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Color in the Universe . . . page 26

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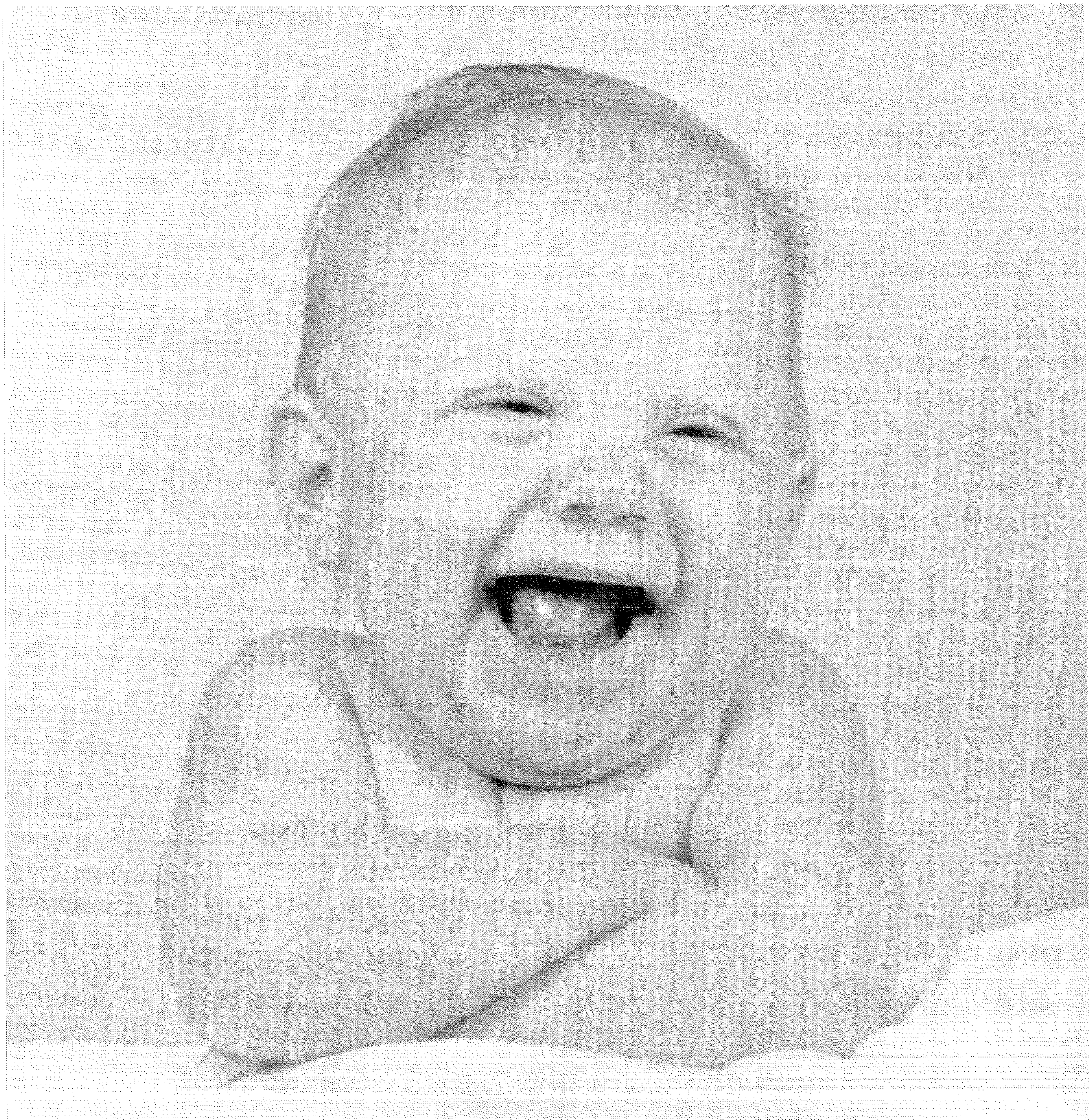

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On Our Cover

is the Great Nebula in Orion, a huge cloud of glowing gas which is visible to the naked eye as the middle star in the sword of Orion, one of the best known constellations in the winter sky. Several very hot blue stars in the center of the nebula light up the gases, and intervening clouds of opaque dust are silhouetted against portions of the nebula. Located nine quadrillion miles from the earth, the nebula has a mass 10 times that of the earth. The color photograph on the cover was made with the 200-inch telescope.

Color in the Universe

The Great Nebula in Orion is one of a group of astronomical objects which have now been photographed for the first time in their natural colors. Color pictures of other nebulae and galaxies are on pages 26 to 31 in this issue. These photographs are the result of almost three years of research under the direction of William C. Miller, photographer for the Mount Wilson and Palomar Observatories. By combining a new ultrafast color film with the exceptional optical speeds and long focal lengths of the Palomar telescopes, astronomers have been able to capture colors that have never been viewed before — even through the world's most powerful telescopes.

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Books

The Autobiography of Charles Darwin

Edited by Nora Barlow

Harcourt, Brace $4.50

Reviewed by A. H. Sturtevant

This year marks the 150th anniversary of the birth of Charles Darwin, and the 100th anniversary of the publication of *The Origin of Species.* It is therefore not surprising that there are many recent publications of Darwiniana. Of these, the most important is the complete text of his autobiography, edited by his granddaughter Nora Barlow. In the same volume is other new material, to be noted below.

The *Origin* is one of the major contributions to the development of human thought. The hypothesis of evolution had been suggested many times before; but with this work it became a part of the main stream of culture, for Darwin here presented an overwhelming body of evidence – and the establishment of the principle of natural selection not only took the mystery out of evolution, but also gave a naturalistic interpretation for the adaptations of living organisms. This was the death blow to a teleological interpretation of biology, and to Paley's "argument from design."

There can be few men, among those who have made major contributions to human thought, about whom there is as much personal information available as there is about Darwin.

His career was largely determined by his trip as naturalist on the *Beagle* (1831-1836), and for this period there is an unusually full record, from which can be traced his gradual development. During the voyage Darwin kept a series of notebooks, which were then worked over into a diary; the formal account that he published *(Journal of Researches)* was then revised from the diary. Lady Barlow, who is herself a biologist, has previously edited and published a series of extracts from the notebooks *(Charles Darwin and the Voyage of the Beagle,* 1946), and the diary *(The Beagle Diary,* 1933). She is an outstanding authority on Darwin, and her notes and discussions in the present volume add greatly to its value.

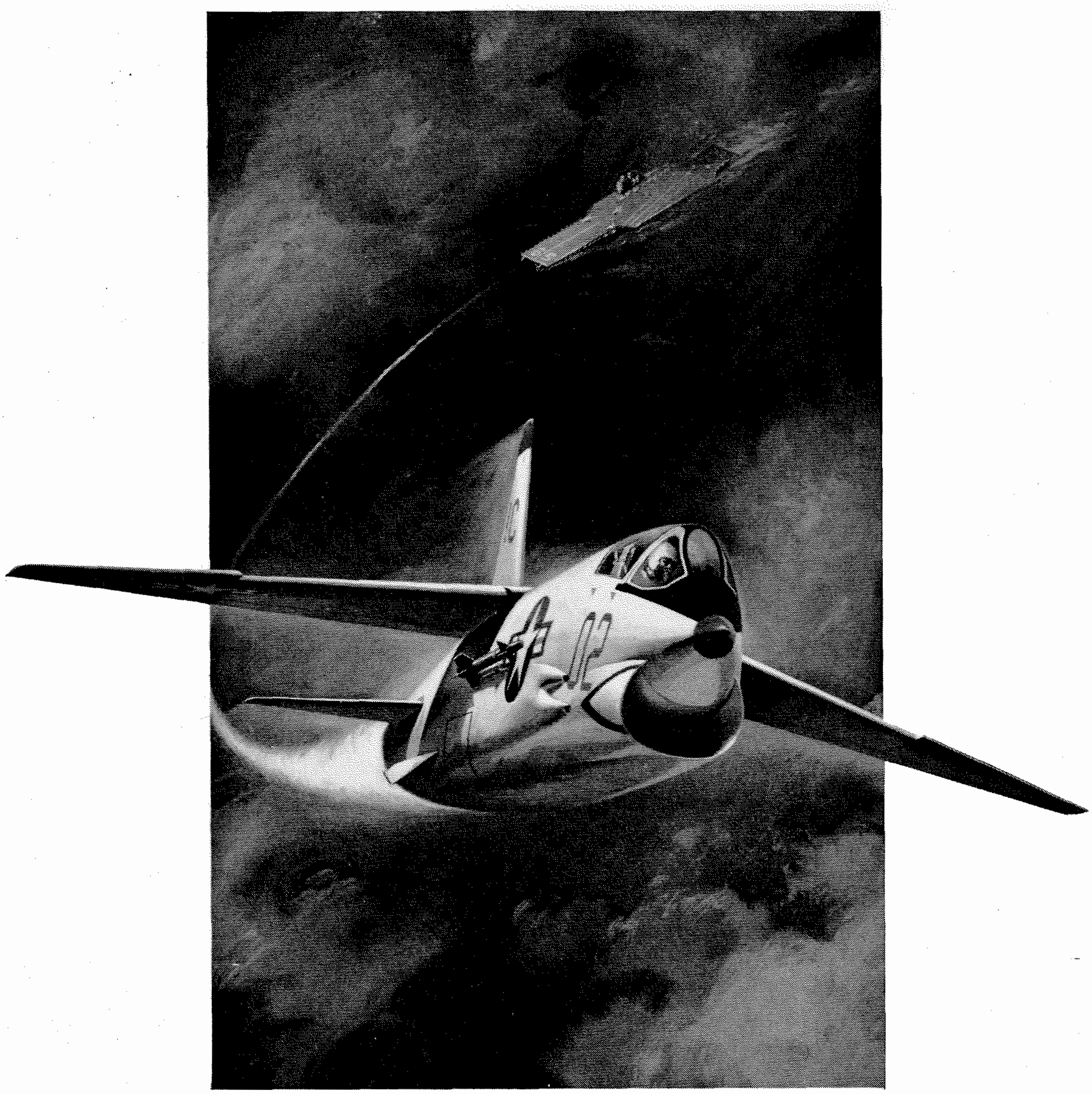
In 1887 Charles Darwin's son Francis published his father's *Life and Letters,* which included a brief autobiography written by Charles for his children and finished in 1876, six years before his death. Some passages in the autobiography were omitted, after much family discussion, and these are now published in the book under review. The new material chiefly concerns Darwin's religious beliefs. He had at one time intended to become a clergyman, but this plan gradually faded out of existence – chiefly during the voyage of the *Beagle.* In later years he became an agnostic, but not a militant one – in fact it is only now possible to see just what his attitude toward religion was.

Other contributions

The fact of evolution and the fact that it, and the general occurrence of adaptations, can be explained without recourse to design or to any supernatural control, is of major importance. It is, perhaps, not surprising that many biologists have concluded that the details are also of major importance. Clearly, the precise family trees of particular groups of organisms are worth studying, as is the working out of the bearing of the newer knowledge of heredity on the mechanism of evolution. But it is arguable that biology has suffered from an overemphasis on evolution since Darwin's time. In this connection it is worth pointing out that Darwin himself made many first-rate contributions that were only rather remotely related to organic evolution – such as his studies on coral reefs, on earthworms, on the fertilization of plants by insects, on insectivorous plants, on the light-reactions of plants, and numerous other topics.

The present volume also has a discussion of Darwin's grandfather, Erasmus Darwin, and of his influence on Charles. Samuel Butler felt that Charles Darwin had been unfair to him, and Lady Barlow discusses this matter at some length, producing new

continued on page 10



material — and incidentally giving a picture of one side of Butler's character.

The autobiography itself is one of the few in which the author succeeds in being reasonably objective about himself, which makes it especially valuable to anyone interested in the history of ideas. It is also of value for the light it throws on the intellectual life of the times. There are brief accounts of Darwin's many scientific friends — Lyell, Hooker, Huxley, Wallace, and others — and also of Herbert Spencer, Grote, Carlyle, Macauley, and other contemporaries.

Above all, it is readable. Here is a first-rate mind — and a man who writes about himself with no reservations, and with no attempt either to show his own importance or to be overmodest.

A. H. Sturtevant has been at Caltech since the division of biology was established in 1928. He has been Thomas Hunt Morgan Professor of Genetics since 1951.

God Bless Our Queer Old Dean

by W. Storrs Lee

G. P. Putnam's Sons, N.Y. . . . $3.95

Reviewed by Foster Strong

As with many of Shaw's plays, the preface of this book may receive more concentrated attention from the reader than will the remainder of the volume. This preface, by Robert M. Strozier, now president of Florida State University but formerly dean of students at the University of Chicago, is a thoughtful and well-written discussion of the historical development of the office of dean of students, and a cogent review, by a perceptive reporter, of the operational headaches and the administrative uncertainties that beset the office in many institutions. (For the alumni who never became well acquainted with the deans' office at CIT, I hasten to assure them that the headaches and difficulties cited by Dr. Strozier are not characteristic of their alma mater.)

Most of Dean Lee's ten chapters and approximately 200 pages sound like those "as told to" reminiscences so popular in magazines such as the *Saturday Evening Post.* In addition to his own experiences (he served as dean of men at Middlebury College for ten years) Dean Lee must have attended most of the deans' conventions in that time and assiduously collected the experiences of other deans.

