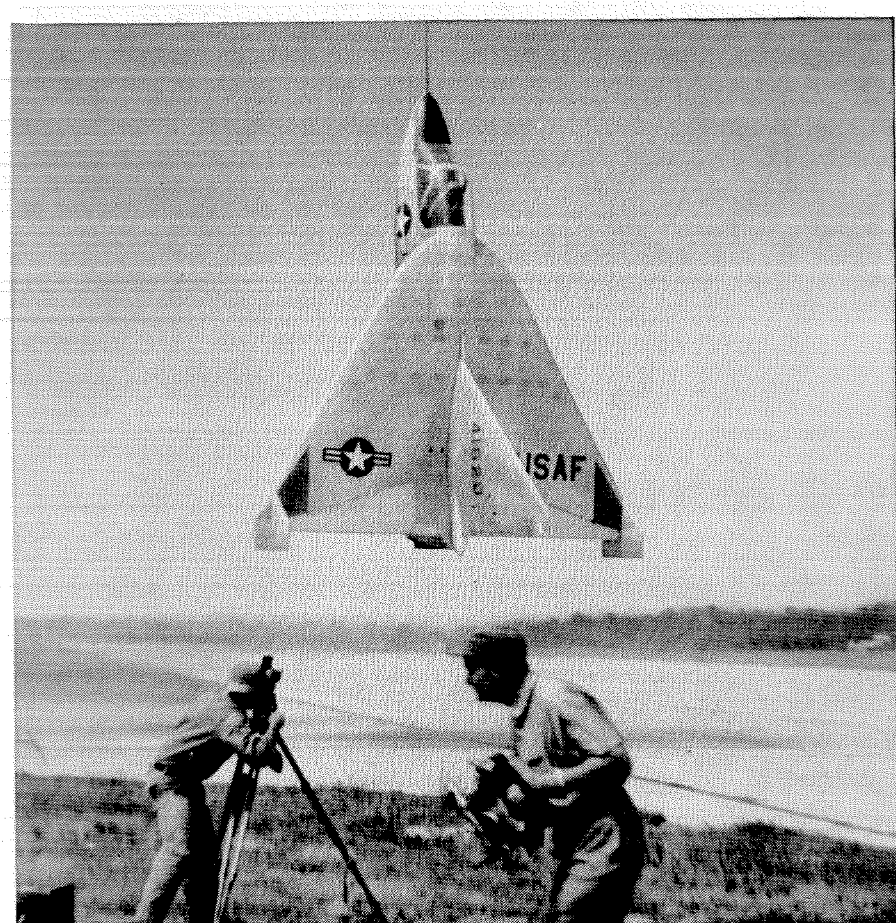
1956

Jan L. Arps writes: "I've been working in Franklin, Alabama as an exploitation engineer for the Shell Oil Company for the past year. On October 20, 1957—our first wedding anniversary—my wife, Peggy, gave birth to a son, John Eric, who is developing into a blond, blue-eyed scene-stealer. Around September, Shell is vacating its offices in Franklin and transferring to Lafayette, La. Was recently visited by *Al Nichols*, '55, who was returning to California from a six-month session at Oak Ridge, Tenn."

Eugene A. Nelson writes: "My wife and I are proud to announce that we are now the parents of a daughter—Lynn Deborah—born on September 15, 1957, in Pensacola, Fla., where I was stationed during flight training in the Navy Air Force. I am presently employed as an engineering geologist by the State of California."

REPORT FROM RYAN

Ryan's Diversification Creates Wide Opportunity for Engineers



X-13 Vertijet Adds New Punch to Airpower

Washington—Unveiled in an unprecedented flight at the Pentagon, the Ryan X-13 Vertijet gave military officials a glimpse of the future of airpower. Like a huge bat, the Vertijet unhooked itself from its nose cable, hovered vertically, then whipped over into horizontal flight and roared out of sight.

World's first jet VTOL aircraft, the Vertijet combines the flashing performance of jet power with the mobility of missile launching. It frees supersonic airpower from runways and airports. Without landing gear, flaps, actuators, the X-13 concept means less weight—more performance in speed and climb.

In the words of a top Air Force General, "The Vertijet has provided military planners with a new capability for manned aircraft of the future."

Achieved in close cooperation with the Air Force and Navy, the Vertijet is based upon Ryan's unsurpassed 2¼ million manhours of research, development, and test in VTOL aircraft.

Navy, Army to Use New Ryan Navigator

San Diego—Navy aircraft—piston engine, jets and helicopters will soon be equipped with Ryan lightweight automatic navigators and ground velocity indicators. Lightest, simplest, most reliable, most compact of their type, these systems are self-contained and based on continuous-wave radar.

