E&S

ENGINEERING AND SCIENCE

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

January 1968

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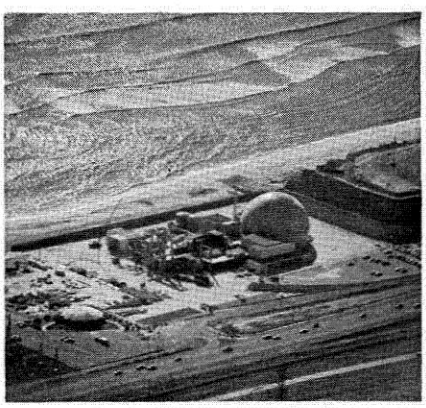

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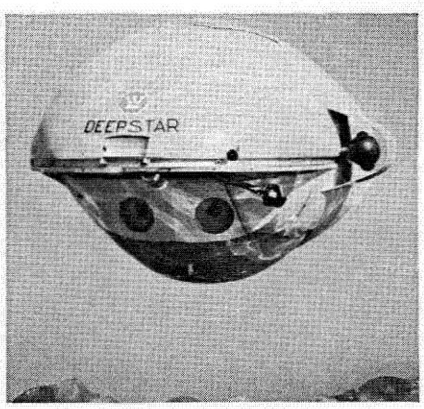

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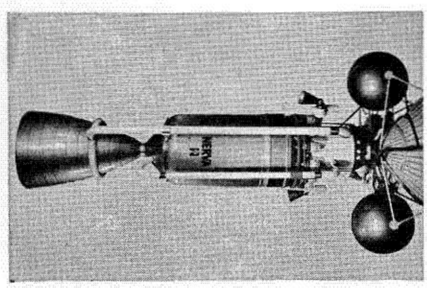

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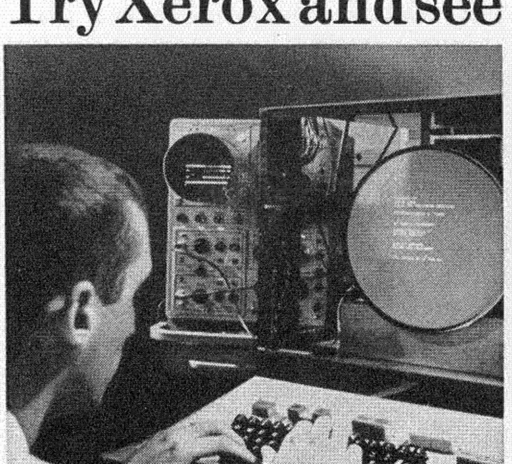

An engineer operates the keyboard of an experimental information storage and retrieval system.

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E&S

ENGINEERING AND SCIENCE

JANUARY 1968 / VOLUME XXXI / NUMBER 4

ON THE COVER

An electron micrograph (magnification approximately 90,000) of the DNA of the virus known as Phi X 174 that has now been synthetically produced for the first time in an active, self-replicating form. This significant achievement, the collaborative effort of Caltech's Robert Sinsheimer and Arthur Kornberg and Mehran Goulian of Stanford University, is described in "DNA—A Perfect Copy" on page 10.

PICTURE CREDITS: Cover—H. Fernandez-Moran; 10, 13, 29-31, 32—James McClanahan; 22, 25, 26—Robert Huttenback; 22, 23—Midge Quenell; 31—Paul W. Bailey

STAFF

Editor and Business Manager—Edward Hutchings Jr.; *Associate Editors*—Bruce Abell '62, Phyllis Brewster, Jacquelyn Hershey, Kathleen Marcum; *Photographer*—James McClanahan.

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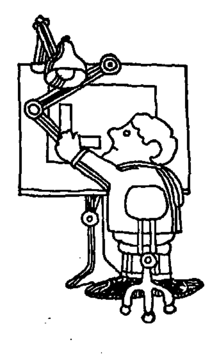
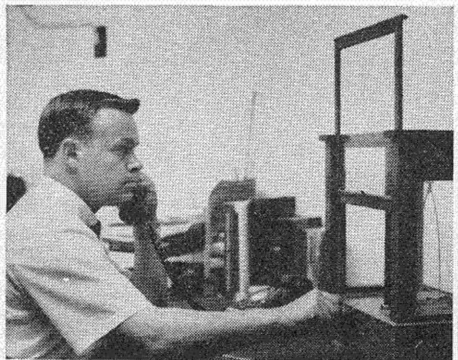
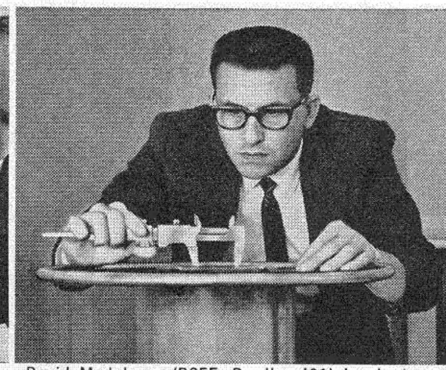


There is a growing need for nonferrous metals. To grow with it, contact Anaconda.