His book contains all of the standard episodes, and lists many of the standard gambits in deanmanship, and perhaps this is acceptable — after all, a reader who deliberately chooses to pick up a book about deans should expect such a catalog.

What is less defensible, however, is the characteristic exaggeration of the "as told to" method; all of the abnormal, or emergency, episodes (only one or two of which may possibly occur in an average dean year) have been gathered together in an apparent time sequence as if they represented a normal operating day. This is inaccurate; what is more, it makes a dean's life sound unbelievably frenetic, and one is bound to wonder if a dean who permitted such a life weren't downright soft in the head.

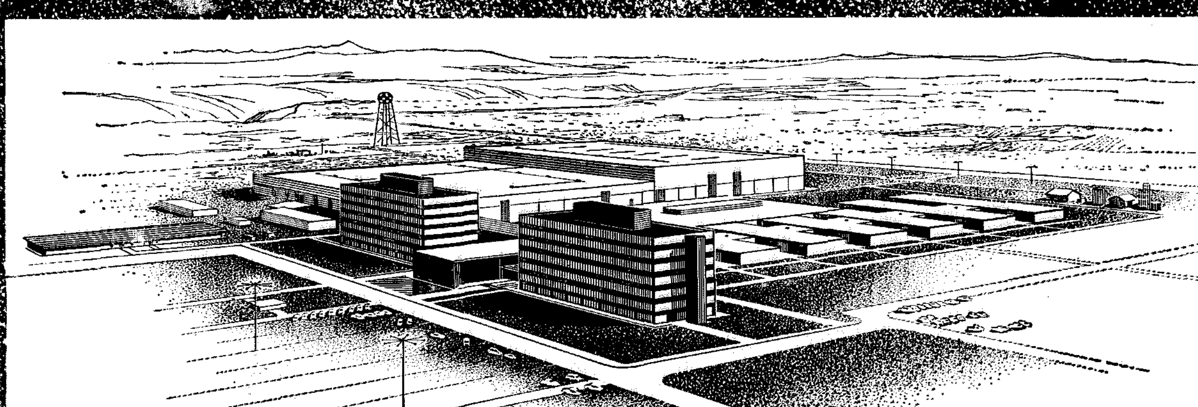
Any reviewer should bear in mind the audience to which a book is addressed. I am unable to meet this responsibility, because I have not been able to guess who the audience might be for this book.

I doubt that many deans will buy the book — they're just not that interested in looking in a distorted mirror.

Some parents of college students may buy the book — and I hope this will not result in forever shutting off future communication between parent and dean.

Some college presidents may read it out of curiosity — and I would expect them to feel on familiar ground in the preface, to read with interest the brief discussion of the ideological schism between the academically-based, father-substitute, old-line dean and the burgeoning ranks of the "personnel" counselors who have been trained to substitute psychological clichés for depth in human relations, and to skip rapidly over the anecdotal chatter that constitutes the major part of the book.

Foster Strong has been Caltech's dean of freshmen since 1945.



The Exploration of Outer Space

by L. A. DuBridge

Is outer space a resource? If so, one very positive thing can be said about it immediately: there is plenty of it!

Outer space is not only plentiful; it is also durable. It never gets used up. In fact, if you want to speak precisely, the quantity of outer space is rapidly increasing! Because of the expansion of the universe, the radius of space is increasing at a rate nearly equal to the velocity of light. This adds quite a lot to the volume of space every year!

A resident of New York, Chicago or Los Angeles must certainly regard space as a pretty transient resource, as he sees the space available to him dwindling each year at a rapid rate. Naturally, therefore, he looks to *outer* space in the hope that most of his neighbors may some day be transported out there. On this point we cannot offer our harassed city dweller much hope. After all, he or his neighbors could, if they chose, move at any time to Texas or Alaska, to the Mojave Desert, Death Valley, or many other places. If he does not like the desert because of the scarcity of water and food, why would he choose the moon where there is also not even any air?

The entire surface area of the moon is only $\frac{1}{16}$ of the surface area of the earth, or $\frac{1}{4}$ of the land area. The whole surface of Mars has an area about equal to the land area of the earth. Hence, if we are looking for extra space to which to transport an excess population, it would clearly be cheaper to build a colossal floating platform over the surface of all the earth's oceans. This would multiply our living area by four, whereas the moon and Mars combined would provide us less than a factor of two. Furthermore, I repeat, the earth has air – blessed air!

To tell the truth, it seems pretty likely that for the next few years the exploration of outer space will be one of our best methods of *using up* natural resources rather than conserving them or increasing them. A lot of steel, copper, oil, coal, many other valuable materials, and much human labor can be bought for the billion dollars a year or so we will be spending on space ventures, and it would be a good thing for the American people to try to understand what the investment is for and what returns it is likely to yield.

It is frequently suggested that on the moon or Mars, or some other planet, we may find huge stores of valuable minerals – gold, copper, uranium, or something else. (We won't find coal or oil, for these come from living things!) But I think it is very clear that it would be far cheaper to extract gold from sea water or uranium from granitic rocks than to haul them from the moon. We are really not running out of these minerals here on earth; we are only running out of cheap sources of them. The moon or Mars can hardly be regarded as cheap sources for anything.

Let me hasten to make it clear that I think a good sound program of space research, space exploration, and possibly space exploitation *is* worth a billion dollars a year to us – possibly very much more than that. I favor a bold, imaginative and extensive program of space activities covering both military and civilian

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"The Exploration of Outer Space" has been adapted from an address given by President DuBridge on the 1959 Forum series presented by Resources for the Future in Washington, D.C., on March 12, 1959.

The nature of the space environment, the goals to be sought in exploration, and the problems we face in attaining those goals.

possibilities – including many research ventures whose potential value, whether military or civilian, cannot possibly be foreseen. My only hope is that this program can be based on realities rather than on fancies.

It is my purpose here to examine space activities from the point of view that the greatest resource to be gained from them is knowledge – new knowledge about our own earth, as well as about outer space; and new knowledge about the techniques of getting out there to gain more knowledge. After all, no human resource is more valuable than knowledge. And when we contemplate what a vast sea of ignorance we face in outer space, it is natural that we should be impatient to get on with the task of replacing ignorance by knowledge.

I shall discuss, first, certain matters related to the nature of the space environment; second, some of the goals to be sought in space exploration; and third, certain of the technological problems we face in attaining those goals.

I. THE SPACE ENVIRONMENT

At first thought it might seem that "empty space" is something about which there is not very much to say except that it is empty and big. Closer examination, however, shows that while space is certainly big it is *not* empty, and it will be instructive to review some of the things we know about it.

Of course, it is really meaningless to talk about the size of space itself, but it is not meaningless to talk about the distances between the various tangible objects in space. In fact, some of these distances are so enormous that it pays to take a look at them before we talk too blithely about the journeys we are going to take out to this object or that. It is not very useful to express these vast distances in miles, because the numbers are too huge to carry meaning. We could follow the lead of the astronomer and express them in light years–that is, the distance traversed by a beam of light in a year at the speed of 186,000 miles per second. This, however, gives an inadequate impression of the distances because light travels at a speed thousands of times greater than that which we can hope to give any material object in the foreseeable future.

I shall, therefore, express these distances in terms of the time required for a possible space vehicle to traverse them. I shall arbitrarily assume that we have a space vehicle which can travel at a constant speed of 25 miles per second, or 90,000 miles per hour. This is 3½ times the speed of escape from the earth; it is just about equal to the speed required to escape the sun's pull when in an earth-like orbit; it is also 50 percent greater than the earth's orbital speed around the sun. How long would it take this vehicle to travel from the earth to various points in space? Here are a few sample items:

To go to	*The time required is*
The Moon	2.9 hours
Mars (nearest approach)	16.0 days
The Sun	43.0 days
Uranus	780.0 days
Pluto	4.5 years
Alpha Centauri (the nearest star)	30,000 years
The center of the Milky Way	560,000,000 years
Andromeda Nebula (the nearest spiral galaxy)	15,000,000,000 years

The conclusion is obvious: All points *within* the solar system (the first five items above) are well within reach of our imaginary vehicle in times reasonable compared to a human lifetime. However, no known object *outside* our solar system comes within a factor of a thousand of being accessible. It is true we can someday probably exceed my assumed speed of 25 miles per second. But the 25,000 miles per second required to bring the nearest star within reach is not in sight. In brief terms: interplanetary but not interstellar space is now open to conquest.

Gravitational fields

Probably the most conspicuous property of interplanetary space is the existence of the all-pervasive gravitational field. The intensity of the field fluctuates greatly, depending on one's position relative to the sun or one of the planets. For example, a body which weighs 100 pounds on the earth would weigh only 25 pounds at 4,000 miles from the earth's surface, and 1 pound at 36,000 miles (40,000 miles from the earth's center). It will weigh 16 pounds on the moon, 38 pounds on Mars. If we recede farther from the earth, but still remain at the same distance from the sun, the latter's attraction with a force of 1/10 of a pound will eventually predominate. This force, in turn, will vary inversely as the square of the distance from the center of the sun and will have appreciable values out to distances of billions of miles.

A gravitational force inevitably means an acceleration and hence *no object in the solar system can remain at rest.* In other words, any object projected from the earth, if it does not return to earth, will go into some sort of orbit about the earth — or, if it escapes the earth's pull, into an orbit around the sun. It would not, without a further "push," orbit about any other object. These closed orbits about the earth or sun are always ellipses (a circle being a special and rather improbable form of an ellipse). In a case where the velocity of an object is high enough for it to escape from the earth, it will still have the velocity of the earth about the sun and will automatically go into a solar orbit.

Furthermore, once the propulsive force has ceased to act on the object (e.g., the rocket has burned out) then the precise path of that object in the gravitational field in space is determined (and its velocity determined too) for all time to come, unless another propulsive force is applied (such as another rocket impulse) or unless the object encounters the retarding effect of friction as it enters an atmosphere. Thus, a satellite projected into an elliptical orbit around the earth, at an altitude sufficiently great to avoid atmospheric friction, will continue in a predictable orbit for years or centuries to come. The particular orbit to be followed will, furthermore, be determined solely by the position and the direction and magnitude of the velocity at the instant the propulsive force ceases. Two objects starting from different initial positions, or with different initial velocities, cannot attain the same orbit. Nor can two objects traverse the same orbit with different speeds; an orbit is not a race track in which one vehicle can overtake another. Nor can two objects in different nonintersecting orbits ever have the same speed; the object farther away from the attracting center must always be going more slowly.

"Perpetual motion"

I emphasize this point of the inevitability of motion and the predetermination of motion in a gravitational field because many discussions of space travel seem to assume that a platform can be established which can float lazily around in space like a boat on a quiet lake. The picture is quite different. A boat in a whirlpool is a more accurate analogy; it simply can't stop.

The rotational nature of this "perpetual motion" gives rise to some odd results. If an object in an orbit around the earth or the sun is suddenly given an acceleration (e.g., by a rocket) in the direction of motion, it will not thereby proceed faster in the same orbit. Instead, the larger centrifugal force will cause it to move off tangentially into a new orbit of larger radius. But, as it moves against the gravitational attraction, it will also slow down and traverse the new orbit at a slower average linear speed and, of course, a longer period of rotation. Conversely, a retro-rocket would cause the object to move inward and attain a higher speed. It is amusing to speculate on the many problems encountered in an environment where one must slow down in order to go faster!

Radiation

A third characteristic of space is the radiation one finds in it.

We know about some of the types of radiation traversing space because they can penetrate both the earth's atmosphere and the earth's magnetic field and reach our instruments. But there are other radiations which cannot reach the earth's surface and which we cannot know about until we begin serious space exploration.

There are, of course, two general types of radiation: (1) *electromagnetic waves* of widely varying length from the long radio waves on through the infrared, visible light, ultraviolet light, to x-rays and gamma rays; and (2) *charged particles* — electrons, protons, and the nuclei of other atoms — with a wide range of kinetic energies from a few electron-volts up to possibly a billion billion electron-volts. Of all these radiations only certain wavelengths in the radio and the visible portions of the electromagnetic spectrum can penetrate our blanket of air, and only the more energetic charged particles can get through the magnetic field and strike even the upper atmosphere. Yet, up to 1957, all of our knowledge of outer space had come through a study of the radiation which does get down to our instruments. Though some instruments have been sent to nearly the "top" of the atmosphere, a whole unknown universe may be revealed as we get clear above the atmosphere and away from the earth's magnetic field.

Indeed, our very first ventures into the regions a few hundred miles above the earth revealed a new belt of radiation — the Van Allen layer — whose existence had been previously unsuspected. It consists of a double cloud of high-energy electrons or protons whose origin is unknown but which appear to be trapped in the earth's magnetic field at distances from a few hundred to 12,000 miles or so above the surface. The intensity is surprisingly great — more than a thousand times the intensity of the known cosmic rays which have been measured by balloon-borne instruments high in our atmosphere. The radiation is intense enough to be a potential hazard to human beings who might like to travel in manned satellites above the earth. And it could ruin photographic plates sent aloft to take pictures of the earth. Many a dream about space exploration has already been abandoned or modified by this discovery — and what additional unsuspected radiation streams are yet to be found no one can tell. Radio, infrared, and ultraviolet telescopes, as well as Geiger counters and other detectors should certainly be sent aloft as soon as possible to begin this fascinating era of discovery, which may well last for many decades before adequate knowledge is obtained.