The navigators provide pilots with required data such as latitude, longitude, ground speed and track, drift angle, wind speed and direction, ground miles covered and course and distance to destination. Ryan is also developing guidance systems for supersonic missiles.

More Orders for Ryan Firebees

San Diego—Nearly $20 million worth of Ryan Firebee jet drone missiles have been ordered by the Air Force and Navy in 1957. In operational use, the Firebee is the nation's most realistic "enemy" target for evaluating the performance of air-to-air and ground-to-air missiles. It possesses the high speed, altitude, maneuverability and extended duration needed to simulate "enemy" intercept problems.

America's number-one jet drone, the Firebee is another example of Ryan's skill in blending aerodynamic, jet propulsion and electronics knowledge to meet a challenging problem...answer a vital military need.

Ryan has immediate career openings for engineers

Look to the future. Look to Ryan . . . where you can grow with an aggressive, forward-looking company. You'll find a variety of stimulating projects. Ryan engages in all three elements of modern flight—airframes, engines and electronic systems.

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In the meantime, see if you can tell which Inco Nickel Alloy proved to be the answer to these problems.

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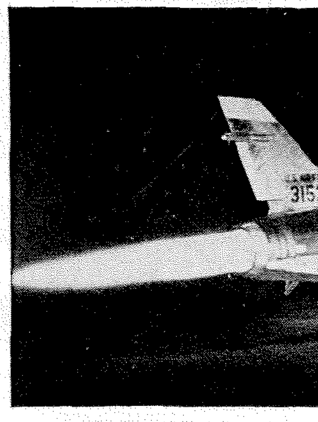
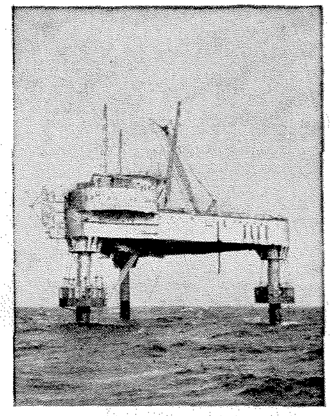
1. **"S" Monel** hard-grade nickel-copper cast alloy
2. ***Inco Nickel***
3. **"K" Monel** age-hardenable nickel-copper alloy
4. **Inconel** nickel-chromium alloy
5. **Monel** nickel-copper alloy
6. **Inconel "X"** age-hardenable nickel-chromium alloy
7. **Monel "403"** non-magnetic nickel-copper alloy

See answers below

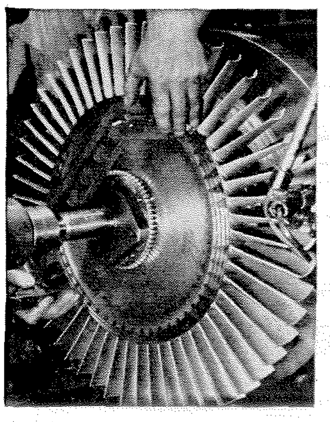
☐ **Oil well drill collar** – Needed: *non-magnetic metal with high strength.* Which Inco Nickel Alloy . . . ?



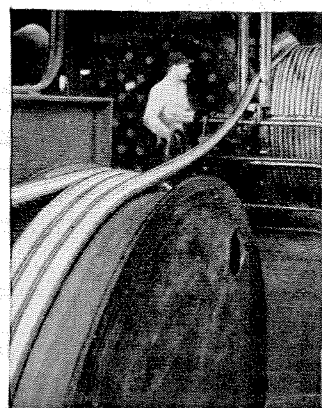
☐ **Jet engine flame tube**–Needed: *oxidation and corrosion resistance at jet engine temperatures.* Which Inco Nickel Alloy . . . ?



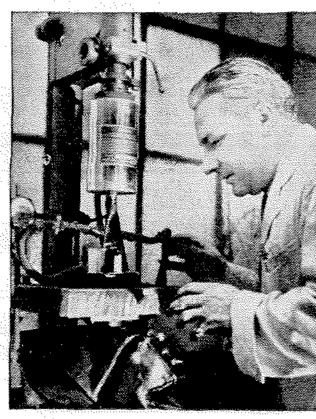
☐ **Radar platform "leggings"** – Needed: resistance to abrasion and marine corrosion. Which Inco Nickel Alloy . . . ?



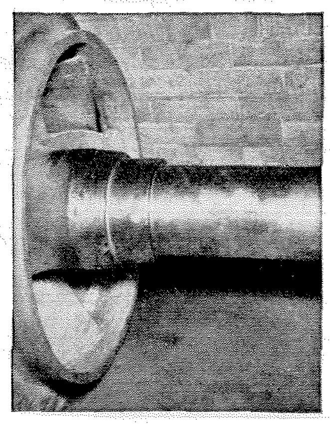
☐ **Gas turbine blades** – Needed: hot strength up to 1500°F., low coefficient of expansion. Which Inco Nickel Alloy . . . ?