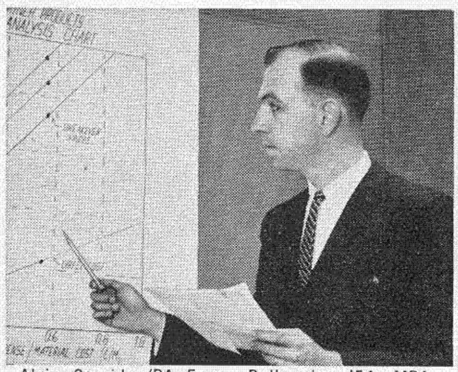


Robert Lindsay (BSME, U. of Kansas '64) is quality control supervisor of Anaconda Aluminum Company's plant in Louisville, Ky.

Joel Kocen (BS Commerce, Wash. & Lee '59; LLB, Wash. & Lee '61) left, is senior tax analyst at New York headquarters of Anaconda.



David Madalozzo (BSEE, Bradley '61) is plant engineer of the new Anaconda Wire and Cable Company mill in Tarboro, N.C.

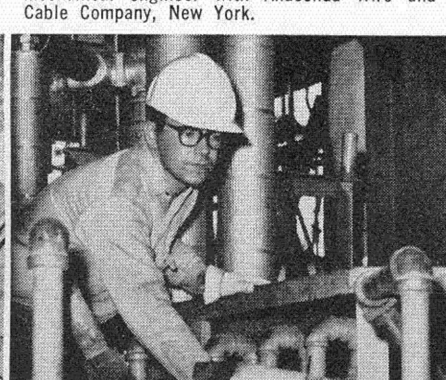


Alvin Cassidy (BA Econ., Bellarmine '54; MBA, U. of Louisville '59) is director of financial planning of Anaconda Aluminum Company, Louisville, Ky.

Robert Zwolinski (BSME, Rutgers '57) is chief mechanical engineer with Anaconda Wire and Cable Company, New York.

Willard Chamberlain (BE Metal. Eng., Yale '53) is manager of Anaconda American Brass Company's Valley Mills, Waterbury and Ansonia, Conn.

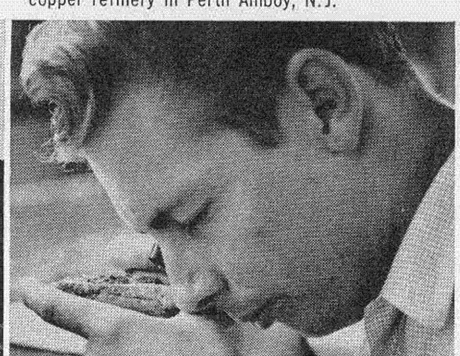
Robert Ingersoll (BS Geol., Montana Tech. '51 MS Geol., Montana Tech. '64) right, is senior geologist, Anaconda's mining operations, Butte, Mont.



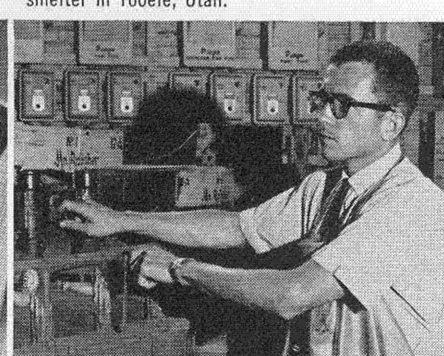
Thomas Tone (BS Mining, U. of Arizona '62) is foreman of the furnace dept. at the electrolytic copper refinery in Perth Amboy, N.J.

Richard Symonds (BS Metal., U. of Nevada '57) is superintendent of the lead plant at Anaconda's smelter in Tooele, Utah.

Jay Bonnar (BS Met., M.I.T. '57; MS Ind. Mgmt., M.I.T. '62) left, is research administrator of Anaconda American Brass Company's research and technical center, Waterbury, Conn.



Wilson McCurry (BSc, Arizona State '64) is an assistant geologist in Anaconda's new mines dept., currently working on development of the Twin Buttes mine near Tucson, Ariz.



Terrence McNulty (BS Chem., Stanford '61; MS Metal., Montana Tech. '63; DSc Metal., Col. School of Mines '66) is senior research engineer, extractive metallurgical research, Tucson, Ariz.