What will be the results of all this? I do not know. New knowledge? Certainly. Many surprises? Probably. Revolutionary new discoveries? Possibly. But in these vast unknown radiation fields of space there certainly lie hidden many secrets about the nature and size and composition of the universe. The cosmic rays which manage to penetrate to the earth's surface have also told us many things about the structure of atoms and nuclei. The rays which cannot reach us may teach us even more.

Electric and magnetic fields

Around every sizable body in space we are likely to find both electric and magnetic fields. We know a little about the magnetic field about the earth, but very little about any electrostatic field. We know — from rather recent observations — a little about the magnetic field of the sun. It is quite weak and quite variable. Some stars are surrounded by very large fields. Very weak but very pervasive fields may spread throughout interplanetary space and throughout our entire galaxy. They might have profound importance in the acceleration and trapping of charged particles — cosmic rays — and even in the large-scale transfer of momentum between the planets and between stars. Only an extended series of properly instrumented flights far into interplanetary space will reveal the nature and extent of such fields.

II. GOALS OF SPACE RESEARCH

A major task of space research programs will be to learn more about the nature of the space environment itself, the radiation streams which traverse it, and the electric, magnetic and gravitational fields which pervade it. Certain other types of space ventures must indeed await the results of the initial explorations of space itself.

However, there are many more things to be done — so many that it is difficult even to classify them. First, however, we may consider the tasks which may be performed by vehicles placed in various orbits around the earth, and then the additional tasks for probes which are projected farther out into the solar system.

Earth satellites

For some time to come, the most important (though not necessarily the most spectacular) scientific missions will be performed by instrument-carrying vehicles projected into orbits at distances from a few hundred miles out to 20 or 30 thousand miles from the earth's surface. In addition to examining the nature and contents of space itself, they may be used to make observations of the earth or of other bodies. In addition to their information-gathering function, they may also perform certain service functions — as radio relay stations, as refueling stations or service platforms, or possibly as carriers for military weapons. I will confine myself to the information-gathering function here, because it is new knowledge that is the great resource we are now interested in.

However much we may love to learn about the moon and the planets and the sun, the earth will always be the object of primary interest to human beings. So what we can learn about the earth from observation stations circling far above its surface is of prime importance.

Even a "dead" or noninstrumented satellite, if it is large enough to be visible from the surface of the earth (e.g., 100 to 300 feet in diameter), could provide us with quite a lot of information. By observing carefully the nature, shape and perturbations of its orbit, one may learn much about the earth's gravitational field and hence about the exact shape of the earth itself and the distribution of mass within it. It should be remarked that the whole science of precise orbital calculations will need much further development. Astronomers have been working for generations to evolve an exact equation for the orbit of the moon. But every new satellite presents a new and difficult orbital calculation. Computing machines now make the task much easier — but the most suitable mathematical techniques must still be worked out, and much more information needs to be acquired about the exact form of the earth's gravitational field itself, and the small but important perturbations caused by the field of the moon, the sun and other planets.

As one looks down at the earth from a satellite, the most obvious phenomenon to be observed is, of course, the cloud pattern. A single good picture from a satellite which is, say, 300 miles high could — if it could be promptly transported or transmitted to the earth's surface — give a view of the entire storm pattern over an area some 2,000 miles in diameter, i.e., over much of the United States. A few dozen such pictures taken almost simultaneously from properly chosen points in the Northern Hemisphere could give for the first time a complete weather picture of the whole hemisphere. It would take a good deal of research to interpret such pictures and to use them for predictive purposes —

but, clearly, enormous contributions to the science of meteorology are in sight. The difficulties and cost of obtaining such collections of pictures continually and reliably, and getting them back to earth stations without losing too much resolution, are of course enormous. But useful information will be obtained even before such ideally complete observations can be made.

The charged layers of the earth's upper atmosphere, which play such an important role in the transmission and reflection of radio waves, will also constitute an area of intense interest. The charge density and thickness of these layers, the influences which cause the molecules to become ionized, and how these change with time and how they depend on events in the sun or other places, will cast important light on radio, television and radar transmission problems.

The strength, shape and variations in the earth's magnetic field out to distances of 100,000 miles could occupy the attention of dozens of properly instrumented satellites. The origin of this magnetism is still a puzzle and, though the solution to the mystery may not be found in space, pertinent information certainly will be.

If we turn our attention from the earth to other objects in space, we find a bewildering wealth of opportunities for making observations which are forever impossible under our blanket of air. However much we can bless this blanket for its life-giving properties, it is still a curse to the astronomer. As has already been suggested, observatories in space which can measure radio, infrared, visible, ultraviolet, and x-rays will undoubtedly reveal wholly unsuspected things about the sun, the planets and the stars. There is every reason to suppose that the radiations which cannot penetrate our atmosphere may carry just as great a wealth of information as those that do, and a new era in astronomy will dawn when space observatories become possible. Unfortunately again, complete space observatories will be very expensive — but even simple ones may be most useful.

These few examples will serve to prove what a gold mine of valuable knowledge may be revealed by instrumented earth satellites.

Manned satellites

I have said nothing about manned satellites. The first man-carrying satellite will be a tremendous achievement and the first passengers will experience a tremendous thrill. The first look that human eyes have of the earth and the heavens from a space vehicle will mark a new epoch in the annals of human experience.

But adventure and prestige are not the only considerations. One must examine carefully what functions men can perform that instruments cannot perform as well or better, and which functions are worth the very great extra cost of carrying a human being aloft, keeping him alive and alert, and getting him back alive. Certainly a vast amount of data can be collected by automatic instruments without human intervention, and space research should not be delayed until the perfection of passenger-carrying vehicles. Nevertheless, the human being — though he is a costly and delicate instrument to carry aloft — does have many attributes which electronic equipment does not yet possess. If intelligently used, man can be a great asset to space research, but if he just goes along for the ride he will be a costly liability. For the next few years the human being can just as well be left at home until we really need him to do the things that instruments cannot do.

Deep-space probes

While earth-satellite vehicles are being used to explore the earth's vicinity, probes to reach the moon, Venus, Mars, and eventually other planets, will soon be launched. Whole new mines of knowledge will be opened up as we get into a position to make visual, photographic, magnetic, and gravitational measurements in the vicinity of these bodies.

We face here, however, some deep difficulties. From the rocket point of view there are no serious problems in projecting deep-space probes into suitable orbits which will pass *near* these bodies. One might even expect someday soon to cause an object to strike the moon. But for the most part, in the foreseeable future, our space probes will sail past their targets and out beyond their gravitational fields to become captured in an orbit about the sun. Such objects will be lost to view forever, and the only information which they will yield is that which they radio back before their batteries burn out, or before they get too far away for the radio transmissions to be detected. Whereas a satellite around the earth might continue in a closed orbit for years, and — when larger solar batteries are available — continue to provide useful information for a long time, our space probes will be one-shot affairs and, as they get millions of miles away, there will be serious difficulties in getting signals from them at all because of the very large amounts of power required.

A great step forward will be made when we succeed in navigating a vehicle into a permanent orbit about the moon — and equip it with solar cells large enough to keep its radio operating for a long time. A great wealth of information can be gleaned from such an experiment.

However, nothing short of a very elaborately equipped vehicle can hope to get into an orbit about Mars or Venus because of the delicate navigational and propulsion problems. And even if this is accomplished when the planet is at the distance of closest approach, it will be only a few days or weeks before the planet and its new satellite — as they increase their distance from the earth — will be hopelessly out of range of the most powerful radio. Thus, a rather sophisticated space technology will be required to begin to obtain continuous information from the vicinity of even these nearest planets. To land instruments on the planets, to explore the more distant planets, and to send manned expeditions to them will be even more difficult.

III. TECHNOLOGICAL PROBLEMS

The success of the first earth satellites and of the first moon probes has led many people to suppose that it is now only a step to the most distant and complex exploratory ventures. It is true that once the first step has been taken it is dangerous to predict that additional steps will not soon follow. It is, however, pertinent to examine the nature of some of the problems yet to be solved.

Consider first the field of rocketry and propulsion. Rockets of thrust of 300,000 pounds are now available and thrusts of a million pounds are in development. These, especially when used in clusters, will send substantial instrumented packages into earth or planetary orbits; i.e., space probes to the region of the moon, Mars, and even more distant planets. Even manned vehicles can be placed in earth orbits with sufficient equipment for a safe return – if the journey does not last too long. A package could also be landed safely on the moon.

However, when one begins to talk about sending even one man to the moon and getting him back alive, one quickly runs into thrust requirements of up to 10,000,000 pounds or more, calling for advances in technology which are far in the future. Space platforms to which the necessary equipment and fuel can be dispatched in smaller packages and then assembled are said to be the answer, but it is not clear whether the technology of such space stations will come more quickly than that of the large rockets. And it is yet to be decided whether a man can bring back enough more knowledge to make his journey profitable.

Some wholly new ideas appear to be called for. There is, in short, room for the development of some propulsion-energy source more useful than a mixture of kerosene and liquid oxygen.

The first thought in this field, of course, is nuclear power. In fact, the space amateur blandly dismisses all difficult propulsion problems by uttering the magic words "atomic energy." But a closer look is clearly called for.

It is certainly true that a fission reactor in a space vehicle could supply a large amount of heat for a very long time without refueling. Unfortunately, heat alone does not provide propulsion. The heat must be imparted to some substance whose molecules, thus speeded up, are then ejected from the vehicle. The simple physics of jet propulsion tells us that the momentum (mass times velocity) of the material ejected during a given time is precisely equal to the increase in the forward momentum of the propelled vehicle. Obviously, the mass of this propellent fluid must be carried along in the vehicle as it leaves the earth. So the limitation on the propulsive effect of a nuclear reactor comes, not when the reactor runs out of uranium fuel, but when the supply of propulsive fluid has been exhausted.

What shall we use for the propulsive fluid? Simple physics again tells us that, for a given total mass of such fluid, the maximum velocity, and hence the maximum momentum, will be imparted (for a given reactor temperature) to the fluid with the lightest molecules. This means that the best possible propellent is hydrogen. However, the problems of packaging many tons of liquid hydrogen (at -252° C.) for a space journey are imposing indeed. Furthermore, even in the liquid state hydrogen is not a very dense substance, so that some 100 tons of it will occupy a lot of precious space and the containing tanks may be pretty bulky. Other less ideal substances may offer more manageable engineering problems. But the point is that while a nuclear reactor for a submarine, for example, has the enormous advantage of carrying a lot of energy in a small mass of uranium fuel, a nuclear rocket must also carry a very large mass of propellent – and much of the apparent advantage of atomic energy is lost. Nuclear rockets *will* be needed someday in launching very large space vehicles, and research on such rockets should be energetically pushed. But nuclear power is not a simple magical answer to all problems.

Possible propulsion schemes

Other possibilities are being investigated, of course – ionic propulsion, photon propulsion, alpha-particle propulsion, etc. It is too early to evaluate their practical possibilities. One thing must be remembered – no propulsion scheme, no matter how exotic, can get away from the basic momentum and energy relations. If a space object is to acquire a large velocity and if it is to escape from a gravitational field, then energy is required – and indeed the energy given to the vehicle itself is very small compared to the energy which must be imparted to the high-velocity escaping propellent. Therefore, any practical propelling device must carry both large amounts of energy and large amounts of propellent mass.

The only scheme I know of which does not have to carry along its own energy source is one using sunlight. Though the sun's radiation pressure is extremely small, it will, over very long periods, provide appreciable momentum. A solar-pressure "sail" can cause an object in an orbit about the sun slowly to "accelerate" (i.e., circle outward into larger orbits) or "retard" (circle inward). Since the small pressure can be available for extremely long times, an orbit gradually spiraling out to very great distances from the sun becomes possible. The journey may take many years, however.

An instrumented satellite must also have energy to operate its instruments and especially must be able to transmit the accumulated information back to an earth station. All space vehicles so far, except the Vanguard satellite, have used dry cells as local power sources — and these have become exhausted in a few days or weeks — often long before the satellite itself has returned to earth. An invisible satellite whose "voice" has gone dead is a pretty useless object. (On the other hand, a great swarm of satellites that can't be turned off could someday be a nuisance too!)

Radio power requirements

Unfortunately, the power requirements for the radio transmitter which is to radio information back to earth get rather imposing as the distance from the earth increases. An earth satellite at a distance of 500 miles or so can be heard by special receivers when transmitting at only 1/100 of a watt. But, as one goes farther out, the inverse-square law begins to take its toll. At 5,000 miles the power for the same receiver and the same signal strength would have to be 100 times as much, or 1 watt; at 50,000 miles, 100 watts; and at the moon, 240,000 miles, one would need about $2\frac{1}{2}$ kilowatts. At the distance of Mars, some 50 million miles, the power has risen to 50,000 kilowatts — 1,000 times the radiated power of a normal cleared-channel broadcasting station, and approaching the power of the very largest electric generating stations now operating on earth.

A part of this difficulty can be overcome by using a directional antenna on the satellite — with the obviously difficult problem of keeping it pointed toward the earth — and by using very large receiving antennas on the earth, 100 or more feet in diameter. But, even at best, the communication problem is one of extraordinary difficulty, and even in the simplest cases one needs some sort of power supply for a long time — and the possibilities of ordinary batteries are limited indeed.