☐ **Submarine cable sheathing** – Needed: non-magnetic metal resistant to marine corrosion. Which Inco Nickel Alloy . . . ?



☐ **Ultrasonic drill** – Needed: high magnetostrictive ability to produce ultrasonic vibrations. Which Inco Nickel Alloy . . . ?



☐ **Shaft sleeve for salt water pump** – Needed: extra-hard casting alloy that resists corrosion. Which one . . . ?

You may have to take this kind of quiz *again*. You may be designing a machine which requires a metal that resists corrosion . . . or wear . . . or high temperatures. Or one that meets some destructive *combination* of conditions.

When you start to design equipment, you will have to select the proper material to meet given service conditions. Over the years, Inco Development and Research has successfully solved many metal problems, and has compiled a wealth of information to help you.

For more on special problems solved with Inco Alloys, send for "Standard Alloys." Write The International Nickel Company, Inc., Dept. 00, New York 5, N. Y.

The International Nickel Company, Inc.
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Oil well drill collar: 3. "K" Monel; Jet Engine flame tube: 4. Inconel; Radar platform "leggings": 5. Monel; Gas turbine blades: 6. Inconel "X"; Submarine cable sheathing: 7. Monel "403"; Ultrasonic drill: 2. Inco Nickel; Pump's shaft sleeve: 1. "S" Monel

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In advanced planning, as in location and design, the new Sun-Times Building is front-page news. For this is the first project to be completed in a development which will transform the area north of Chicago's Loop into a city of the future.

There can be only one basis for selecting physical equipment for such a plant: the ability to perform efficiently and economically *for years*. This is why Jenkins Valves are standard on all plumbing, heating and air conditioning lines in the block-long structure.

The extra measure of performance and reliability built into Jenkins Valves has for generations assured long operating life and low maintenance cost. That's well to remember when you specify valves . . . especially since the valves that bear the famous Jenkins Diamond mark *cost no more*. Jenkins Bros., 100 Park Avenue, New York 17.

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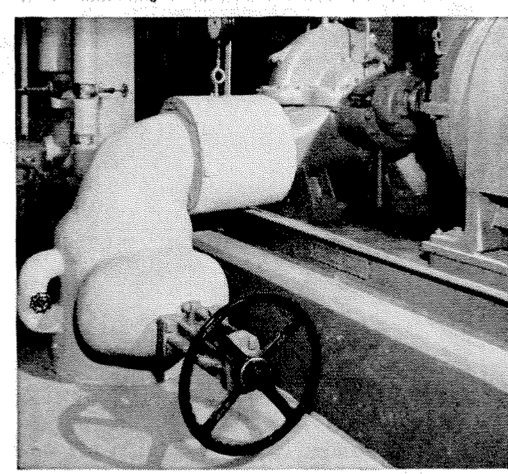

10" Fig. 651-A Jenkins Iron Body Gate Valve, fitted with by-pass, on suction line of pump which supplies Chicago River Water as condenser water and process water for type foundry requirements.

JENKINS
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VALVES
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CALTECH CALENDAR

Alumni Events

June 11 — Annual Meeting
Rodger Young Auditorium

June 28 — Annual Picnic
Knott's Berry Farm

Athletic Schedule

BASEBALL

April 19
Pomona-Claremont at Caltech
April 23
Redlands at Caltech
April 26
Whittier at Whittier
April 30
Occidental at Occidental
May 3
Redlands at Redlands

TENNIS

April 18
Santa Barbara at Caltech
April 19
Pomona-Claremont at Claremont
April 23
Redlands at Caltech
May 3
Whittier at Caltech

TRACK

April 19
Pomona-Claremont at Claremont
April 23
Whittier at Caltech
April 26
Cal Poly (Pom.) & Westmont at Caltech
May 2
All-Conference at Occidental

GOLF

April 18
UC, Riverside at Caltech
April 21
Occidental at Occidental
May 2
Pomona-Claremont at Claremont
May 5
Whittier at Whittier

Friday Evening Demonstration Lectures

LECTURE HALL
201 BRIDGE, 7:30 P.M.

April 18
Geologic Time Table—
by Dr. Gerald Wasserburg

April 25
Sex in Viruses—
by Dr. Franklin Stahl

May 2
Radio Astronomy—
by Professor John Bolton

May 9
How Do Genes Duplicate?—
by Dr. Matthew Meselson

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Secretary-Treasurer — Norman Bulman, '52
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Meetings: Informal luncheons every Thursday
Fraternity Club, 345 Bush St., San Francisco

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Portland Cement Association

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University Club, 1319 "K" St., Sacramento

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U. S. Navy Electronics Laboratory

1,000 styles—750 stores—yet photography gives headquarters inventory figures overnight

Thom McAn ends ten-day hand-copying jobs with Kodak's Verifax Copier—now gets complicated sales, size and style data off in a day.