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IN THIS ISSUE

NEW UNDERSTANDING

The puzzle of the genetic substance DNA continues to be worked out piece by piece. Three new contributions to the emerging picture have recently been made by three Caltech scientists in three separate research projects. Robert Sinsheimer, professor of biophysics, participated in the Caltech-Stanford work which produced the first genetically active DNA in a test tube (pages 10-11). Giuseppe Attardi, professor of biology, and his wife, Barbara, have confirmed that messenger RNA is produced outside a cell's nucleus (pages 12-13). And Jerome Vinograd, professor of chemistry and biology, has found that ring-shaped DNA exists in chains of up to seven links (page 14).

NUCLEAR POWER

Milton Plesset, Caltech professor of engineering science, is an authority on the problems and progress of nuclear power. His article on pages 15-19 has been adapted from a talk given at Beckman Auditorium on November 6. In it he gives some background on the current draft of a nonproliferation treaty and suggests some amendments that might bring eventual agreement.

VISITOR FROM OUTER SPACE

A unique iron meteorite, named Colomera for the area in Spain where it was found, is now at Caltech. Its study is of special interest to nuclear geochemists because the silicate inclusions in its makeup contain information about the age and lifetime experiences of the meteorite. What is in store for Colomera is described on page 32.

CHITRAL REVISITED

Robert Huttenback is not only professor of history and master of student houses at Caltech, but he is a hardy traveler, a persistent researcher, and a teller of tales as well. "Chitral Revisited," on pages 22-27, is a happy result of the combination. Dr. Huttenback made the journey to Chitral with Peter Fay, Caltech associate professor of history. Their tale is illustrated by Dr. Huttenback's own photographs—slightly altered, for artistic effect, by a process called double-tint posterization.

LETTERS

NOT LIKE IT USED TO BE

Blacker House, Caltech

EDITOR:

I was disappointed in reading all three letters in the December *E&S*. If they are representative of letters received. I must conclude that Techers take their apathy with them when they graduate. One reader did not like the new format, but neither he nor his wife bothered to open the cover to see if the issue was *E&S* or a "drug or mail order store" catalog. He did not notice that Alumni News has been transferred to the *Caltech News*.

Another reader admitted his laziness in not wanting to read all of the longer, improved *E&S*. As a student I enjoy reading articles about campus research, about social problems related to technology, and about Caltech news and history.

In the third letter George Sawyer has closed his mind to change and has overlooked several facts. He claims, without basis, that "the Institute does not belong to the present group of students or employees." Yet they, particularly the energetic faculty, are "giving of their energies" just as much, if not more, than the anonymous "owners" of Caltech. Mr. Sawyer has ignored the fact that "the owners' policies and practices" have evolved over Caltech's entire 75-year existence. Those of today are not the same as in 1925, when Caltech began to chart its course; certainly they are different from those during World War II, when much campus research was directed toward the war effort. Present Caltech students and faculty members have not only the "natural rights" but also the responsibility to evaluate and to change, if necessary, Caltech's future. Mr. Sawyer himself states that "maintaining things of value requires constant monitoring and the rebuilding of parts that have decayed." If dissatisfied students and teachers left, instead of trying to make improvements, Tech would remain frozen, not keeping up with changes in society.

In his fear of the proposals submitted to ASCIT last spring, Mr. Sawyer has redefined "sloppy and dirty nature" to refer to people with whom he disagrees. But all alumni should take note of the changes proceeding on campus. Pass-fail grading is now a definite policy, both for freshmen and some upperclassmen. Students are now working with faculty committees. Only administration and trustees' approval is needed before women are admitted as undergraduates.

A growing social awareness, as evidenced by the interest in the ASCIT Research Project, is paralleled by an expansion of the humanities and social sciences at Tech, as detailed in the recent *President's Report*. It is the hope of many that the new wave of enthusiasm on campus will supplant any remaining apathy.

ROGER M. GOODMAN '70

A CHANGE OF NAME

Houston, Texas

EDITOR:

In recognition of Caltech's broadening view of its domain and responsibilities, I suggest you alter the title of your magazine to SEE, Science, Engineering and Environment.

R. S. MACALISTER '47

ARCHITECTS ANONYMOUS

South Pasadena

EDITOR:

In the December issue of *E&S* you feature Caltech buildings designed by some extremely distinguished architects, and yet no credit is given to them. I think it would add to the kudos of the campus if we gave credit to these gentlemen who are really making a fine contribution.