Present zinc-silver batteries provide 20 watt-hours per pound of weight. It would take 440 pounds to operate a radio set consuming 1 watt continuously for one year; at 100 watts they would last only 4 days. Using intermittent operation — transmitting only on signal from the earth — correspondingly longer times can be obtained. Theoretically it should be possible to improve this performance by a factor of about 10. For orbits near the earth, where only a few watts of power will be sufficient, dry batteries will clearly be very useful. For distant ventures, however, the radio power required is so great that batteries become hopelessly inadequate.

Solar power at once suggests itself — and has indeed proved its potentialities in the Vanguard satellite whose solar-powered radio was still operating a year after launching. The power level was very small, however. Larger power requires larger area with corresponding engineering problems. The power available from the sun is, near the earth, of the order of 100 watts output per square meter of effective surface area, for solar cells of present types. Thus large arrays of cells, or else large concave reflectors to concentrate the energy, will be required. For satellites which are near the earth, and hence in its shadow about half the time, some storage battery may be required — and the weight and life requirements become immediately more difficult.

An ingenious but extremely expensive device has recently been constructed in which an intense radioactive source, activated in a nuclear reactor, is used as a source of heat to activate a thermoelectric couple. Available devices might provide a few watts of power, but the most suitable isotope (polonium) has a half life of only 138 days — which cannot be prolonged even though only occasionally used.

It would appear that unless a new invention is made, the outlook for having sizable energy sources which will supply considerable power for long periods of time and for distant journeys is very gloomy indeed. So we may expect to spend millions of dollars to launch a satellite, only to have its voice fail after only a few weeks of operation — or to have it quickly fade away at large distances. Here is a real problem worthy of the best developmental efforts.

It is clear, too, that power for operation of a radio transmitter is only one requirement for an instrumented satellite. The instruments themselves, the navigation and control equipment, the cameras, Geiger counters and other equipment for scientific observation all require energy also.

If the satellite carries human beings, additional requirements arise. Food, oxygen, and water will add up to substantial loads for long journeys. For orbits closer to the sun or farther from the sun than the earth, the temperature control problem will become serious — requiring additional energy.

A good investment

In summary it can be said that space exploration opens up fantastic new vistas for research and exploration. New knowledge of the earth, of space and of our neighboring planets, which has been hidden from human beings since the beginning of time, will soon be available. The new knowledge will be a resource of unimaginable and unpredictable value. It will, however, be acquired at very great cost. Space is large; travel times are immense; the energy requirements for some ventures may be colossal; the technological problems will constitute a challenge to man's ingenuity for generations to come. But new inventions, designed to aid space travel, will also aid many more earthly ventures and yield new dividends to technology. These combined with the new knowledge of unforeseeable uses will certainly make space research — like all other scientific research — an exceedingly good investment.

The Fastest Camera at Caltech

A Caltech engineer has designed an instrument which is potentially the world's fastest movie camera. A combination of speed and short exposure time, each independently controlled, makes the camera unique and increasingly valuable to research. A shutter speed of one 20-millionth of a second has already been attained, pictures have been taken at a rate of 1,000,000 frames a second, and there is a good possibility that even faster pictures may be taken in the future.

Adapting parts from radar apparatus, airplanes, and other handy sources, Albert T. Ellis, associate professor of applied mechanics at Caltech, designed this ingenious camera for the express purpose of taking photographs of cavitation bubbles that are born and die within a few thousandths of a second. These are the destructive bubbles which collapse and cause shock waves that lead to fatigue and eventual disintegration of metal in ship propellers, water pumps, and turbines in hydroelectric plants.

The camera is now being applied successfully to many other new problems requiring the observation of extremely fast phenomena. These include explosions, high frequency fatigue in aircraft metals and other materials, and stress and strain field propagation in metals.

The fast camera is proving particularly valuable in high speed impact research. Pictures are taken of stress waves traveling in metals subject to impacts. Such impacts may occur, for example, when meteor particles hit space vehicles. The waves are made visible in the pictures by bonding photoelastic materials to the metal surface. The 11,000 mile-per-hour speed of these waves makes exposure times of one 20-millionth of a second necessary. One of the tests involves firing a bullet at 6,500 feet per second into a solid block of ordinary gelatin – since current research indicates that very high speed impacts cause metals to behave like liquids.

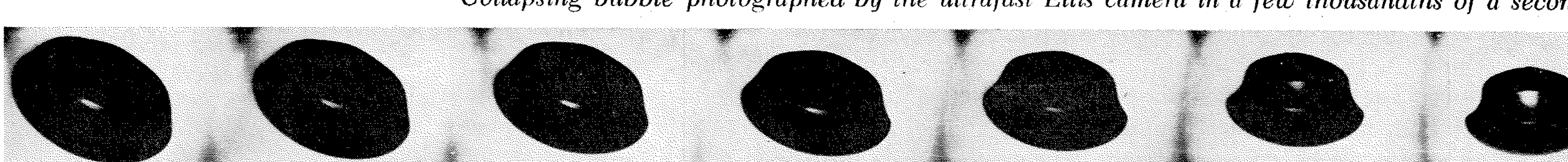
In another test, an air gun propels a hammer against a piece of metal, setting up sound waves. Just before hitting the metal, the hammer closes an electrical circuit and this sets off the camera, producing a picture at the exact moment of impact.

The camera stands about five feet high, including the table to which it is firmly bolted. It takes either 120 frames of 35 millimeter film at each loading, or 240 frames of film half that size. Because of the swiftness with which it goes through its sequence of pictures and the speed of the reactions it photographs, camera and reaction must be synchronized. This requires clever triggering devices.

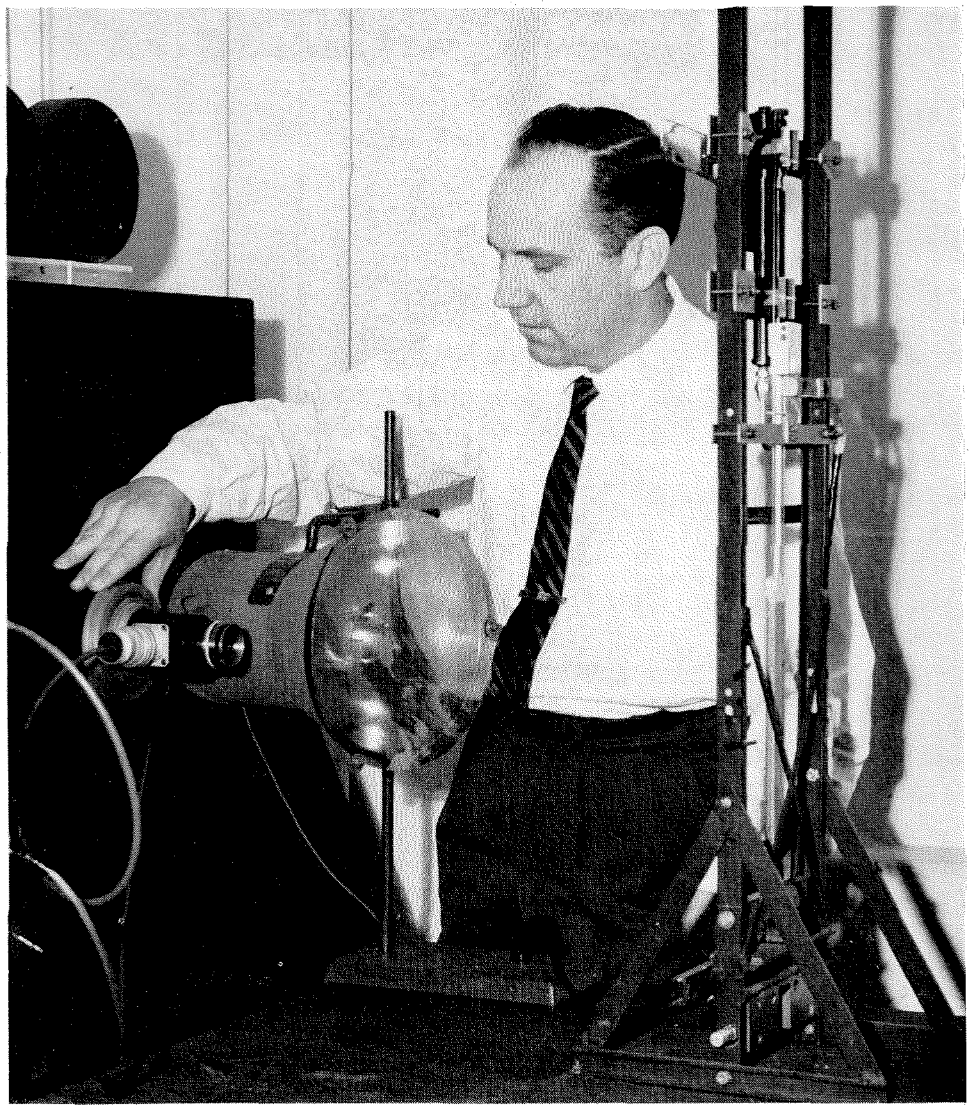
To capture cavitation bubbles, for instance, Dr. Ellis places a beam of light through water where the bubbles will form. Two photoelectric cells are out of line of the beam but close enough to pick up any light scattered from the beam by the forming bubbles. Picking up such scattered light by the photoelectric cells triggers the camera.

The camera has its own lighting system. A tremendous amount of illumination is required to expose film at such rapid speeds. A flash lamp is used that gives 60 times more total light than the most powerful flash bulb. About 6,000 volts of electricity are needed to achieve this brightness and the light is sustained

Collapsing bubble photographed by the ultrafast Ellis camera in a few thousandths of a secon



Albert T. Ellis, associate professor of applied mechanics, with the unique ultra-high-speed camera he developed for taking movies at the rate of 1,000,000 frames a second and faster.



for only about one five-hundredth of a second.

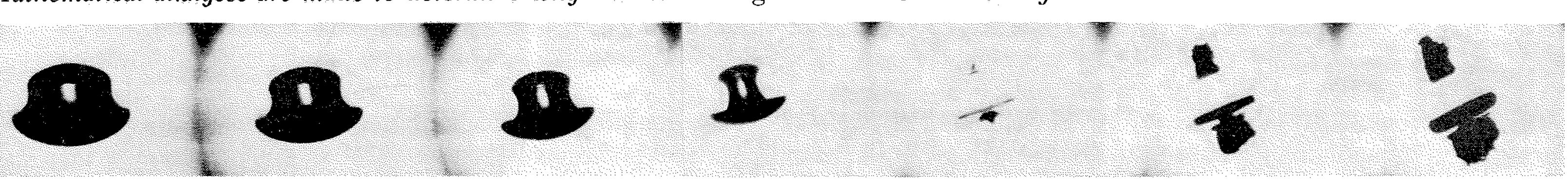
The shutter is capable of reacting at one billionth of a second. Since no mechanical shutter could achieve anything like this speed, it must be operated electronically. For this, an electro-optical shutter called a Kerr Cell is placed in the middle of the lens system, which consists of one or two optical lenses for focussing and two polaroid filters.

The first polaroid filter passes only light that is polarized in one direction. The second filter is turned so that this light will not pass until the Kerr Cell gives the light an additional rotation. The escaping light then focuses onto a mirror in the film box. The film remains stationary while the mirror spins at a rate of 100,000 revolutions per minute, deflecting the light images from the electronic shutter to the film.

The Ellis camera was built at Caltech during a program of basic studies in hydrodynamics under the direction of Milton S. Plesset, professor of applied mechanics. The program was supported by the Office of Naval Research. The camera is currently being used in studies on the mechanical and chemical aspects of cavitation, under a National Science Foundation grant.

In the future, Dr. Ellis hopes to continue with more advanced research on high speed impact, high frequency fatigue, and wave propagation in metals with the ultrafast camera. This extended research should prove valuable, not only in cavitation, but also in the fields of missile mechanics and space exploration.

[M]athematical analyses are made to determine why bubbles damage underwater machinery.



The Month at Caltech

Heineman Prize

Murray Gell-Mann, Caltech professor of physics, has been named 1959 winner of the Dannie Heineman Prize for Mathematical Physics. The $2500 prize, conferred every two years, was established by the Heineman Foundation for Research, Education, Charitable, and Scientific Purposes, Inc., to encourage research in the field of mathematical physics and to recognize outstanding publication in this area. Dr. Gell-Mann was cited for "his contributions to field theory and to the theory of elementary particles."

This year, for the first time, the Heineman Prize is being administered by the American Institute of Physics in cooperation with the American Physical Society. It will be formally presented to Dr. Gell-Mann at the society's spring meeting in Washington on May 1.

Dr. Gell-Mann was graduated from Yale University in 1948 and, two years later, at the age of 21, he received his PhD from the Massachusetts Institute of Technology. He was at the Institute for Advanced Study at Princeton for a year, then joined the teaching staff at the University of Chicago in 1952, serving on the research staff at the University of Illinois during the summers of 1951 and 1953. After teaching at Columbia University, and further research at the Institute for Advanced Study, he came to Caltech in 1955 as associate professor of physics.

Dr. Robert F. Bacher, chairman of the Division of Physics, Mathematics and Astronomy at Caltech, says:

"Murray Gell-Mann is one of the leading theoretical physicists in the United States in the last 25 years. He has made major contributions in a number of important fields in theoretical physics.

"His introduction of the idea of 'strangeness' in accounting for the long life of unstable particles produced in high-energy nuclear interactions has played a very important part in our comprehension of these particles and their relation one to another. This is a major contribution to particle physics.