BEFORE, when Thom McAn's merchandise manager or stylist needed word on sales or style trends in certain stores, it took as much as ten days to hand-copy the records.

But today, when headquarters located in New York requests information on any shoe style or store, the New England merchandising center gets the latest facts and figures away in that night's mail. And styling, buying and distributing functions get 24-hour—instead of ten-day—service on vital stock allotment statistics.

This is because the facts, kept on files of removable panels and cards, can be slipped into a Kodak Verifax Copier and copied, photographically accurate, in a minute.

Photocopying is just one of hundreds of ways photography works today for all kinds of businesses, large and small. It helps with product design, takes kinks out of production, increases sales, improves customer and personnel relations.

Thom McAn calls the Verifax Copier "the kingpin of the allotment control system." It copies a store's style allotment records and width breakdowns and in less than 60 seconds has a dry print ready for the mails.

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Kodak
TRADE MARK

One of a series*

Interview with General Electric's Earl G. Abbott Manager—Sales Training

Advancement in a Large Company: How it Works

Where do you find better advancement opportunities—in a large company or a small one? To help you, the college student, resolve that problem, Mr. Abbott answers the following questions concerning advancement opportunities in engineering, manufacturing and technical marketing at General Electric.

Q. In a large Company such as General Electric, how can you assure that every man deserving of recognition will get it? Don't some capable people become lost?

A. No, they don't. And it's because of the way G.E. has been organized. By decentralizing into more than a hundred smaller operating departments, we've been able to pinpoint both authority and responsibility. Our products are engineered, manufactured and marketed by many departments comparable to small companies. Since each is completely responsible for its success and profitability, each individual within the department has a defined share of that responsibility. Therefore, outstanding performance is readily recognized.

Q. If that's the case, are opportunities for advancement limited to openings within the department?

A. Not at all. That's one of the advantages of our decentralized organization. It creates small operations that individuals can "get their arms around", and still reserves and enhances the inherent advantages of a large company. Widely diverse opportunities and promotions are available on a Company-wide basis.

Q. But how does a department find the best man, Company-wide?

A. We've developed personnel registers to assure that the best qualified men for the job are not overlooked. The registers contain complete appraisals of professional employees. They enable a manager to make a thorough and objective search of the entire General Electric Company and come up with the man best qualified for the job.

Q. How do advancement opportunities for technical graduates stack-up with those of other graduates?

A. Very well. General Electric is recognized as a Company with outstanding technical skills and facilities. One out of every thirteen employees is a scientist or engineer. And approximately 50 per cent of our Department General Managers have technical backgrounds.

Q. How about speed of advancement? Is G.E. a "young man's Company"?

A. Definitely. A majority of all supervisors, managers and outstanding individual contributors working in the engineering function are below the age of forty. We believe that a job should be one for which you are qualified, but above all it should be one that challenges your ability. As you master one job we feel that consideration should be given to moving you to a position of greater responsibility. This is working, for in the professional field, one out of four of our people are in positions of greater responsibility today than they were a year ago.

Q. Some men want to remain in a specialized technical job rather than go into managerial work. How does this affect their advancement?

A. At G.E. there are many paths which lead to higher positions of recognition and prestige. Every man is essentially free to select the course which best fits both his abilities and interests. Furthermore, he may modify that course if his interests change as his career progresses. Along any of these paths he may advance within the Company to very high levels of recognition and salary.

Q. What aids to advancement does General Electric provide?

A. We believe that it's just sound business policy to provide a stimulating climate for personal development. As the individual develops, through his own efforts, the Company benefits from his contributions. General Electric has done much to provide the right kind of opportunity for its employees. Outstanding college graduates are given graduate study aid through the G-E Honors Program and Tuition Refund Program. Technical graduates entering the Engineering, Manufacturing, or Technical Marketing Programs start with on-the-job training and related study as preparation for more responsible positions. Throughout their G-E careers they receive frequent appraisals as a guide for self development. Company-conducted courses are offered again at all levels of the organization. These help professionals gain the increasingly higher levels of education demanded by the complexities of modern business. Our goal is to see every man advance to the full limits of his capabilities.

If you have other questions or want information on our programs for technical graduates, write to E. G. Abbott, Section 959-9, General Electric Co., Schenectady 5, N. Y.

***LOOK FOR other interviews discussing: • Qualities We Look For in Young Engineers • Personal Development • Salary.**

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