"In collaboration with Dr. Richard Feynman, professor of theoretical physics at Caltech, he has produced a theory of the weak interactions responsible for Beta decay which has given both a qualitative and quantitative account of these interactions. In the past, theories of weak interactions have always been in disagreement with some experimental results.

"The present theory with which Dr. Gell-Mann has been associated initially disagreed with some experimental results which were believed to be well established, but further experimental work during the past year is indicating that the theory is correct in all respects. This is indeed another major advance in the field.

"The subjects on which Dr. Gell-Mann works are on the outermost frontier of microscopic or particle physics and he has already made some very important contributions. In addition to his own work he is very active in his relations with post-doctoral fellows and graduate students."

Space Conference

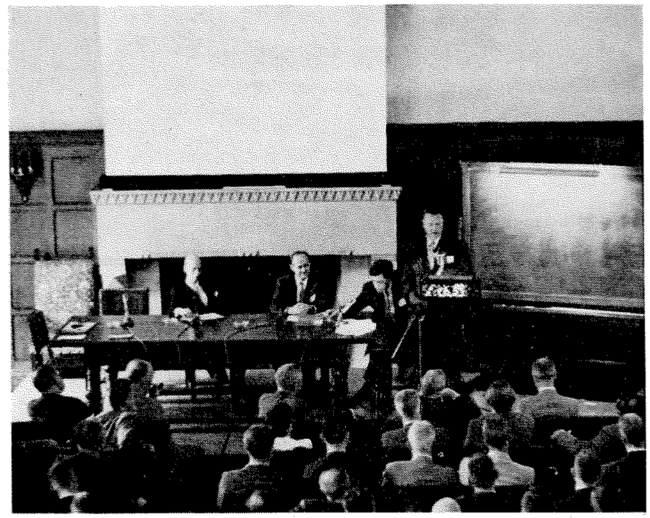
The Institute sponsored a two-day conference on the campus last month on "The Realities of Space Exploration." Participants included some of the country's top space scientists.

Despite the fact that one of the national press services reported some controversial off-the-floor comments as part of the formal program, in an attempt to make the conference sound livelier, the affair was notably sedate – and successful in its aim to discuss some of the *realities* of space exploration.

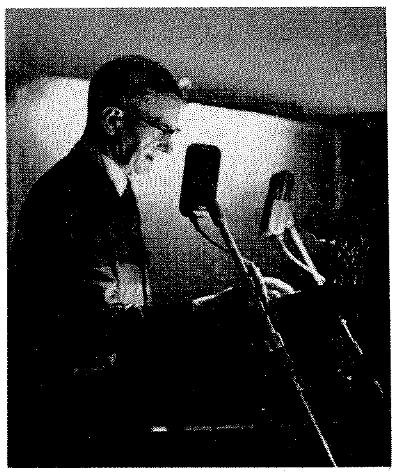
Among the participants were T. Keith Glennan, administrator of the National Aeronautics and Space Administration; William W. Kellogg, head of the planetary sciences group in the engineering division at the Rand Corporation; Abe Silverstein, director of space flight development for the National Aeronautics and Space Administration; Norris E. Bradbury, director of the Los Alamos Scientific Laboratory; and Ernst Stuhlinger, director of the research projects laboratory of the Army Ballistic Missile Agency.

The conference was arranged by the California Institute of Technology Industrial Associates, under the direction of Chester McCloskey. The Industrial Associates are a group of 40 companies which give financial support to the Institute's teaching and research programs.

THE REALITIES OF SPACE EXPLORATION



Symposium on "The Future of Space Exploration:" Ralph P. Johnson of Thompson Ramo Wooldridge; William H. Pickering, director of JPL; W. Duncan Rannie, Caltech professor of jet propulsion; Louis N. Ridenour, Jr., of Lockheed's Missile Systems Division.



Sydney Chapman, chairman of the Central Committee of the IGY, associate of the Geophysical Institute of the University of Alaska, and of the High Altitude Observatory of the University of Colorado.

James A. Van Allen, professor and head of the department of physics at the State University of Iowa, in fuller explanation of his report on "The Radiation Environment of the Earth and Other Planets."

W. Randolph Lovelace, II, director of the Lovelace Foundation for Medical Education and Research, discusses his talk on "The Biological Problems of Manned Space Flight."

COLOR IN THE UNIVERSE

The nebulae and galaxies pictured on these pages have never before been seen in natural color — even through the most powerful telescopes. Closer, brighter objects like the planets have been photographed in color, but the dramatic colors of distant, faint objects have never been captured before. Now, with the advent of an ultrafast color film, a whole new field in astronomical photography has been opened. The new film, coupled with the exceptional optical speeds and long focal lengths of the 48-inch Schmidt and the 200-inch Hale telescopes at Palomar Observatory, has at last made it possible to see some of the splendors of space in their true colors. Aside from their beauty, color portraits have a rare research value in the science of astronomy. Even though the new color pictures are unexplored scientifically, astronomers have already discovered that various states of excitation can be seen in the fine details of these nebulae — and the brilliant colors immediately reveal the relative temperatures of far-off stars.

THE NORTH AMERICA NEBULA

This vast body of gas shaped like the continent of North America shines by the same mechanism of fluorescence that makes a neon light glow. The nebula appears pure red because of the filtering action of intervening dust in space, which removes the other colors radiated by the gas. Photographed with the 48-inch telescope.

THE CRAB NEBULA

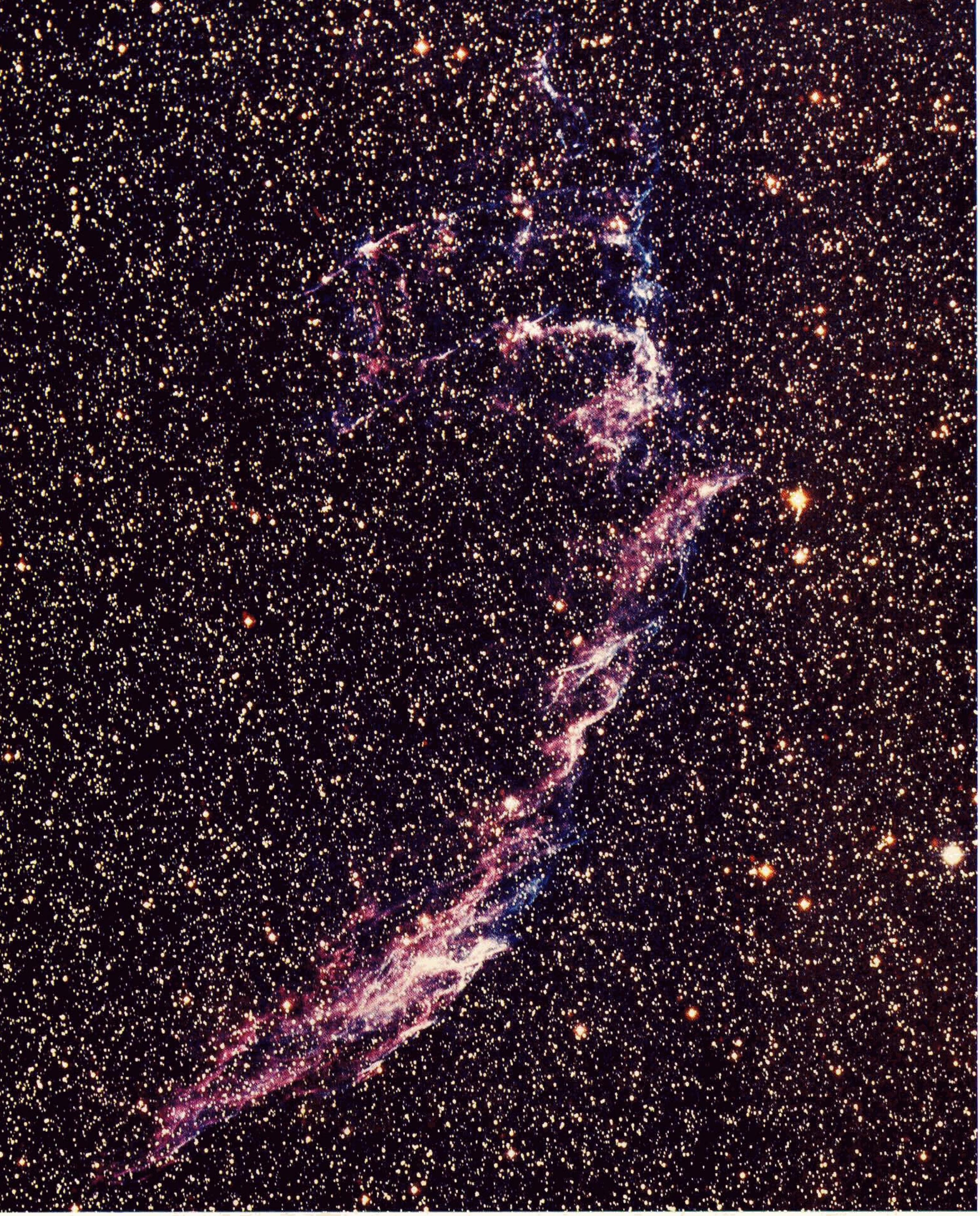
This large cloud of gas is the result of an exploding star called a supernova. Old Chinese records tell of the sudden appearance of a very bright star in 1054 A.D. and the Crab Nebula is quite probably a cloud thrown off by the supernova at the time of its explosion. High-energy electrons, still dashing about as a result of the explosion, cause the center of the nebula to glow with nearly white light. Photographed with the 200-inch telescope.

THE RING NEBULA IN LYRA

This nebula can be seen through relatively small telescopes. The blue stars at the center of the ring are the source of powerful ultraviolet light which causes the gases in the ring to radiate in their characteristic colors by fluorescence. Photographed with the 200-inch telescope.

THE GREAT GALAXY IN ANDROMEDA

This spiral galaxy, composed of billions of stars (many of them larger and hotter than our own sun) resembles our Milky Way galaxy. The outer portions of the galaxy appear bluer than the rest because the dominant stars in that region are the very young hot stars which have recently formed from the gas clouds present. The central regions are reddish because the prominent stars there are all older, cool, red giant stars. Photographed with the 48-inch telescope.



THE VEIL NEBULA IN CYGNUS

The colors radiated by these filaments of gas result from the nebula's rush through space. The gas clouds were ejected from an exploding star more than 50,000 years ago at a speed of nearly 5,000 miles a second. Because of constant collisions with atoms of gas, their speed has now been slowed to about 75 miles a second. The force of the collisions ionizes the gas and causes it to glow with color. Photographed with the 48-inch telescope.

Why there is color in the universe

The four processes that cause all bright objects in the universe to shine are also capable of producing spectacular and subtle colors. Our moon, the planets, and sometimes even clouds of dust in space, shine by reflected light – and their color is largely determined by the illuminating source. The stars (including the sun) shine as a result of their great heat – and their color is determined by their temperature; red if relatively cool, white if very hot, or blue if intensely hot. The bodies of gas called nebulae absorb invisible ultraviolet light from any very hot nearby star, then re-radiate the energy by fluorescence in visible wavelengths or colors. The colors in the nebulae depend upon the nature of the gases present, and the extent to which these gases are excited by the ultraviolet light. Nebulae can also shine as a result of collisions between atoms, or between atoms and high-energy particles such as electrons. Anyone familiar with the Ring Nebula in Lyra or the Great Nebula in Orion from telescope views, may be surprised at the strong colors shown here. But, at low light intensities, the eye loses its sensitivity to color long before it loses its sensitivity to light. So, when looking through a telescope, the eye usually gets enough light to detect these objects, but not enough to distinguish their colors. Now, with the advent of the new color film, combined with the power of Palomar's telescopes, it is possible to see some of the wonders of space in their original colors for the first time.

Adventures in the Culinary World

To eat, one must have a place to eat. This apparently obvious truism is discovered anew by each Caltech frosh, wrenched suddenly away from the free room and board system ("home"). Where does he go? With three years of intensive culinary research under my belt, I can hopefully attempt to answer this question.

The Student Houses

Specializing in Oriental cuisine, this delightful villa often lives up to its proud motto: "Virus Fortudinus Ealmay Mortuay Unchmay." ("The Hearty Man Ate a Condemned Meal.") Spanish decor and unique waiting service have combined to attract a steady and devoted clientele. Nine months out of the twelve, three meals a day, the Houses are filled to capacity with happy starch-consumers.

Actually, despite much grumbling, the food is generally palatable and sometimes even mildly delicious. Breakfasts are simple but bountiful: eggs, orange juice, now and then a rasher of bacon. Lunch revolves around the "extended meat" dish – chopped beef on noodles, chopped turkey on noodles, chopped noodles on noodles (Friday).

Meat and potatoes comprise the time-honored evening formula. The meat varies from very good (steaks, a la infrequent), to fair (chicken, roasted in original feathers), to poor (Sunday lamb). The potato, food of a thousand guises, provides the real variety. Mashed, fried, sweet, baked, chopped, flung, heaped – the potato-smith's cunning knows no bounds.

An integral part of each Student House meal is the announcement period. Dinner without announcements can be as unsatisfying as dinner without dessert. They may be very serious and momentous – "I'm proud to introduce to the House Dr. Robert Oppenheimer, visiting us as part of the Leaders of America program." More often, though, they tend to be mildly facetious – "We, the men of blank blank alley now challenge the uncouth denizens of such and such alley to battle in these manly sports of yore: Hitchhiking for distance, and broomstick throwing for number of Athenaeum members. An Athenaeum member shall be defined as . . . "

Though the members of the Houses pay in advance for 21 meals a week, very few are sedentary enough to consume that number. Rather, the Houses serve as a jumping off place for further adventures in the culinary world. On certain unforgettable days this jumping-off may reach lemming proportions.

Sunny Italy

Nestled down on picturesque Rosemead Boulevard, Sunny Italy does one thing extremely well: pizza. It's a strange but true fact that pizza was actually invented by the Italians. But, of course, this makes scant difference in this great land of ours. Irishman, Oriental, and Republican alike can be found here, revelling in the hundreds of pizza varieties. Starting with plain cheese pizza, one can work his way up to the apex – super combination pizza. Laden with anchovies, pepperoni, hamburger, mushrooms, it is served still steaming from the oven's heat. It burns the fingers (the only correct way to eat pizza, of course) but gladdens the palate.

Warning: Sunny Italy is not recommended for Saturday night stags. At this time the place fills with young couples from the surrounding high schools. Sour grape juice tends to spoil the delicate pizza flavor.

Chef's Cafe

Here is a definite case of split personality. By day Chef's is just one more innocuous short-order shop. Cleaner than most, it offers good basic food and prayers on the back of its menu. The "Daily Double" provides satisfying fare for under one dollar, a rare phenomenon nowadays.

Nighttime is a different story. Open *all* night (you may have to wait in line at 3 a.m.) it is heavily frequented by traveling salesmen and the Pasadena Playhouse crowd. Someone has estimated that the average hair length of its male clientele runs to something over 2½ inches.

The women here are often quite pretty, made up heavily or not at all, and sometimes openly affection-

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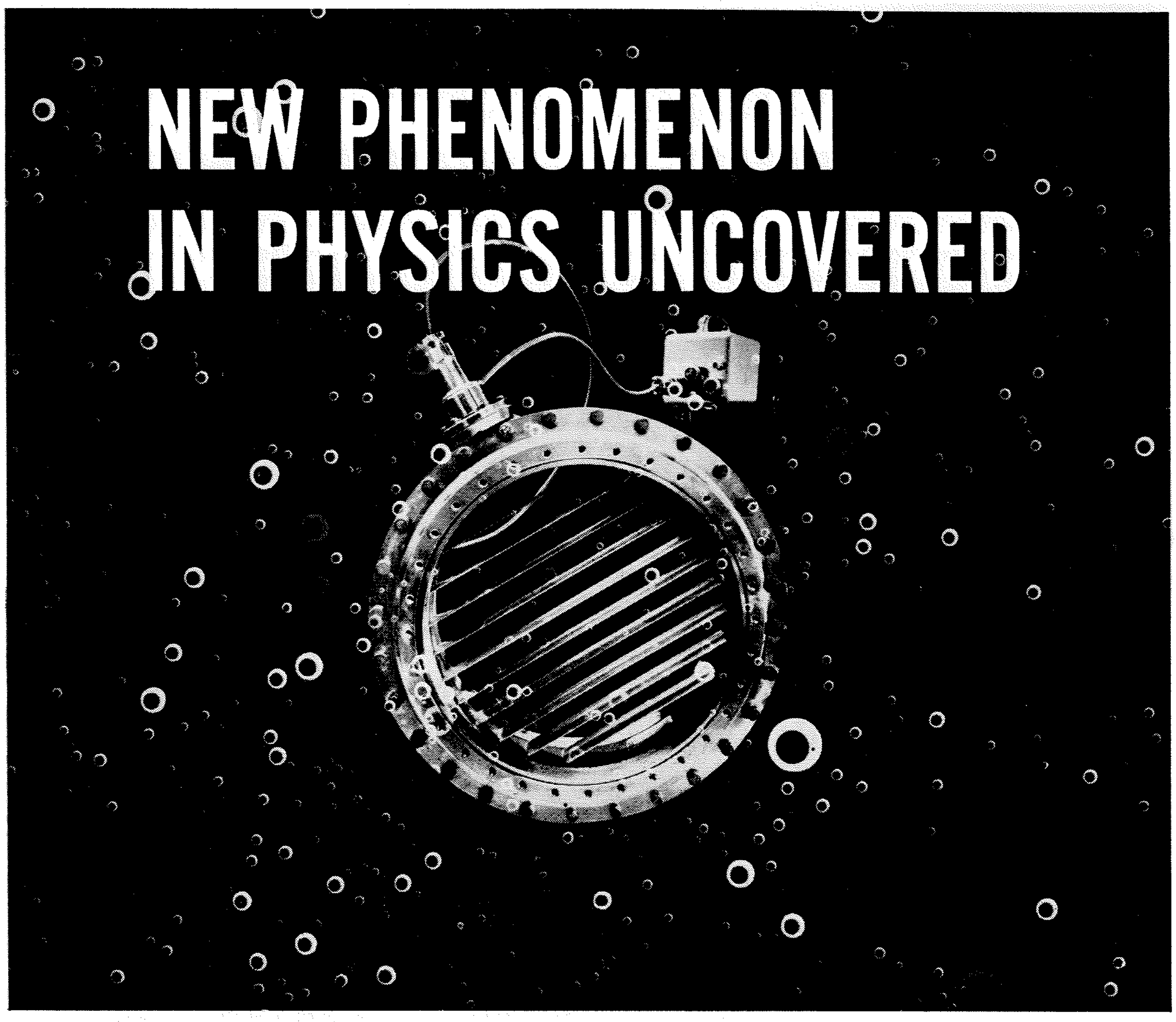

NEW PHENOMENON
IN PHYSICS UNCOVERED

ate to their escorts. For twenty-five cents (the price of a vanilla pudding) you just can't beat the floor show.

Dino's

Another Italian restaurant, but completely different from Sunny Italy. Orders here run more to spaghetti, lasagna, ravioli, and other Mediterranean unpronounceables. The food is authentic (according to local gourmets) and, even more important, delicious. Specialty of the house is minestrone soup, thick enough to eat with a fork.

Dino's is perhaps the perfect place for a small midweek date. Greeted at the door by the friendly headwaiter (who makes it a point to remember names) you are led to a high-backed green booth, softly lighted and quite comfortable. No one rushes the meal, and the place is virtually empty after midnight. A perfect setting for the old heart-to-heart talk. Ah, a glass of wine, a breadstick, and thou.

Bob's

A recent crisis has occurred in the average Techman's life: Big Boy hamburgers now cost 50c, a full nickel more than the old reliable price. If this had happened my freshman year, I'd be about $5 poorer now.

There are actually two Bob's in Pasadena, near Bob's and far Bob's. But only the insensitive patronize far Bob's, and I'll not mention it again.

Among other attractions, Bob's publishes its own free comic book, readily available as you enter. In past months there's been quite a competition over solving the Big Boy crossword puzzle. Record time is now under 20 seconds. Lately the trend has shifted toward trying to break the Big Boy code. This is now nearly accomplished (a triumph for American science), and there have even been (unverified) rumors of dirty words concealed in the dialogue.

No one has ever successfully analyzed the contents of a Big Boy hamburger. However, I do feel it is my duty to quelch a nasty rumor. There *is* meat in them, or at least something that gives the fleeting illusion of meat.

No discussion of Bob's would be complete without mention of the waitresses. Almost immaculate in their black and white uniforms, they tend to be young, sometimes pretty, and surprisingly cheerful considering the work they do. My thanks to them for many an enjoyable 50c meal.

Near Bob's has recently undergone interior redecoration, the predominant color now being pink instead of green. This is really too bad. The green interior had a certain coziness not usually found in the mass-production hamburger trade. But then I suppose there's something about pink that makes people eat like mad.

Le Bayou

A refuge for those too proud for Bob's. Actually, at the drop of 75c they will serve up the biggest, most succulent hamburger in Pasadena. They also offer steaks, Spanish food, ribs, etc., but no Techman in recorded history has been rash enough to sample these exotically priced items. This may explain the rather unenthusiastic reception given large groups of students arriving during rush hour (7 p.m.).

For those who have reached majority, Le Bayou also offers stimulating liquid refreshment. Smugness reaches its all-time high on the face of legal-voter Techman nursing a beer with his hamburger, while his junior companions have to content themselves with milk.

Raarup's

The Ford family of the hamburger trade, Mr. Raarup, Mrs. Raarup, son Pete Raarup, and Mrs. Raarup-the-younger dish out Californiaburgers for only 40c each (highest meat-to-money ratio in the neighborhood).

Open only during the daylight hours, Raarup's often does yeoman work providing respite from a disastrous Student House lunch. As the carloads of queasy students begin to arrive, Mrs. Raarup will announce in her cheerful Texas twang, "Must be another tuna-in-gelatin day at Caltech."

The Caltech Coffee Shop

Our own beloved Greasy. (Mrs. Lyall says she doesn't mind "Greasy," but "Greezy" is definitely faux pas.) This is perhaps the only institution on campus known equally well to the faculty members, students, and hired personnel. As you wander among the tables carrying your 90c lunch (generally excellent), intriguing bits of conversation float by:

". . . and of course, as soon as I thought of calculating the neutrino cross section . . ."

". . . convergent! How can anyone in his right mind assume convergence on a . . ."

". . . yeah, that's the one, the secretary in the black whatchamacallit. What a . . ."

Perhaps you're not interested in a complete meal. Eighteen cents still buys a good piece of pie and a half hour off from lab. You dine in the company of such celebrities as Dr. Feynman, Dean Strong, and Officer Newton, to mention only a few. Pie, science, and secretaries — an unbeatable combination.

— Brad Efron '60

Personals

1925

Thomas P. Simpson has just been made manager of engineering and operations analysis for Socony Mobil in New York. He has been with the company since 1942. Tom was one of the developers of the Thermofor Catalytic Cracking Process which was vital in the manufacture of high-octane gasoline for the Armed Forces during World War II. He lives in New York City and has two sons, Gilbert and Thomas, Jr.

Markham E. Salsbury is now chief engineer of the L. A. County Flood Control District. He was formerly senior assistant to the chief.

Clarence Weinland is now associate for ordnance sciences in the Weapons Planning Group of the U. S. Naval Ordnance Test Station at China Lake.

Albert J. Ferkel, superintendent of the chemicals department of the Atlantic Refining Company in Philadelphia, retired last month and started on a four-month cruise around the world. He plans to settle in Southern California after the trip.

1926

Dan G. Dinsmore writes that "the big event in my life this past year was being made a grandfather on October 25. Our daughter presented us with a granddaughter. Regarding my work, I am still secretary-treasurer of my corporation in Los Angeles – but the name has been changed to the Christie Electric Corporation."

1934

George F. Rucker, MS, who has been manager of the Leeds & Northrup Co. office in Los Angeles, has been promoted to manager of the firm's market development division in Philadelphia.

1936

Takeji Onaka, MS, writes from Osaka-Fu, Japan, that he is now chief of the quality control department of the Nitto Electric Industrial Company, Ltd. The company manufactures electrical insulating materials, dry batteries, recording tape, and tape recorders.

Charles Jordan, MS '37, is now a senior research physicist at Electro-Optical Systems, Inc., in Pasadena. The company specializes in research programs in advanced electronics, solid state physics, energy research, and fluid physics.

1936

Frank W. Davis, chief engineer at Convair's Fort Worth plant, is now vice president and general manager there. Frank joined Convair as an engineering test pilot in 1940, after four years as a pilot in the Marine Corps. He is married and has three children.

Peter H. Wyckoff, MS, writes that he is now chief of the aerophysics laboratory at the Air Force Cambridge Research Center in Bedford, Mass. "For the past four years I have been active in the upper atmosphere rocket program," writes Peter, "and was Air Force project officer for the IGY rocket launchings at Ft. Churchill, Canada. I am a member of the rocket and satellite panel, and also a member of the technical panel on rocketry for the U. S. National Committee for the IGY. Locally, I have been elected president of the AFCRC branch of the Scientific Research Society of America."

1941

Joseph W. Trindle, MS '49, writes from Tetuan, Morocco, that "I find myself living in no missionary grass shack but in a decent house, married to a good cook, driving a good American car, and even luxuriating under a first-rate hot shower. Although a nearby house was very recently used as the Crown Prince's headquarters in the current Riff war, we get more news of the Riff in *Time* than we do from local sources.

"Except for too little time spent doing private tutoring in physics and algebra and too much time spent fiddling with a jerry-rigged X-ray machine in our Tangier hospital, my technical experience is lying fallow. My log-log duplex is still around, however, to figure how many liters per hundred my car burns.

"My main job is to struggle with two kinds of Arabic, Spanish and French, in order that I may preach the Gospel of Jesus Christ. My wife and I are expecting our first child momentarily. I preside over some 20 Moroccan boys who come every Friday to hear my preaching, and I have to resist the temptation to beat their bottoms when they mock outside the gate. We have toured England, the States, and Morocco since our marriage, and would like to sit still in this decent house for a spell."

1942

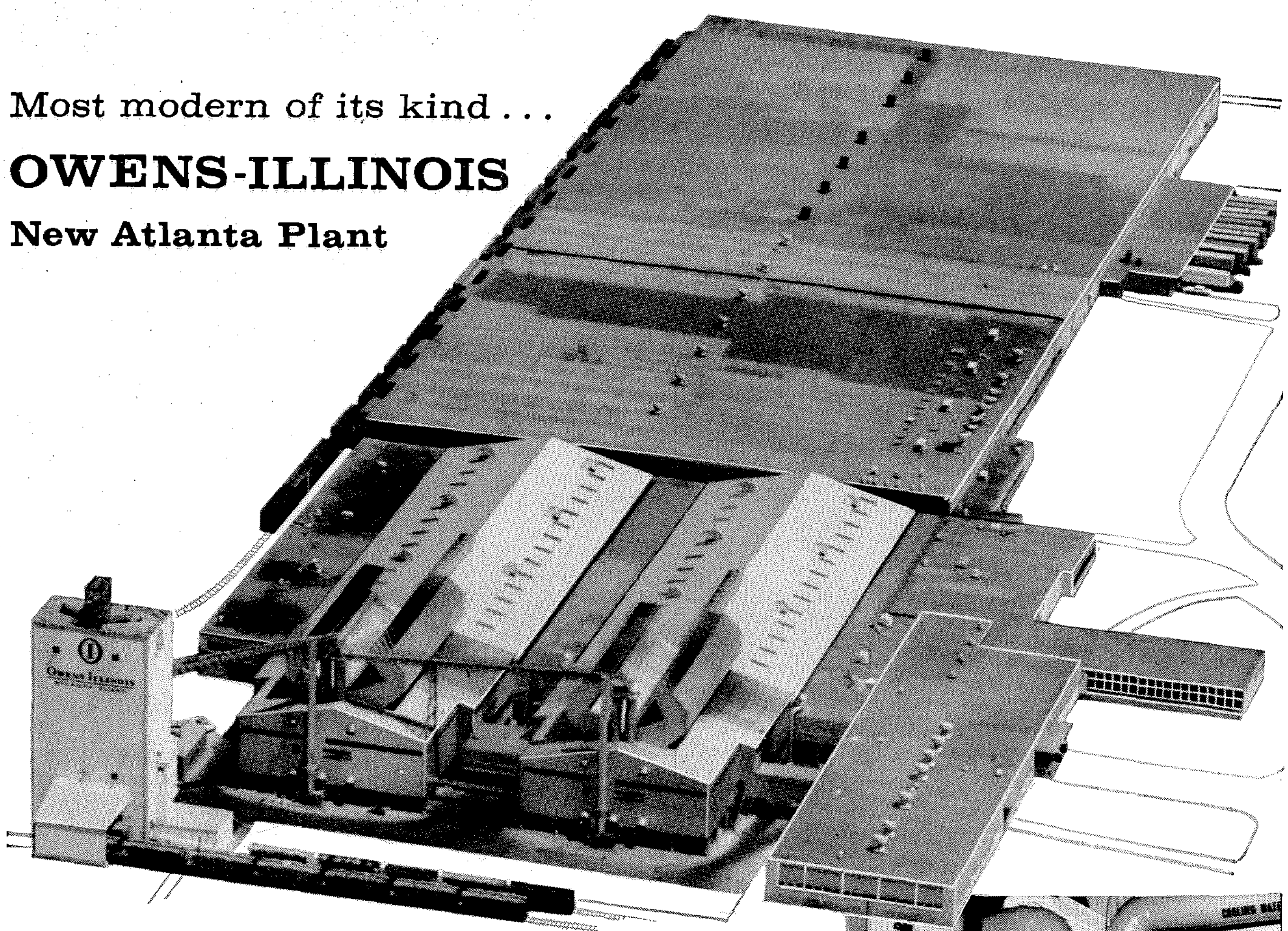
Gordon K. Woods is head of the management engineering division of Industrias Kaiser Argentina, a four-year-old Argentine Corporation in which Willys Motors of Toledo, Ohio, hold one third of the stock and the management contract. "My wife and I, and our three sons, have lived here for almost four years," he writes, "although we have made various trips to the States and Europe during that time. We have lived through some rather important Argentine history . . .

continued on page 44

Most modern of its kind . . .

OWENS-ILLINOIS

New Atlanta Plant



Architects and Engineers: Robert and Company Associates, Atlanta, Ga.

General Contractor: George A. Fuller Company, Altanta, Ga.

Mechanical Contractor: Standard Engineering Company of Washington, D.C.

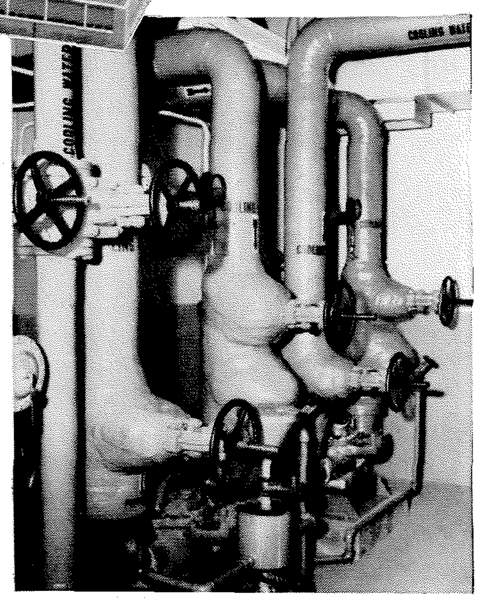
JENKINS VALVES control important service lines

DESIGNED to be the most modern glass container plant in the world, covering 619,000 square feet and highly automated, this new Owens-Illinois plant can produce millions of glass containers annually.

In the glass manufacturing operations trouble-free service piping lines are an essential. Cooling operations require a flow of recirculated water equal to 2-million gallons per day. The furnaces consume about 3-million cubic feet of natural gas per day.

The fact that Jenkins Valves, in large numbers, are used to control water, gas, steam, compressed air and air conditioning lines in this new plant will not surprise most experienced architects, engineers and contractors. For nearly a century, "JENKINS" has been a common specification to assure maximum reliability.

It will pay you to have this important assurance when you specify or install valves . . . especially since Jenkins Valves cost no more. Jenkins Bros., 100 Park Avenue, New York 17.



Some of the many Jenkins Bronze and Iron Valves which control the complex service piping system in the Owens-Illinois plant.

JENKINS VALVES

LOOK FOR THE JENKINS DIAMOND ®

JENKINS SINCE 1864

Jenkins Bros

Sold Through Leading Distributors Everywhere

"The richness of the country's practically untapped natural resources leads one to believe that her economic problems are essentially political in nature. In fact, the economic necessity of the moment has dictated a mild austerity program including such novelties as two beefless days a week. As Argentines of all classes are accustomed to eating well, consuming less beef to allow for exportation seems to them a hardship. The Argentine laboring man is still probably consuming more meat than in any other country in the world. Workingmen not employed in shops or offices carry raw meat to work to barbecue over a small fire for a lunch of meat, bread and wine.

"While originally we lived in Buenos Aires, we are now in Córdoba, Argentina's second largest city, and a great cultural center, in which one of the oldest universities in our hemisphere is located. Our two oldest boys, 11 and 14, are quite proficient in Spanish, having had their schooling in Spanish for four hours each day (Argentine law) as well as the usual American curriculum. Our four-year-old son spoke only Spanish until quite recently.

"Many of our family activities here are similar to those in the States. We swim, picnic, ride, play golf, collect and sort stamps, and enjoy amateur radio. However, even these usual diversions are a bit different here than in the States. Due to the reversal of seasons, combination Christmas and swimming parties are common. Picnics are more apt to be asados (similar to barbecues) to which we ride on our horses after sending ahead a group of gauchos to build the fire and have the beef cooking when we arrive. The only proper eating tool on such expeditions is a gaucho knife, to spear your beef and put it between two slices of bread.

"Social life here is pleasant – the Argentines being by nature hospitable. There are many parties, some informal with singing and guitar playing, and sometimes the maids are persuaded to perform the native dances in the wee small hours; and again there are many formal parties, Sunday morning cocktails at 11 being not uncommon in the latter class.

"We see too few Caltech people down this way, but last year had the great pleasure of spending some time with Dean and Mrs. Watson and we often see Governor Gallardo, until recently governor of the Province of Córdoba. I was quite surprised to discover that he had been a graduate student in meteorology at Caltech while I was there."

1943

J. Earl Thomas, PhD, has joined the engineering staff of the semiconductor division of Sylvania Electric Products, Inc., in Woburn, Mass. Head of the physics department at Wayne State University in Detroit, and an authority on solid state physics, Earl will continue his university affiliation until June, when he will take full charge of the research and engineering activities of Sylvania's semiconductor division.

Alfred G. Knudson, Jr., PhD '56, has been chairman of the department of pediatrics at the City of Hope Medical Center in Duarte since 1956. His research has been mainly in leukemia and hereditary diseases. The Knudsons have three girls – 5, 7 and 8.

W. Kent Wong, MS, (whose name was Yung Chiang Hwang at Caltech) has been working as a consulting engineer for manufacturers, aircraft industries, and petroleum and chemical construction industries in Chicago, San Francisco, Dallas and Houston. He has now set up his own business as a consulting engineer in Bellaire, Texas, and has also become a U.S. citizen.

1944

William H. Bond writes from Del Mar, Calif., that "after being loaned to the Argonne National Laboratory from '54 to '56, and spending the following year at the General Atomic Division, I returned to Convair to supervise the propulsion section of the thermodynamics group. Last November 18 I had the uncanny luck to observe a cloudlike activity in the Alphonsus crater of the moon with Dr. H. F. Poppendiek of La Jolla and Bill, Jr., 11. Our other children are Barbara, 9, and Brenda, 7."

Dean R. Chapman, MS '44, PhD '48, aeronautical research scientist of the National Advisory Committee for Aeronautics, has received a Rockefeller Public Service Award which will enable him to study next year at Cambridge University in England. The Chapmans live in Palo Alto with their two children – Anita, 10, and Donald, 6.

1945

Donal B. Duncan, PhD '51, has been named to the National Aeronautics and Space Administration's Advisory Committee on control, guidance and navigation. He is manager of advanced engineering for Autonetics, a division of North American Aviation, in El Segundo.

William C. Cooley, MS, is now program chief of the space propulsion and auxiliary power units in the National Aeronautics and Space Administration in Washington, D. C. He was formerly assistant program engineer on the "Rover" nuclear rocket program at Rocketdyne in Canoga Park.

1948

Vincent R. Honnold writes that he received his PhD in physics from Notre Dame in 1954, and since then has been working in the research department of the U. S. Naval Ordnance Test Station at China Lake. He's doing research in solid state physics (not *everybody* up there tests rockets, he says) and he is now head of the solid state physics branch of the physics division. The Honnolds have four children – Maryanne, 9, Susan, 8, Vincent, 3, and Michael, 1.

Lt. Col. James K. Taylor, MS, was graduated on January 16 from the Armed Forces Staff College in Norfolk, Va.

Comdr. R. A. Weatherup, USN, writes: "As a career Naval officer, I usually work in engineering and engineering administration only when on shore duty. But now I'm at sea as the commanding officer of the *USS Burton Island*, which is an icebreaker whose home port is normally in Seattle (though she isn't there much). It's an enjoyable duty and I probably won't go ashore for at least a year."

1949

Don E. Hibbard writes that he and his family have been living in Maracaibo since July 1958. "I have been working here for the Texas Petroleum Company, following the Seaboard merger," writes Don, "and despite the heat, we like it quite well. The children have become almost completely bilingual and have far outshone my efforts at mastering the language. Geologically, the Maracaibo Basin is extremely interesting. Both stratigraphy and structure are very complex, which helps to make this the second most prolific petroleum province in the world. Our company is now participating in a group bringing in wells producing up to 7,000 barrels per day each.

"So far I have seen *Ben Austin* '46, who was on a trip here; *John Calligeros* '46, who is working for Creole; and Pete Folmer (frosh-sophomore '45-'46), who is with Richmond."

Frank Shelton, PhD '53, is technical director of the Armed Forces Special Weapons Project, which develops military requirements for atomic weapons and was responsible for the overall scientific direction of last summer's high altitude explosions which created a sheet of radiation around the world. Formerly employed by Sandia, Frank has been at the Pentagon in Washington for the last 3½ years. The Sheltons have three

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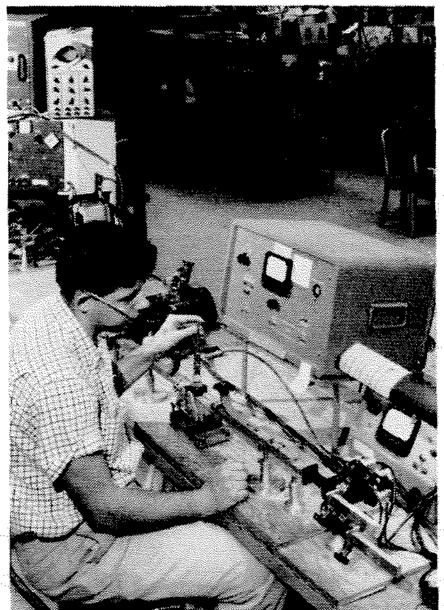
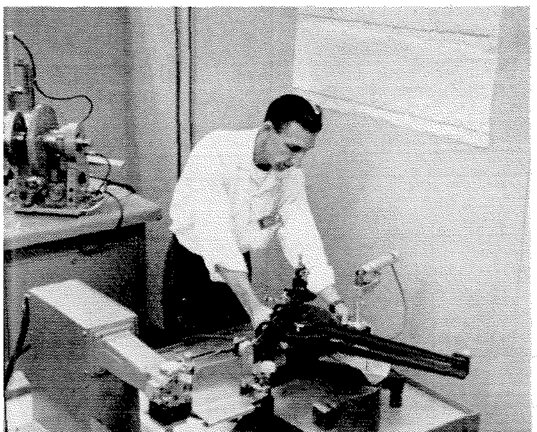
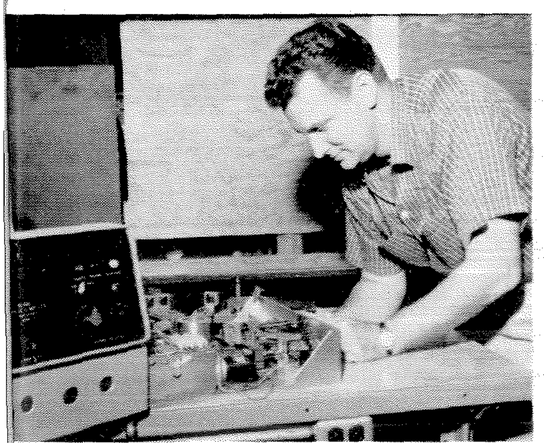
2. apparatus



1. research





3. instrumentation

4. semiconductors

1. central research laboratory Basic and applied research in solid state physics, materials, devices, data systems, and earth sciences with particular emphasis on semiconductors, electroluminescence, ferromagnetics, resonance, low temperature phenomena, dielectrics, infrared, geophysics, digital techniques, masers, memories, and transistors; physico-chemical studies of diffusion, alloying, crystal growth, and crystalline structure.

2. apparatus division Design, development and manufacture of systems — reconnaissance, airways control, antisubmarine warfare, missile and anti-missile, countermeasures, airborne early warning, navigation, attack control, and engine control. Equipments, including: radar, infrared, sonar, magnetics, digital circuits, timers, telemetering, intercom, microwave, optics, detector cells, engine instruments, transformers, time standards, and other precision components.

3. industrial instrumentation division Design, development and manufacture of commercial electronic and geophysical instrumentation including data gathering, recording and processing; circuit and instrument packaging; meter movements and transducer elements; remote measurement and control systems.
(NOTE: This division is located in Houston.)

4. semiconductor-components division Design, development and manufacture of semiconductors — transistors, diodes, rectifiers — and other electronic components including capacitors and resistors. Special studies in materials purification and analysis, surface treatment, circuit design, and circuit applications. Design of mechanization test equipment. Supervisory positions in manufacturing engineering and production management.

keep an eye on T/I

DEPT. 1305

TEXAS INSTRUMENTS
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daughters, ranging from 5 to 9 years old.

1950

Bruce Robinson, Jr., left his job as geologist with the Bishop Oil Company in Denver to accept a position as a petroleum geologist with the Kern County Land Company in Bakersfield last spring. "We miss the Denver climate," he writes, "and also all the Caltech people who were with us there—*Breck Parker* '50, *Ralph Stone* '50, *Dave MacKenzie* '50, and *Don Baker* '50. Our two daughters (Lynn, 5, and Meg, 7) are in school now."

Robert L. Nelson, MS, PhD '52, is now division geophysical supervisor of the Pan American Petroleum Corporation's central division in Oklahoma City. He has been with the company since 1952.

Alfred Thiele is now with Atomics International in Canoga Park. His work is still in the field of reactor physics and at present he is conducting critical assembly experiments. The Thieles have two sons and are getting settled in a new home.

Carrol R. Lindholm left the Motorola Research Laboratory in Riverside last August to join the electronics department at the RAND Corporation in Santa Monica, where he is working on problems in the very broad field of communications systems. The Lindholms and their four daughters live in a new home in Canoga Park, right next door to *Al Thiele* '51. Another Caltech man, *Joe Green*, '49, PhD '57, lives a couple of blocks away.

1952

Gerald D. Fasman, PhD, writes that "after two years at Cambridge, England; one year at Zurich, Switzerland; and one year in Israel; I have been living in Boston for the past three years. I am associated with the Children's Cancer Research Foundation at the Harvard Medical School. I was married in England and now have one son."

Richard S. Winkler, MS, writes from the Netherlands: "At the present time I am employed by the Aramco Overseas Company in The Hague. I have been working for them for the last seven years in New York, Saudi Arabia, and Holland. I married a very lovely Dutch girl last year and we are expecting onr first child in May.

"I have become quite continental and an expert on ski runs in the Alps. Somehow it is possible to get around Europe without being conversant with the local languages, but I certainly wish I had taken both German and French in college.

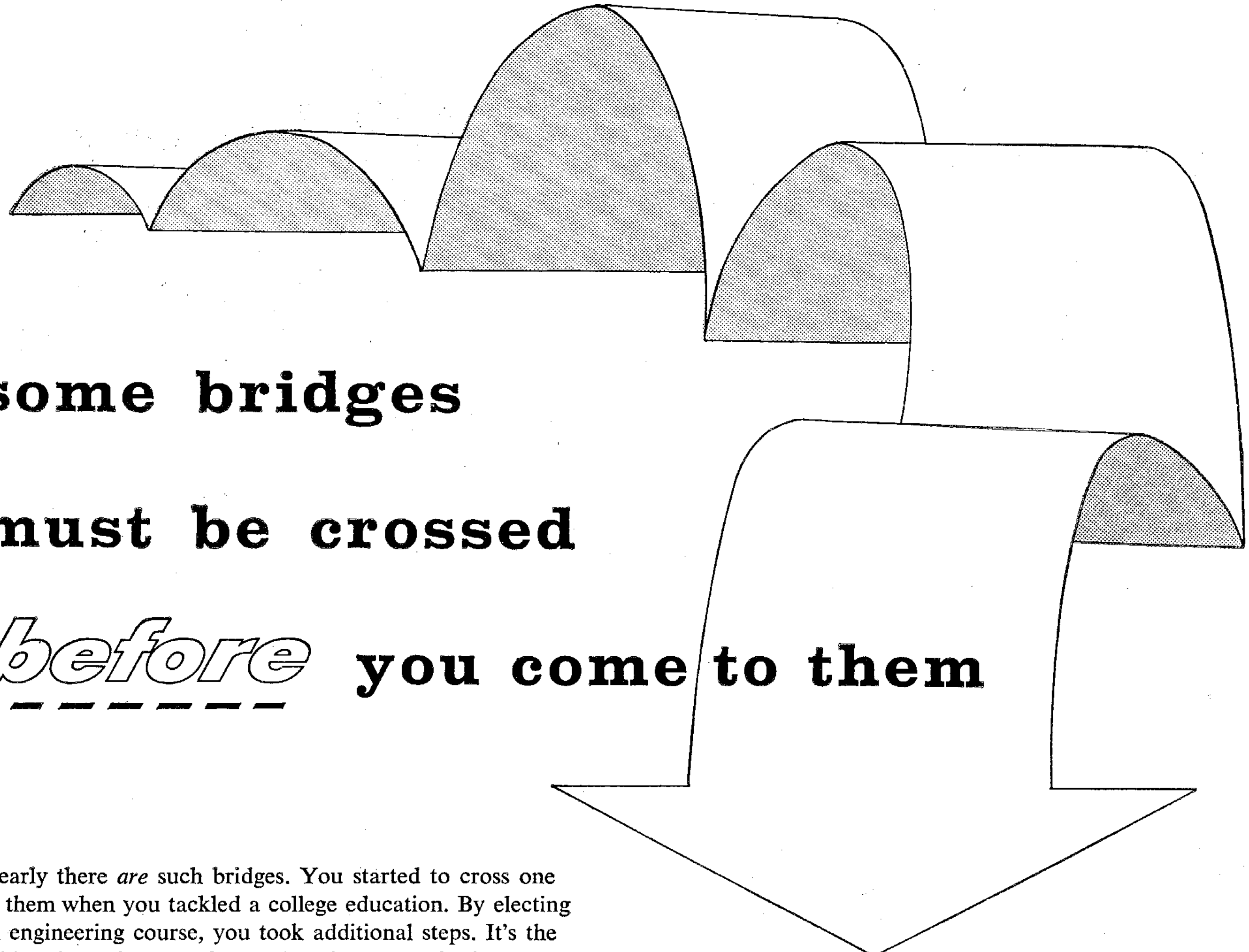
"Many American firms are opening offices here and are hoping to take advantage of the European Common Market. They are considerably recovered from the war here and soon should have a more rapidly growing economy. Many Fulbright students are still here and American culture, records, movies, and other consumer goods are widely used."

1953

Gene M. Jordan has been promoted to the position of systems analysis branch manager of the Bendix Aviation Corporation's new Eagle Weapon System contract. The Jordans, who have recently moved into a new home in the San Fernando Valley (Chatsworth) have two children and are expecting a third in August.

1955

Major William C. Benton, AE, leaves the NOTS China Lake station in June, after two years there. He will be assigned to the Bureau of Ordnance of the Navy Department in Washington, D. C.



CALTECH CALENDAR

ALUMNI CALENDAR

June 10	Annual Meeting
June 27	Annual Picnic

ATHLETIC SCHEDULE

Tennis

April 21
Pasadena College at Caltech

May 2
Redlands at Caltech

May 9
Whittier at Whittier

Baseball

April 22
San Fernando State at Caltech

April 25
Redlands at Caltech

April 29
Occidental at Caltech

May 6
Occidental at Caltech

Swimming

April 24
Claremont-Harvey Mudd at Claremont

May 1
Pomona at Caltech

May 8
Occidental at Caltech

Track

April 24
Pomona at Caltech

May 1
All-Conference Meet at Occidental

May 9
Fresno Relays at Fresno

Golf

May 1
So. Calif. Tournament at Hesperia

FRIDAY EVENING DEMONSTRATION LECTURES

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

April 24
Structure of Magnetic Molecules
— Harden McConnell

May 1
Failure of Materials
— Thad Vreeland, Jr.

May 8
The Eye of the Fungus
— *Max Delbruck*

May 15
A Physicist Visits Moscow and Samarkand
— William Fowler

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U. S. Navy Electronics Laboratory

One of a series

Interview with General Electric's Hubert W. Gouldthorpe Manager—Engineering Personnel

Your Salary

Although many surveys show that salary is not the prime factor contributing to job satisfaction, it is of great importance to students weighing career opportunities. Here, Mr. Gouldthorpe answers some questions frequently asked by college engineering students.

Q. Mr. Gouldthorpe, how do you determine the starting salaries you offer graduating engineers?

A. Well, we try to evaluate the man's potential worth to General Electric. This depends on his qualifications and our need for those qualifications.

Q. How do you evaluate this potential?

A. We do it on the basis of demonstrated scholarship and extra-curricular performance, work experience, and personal qualities as appraised by interviewers, faculty, and other references.

Of course, we're not the only company looking for highly qualified men. We're alert to competition and pay competitive salaries to get the promising engineers we need.

Q. When could I expect my first raise at General Electric?

A. Our primary training programs for engineers, the Engineering Program, Manufacturing Program, and Technical Marketing Program, generally grant raises after you've been with the Company about a year.

Q. Is it an automatic raise?

A. It's automatic only in the sense that your salary is reviewed at that time. Its amount, however, is not the same for everyone. This depends first and foremost on how well you have performed your assignments, but pay changes do reflect trends in over-all salary structure brought on by changes in the cost of living or other factors.

Q. How much is your benefit program worth, as an addition to salary?

A. A great deal. Company benefits can be a surprisingly large part of employee compensation. We figure our total benefit program can be worth as much as 1/6 of your salary, depending on the extent to which you participate in the many programs available at G.E.

Q. Participation in the programs, then, is voluntary?

A. Oh, yes. The medical and life insurance plan, pension plan, and savings and stock bonus plan are all operated on a mutual contribution basis, and you're not obligated to join any of them. But they are such good values that most of our people do participate. They're an excellent way to save and provide personal and family protection.

Q. After you've been with a company like G.E. for a few years, who decides when a raise is given and how much it will be? How high up does this decision have to go?

A. We review professional salaries at least once a year. Under our philosophy of delegating such responsibilities, the decision regarding your raise will be made by one man—the man you report to; subject to the approval of only one other man—his manager.

Q. At present, what salaries do engineers with ten years' experience make?

A. According to a 1956 Survey of the Engineers Joint Council*, engineers with 10 years in the electrical machinery manufacturing industry were earning a median salary of $8100, with salaries ranging up to and beyond $15,000. At General Electric more than two thirds of our 10-year, technical college graduates are earning above this industry median. This is because we provide opportunity for the competent man to develop rapidly toward the bigger job that fits his interests and makes full use of his capabilities. As a natural consequence, more men have reached the higher salaried positions faster, and they are there because of the high value of their contribution.

I hope this answers the question you asked, but I want to emphasize again that the salary *you* will be earning depends on the value of *your* contribution. The effect of such considerations as years of service, industry median salaries, etc., will be insignificant by comparison. It is most important for you to pick a job that will *let* you make the most of your capabilities.

Q. Do you have one salary plan for professional people in engineering and a different one for those in managerial work?

A. No, we don't make such a distinction between these two important kinds of work. We have an integrated salary structure which covers both kinds of jobs, all the way up to the President's. It assures pay in accordance with actual individual contribution, whichever avenue a man may choose to follow.

*** We have a limited number of copies of the Engineers Joint Council report entitled "Professional Income of Engineers—1956." If you would like a copy, write to Engineering Personnel, Bldg. 36, 5th Floor, General Electric Company, Schenectady 5, N. Y.** 959-7

LOOK FOR other interviews discussing: • Advancement in Large Companies • Qualities We Look For in Young Engineers • Personal Development.

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