HENRY DREYFUSS

Much as we hate to admit it, you're right. A quick check through our back issues reveals that we pay all kinds of attention to the donors and the occupants of our buildings, but we seem to overlook the designers. For the record, here is an up-to-date list of the proposed buildings for which architects have been contracted:

Astrophysics—Edward Durrel Stone, Inc.
Graduate Residence Houses—Eggers, Wilkman & Whittle
Chemical Physics (completed)—Risley, Gould & Van Heuklyn
Behavioral Biology and Humanities—Robert E. Alexander & Associates
Geophysics—George Vernon Russell & Associates
Business Operations—Welton Becket & Associates
Gymnasium—Roland Coate
Central Plant (completed)—M. A. Nishkian Company
Radio Astronomy (at Owens Valley)—John Lautner
Palomar 60" Telescope dome—Richard Rose

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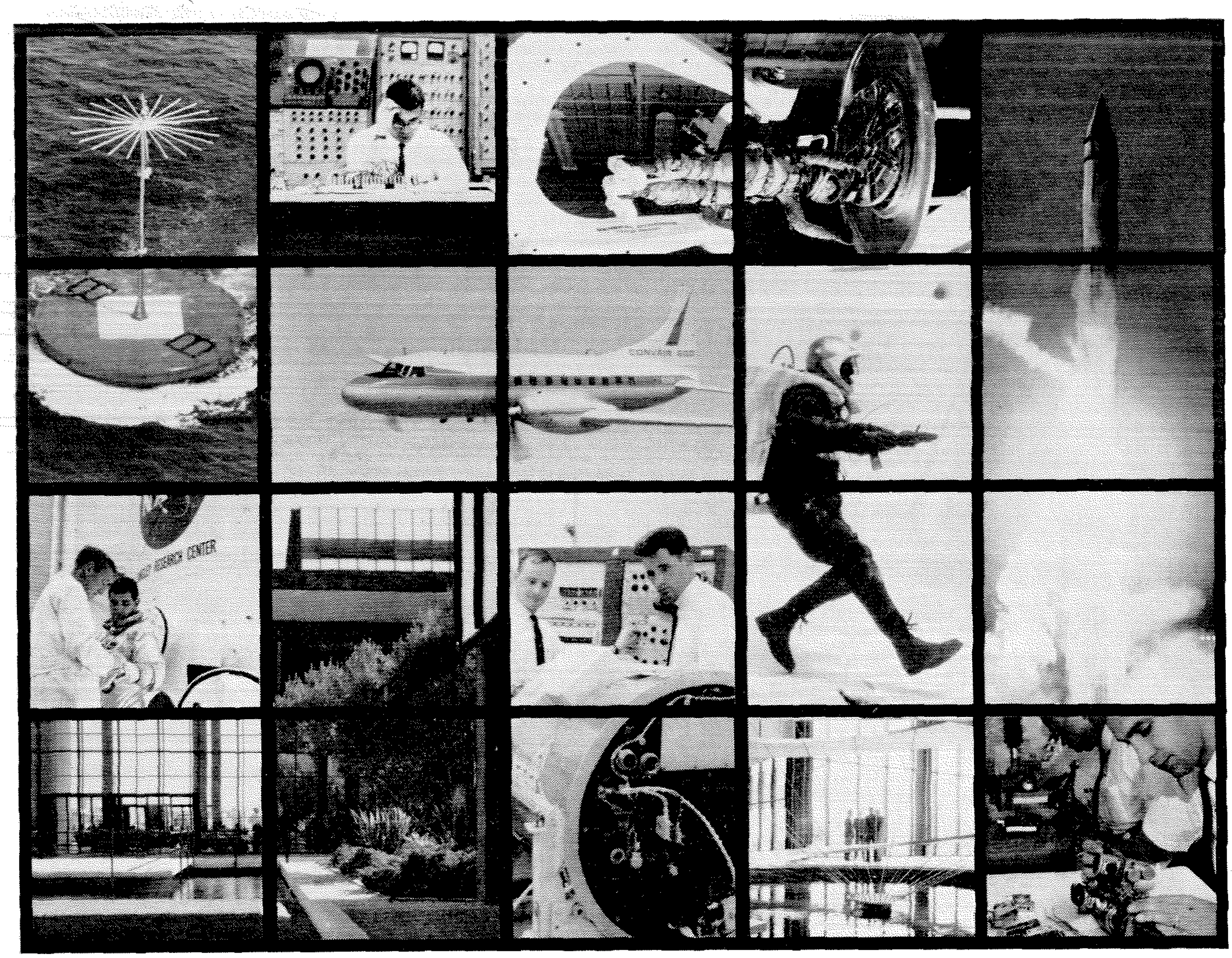

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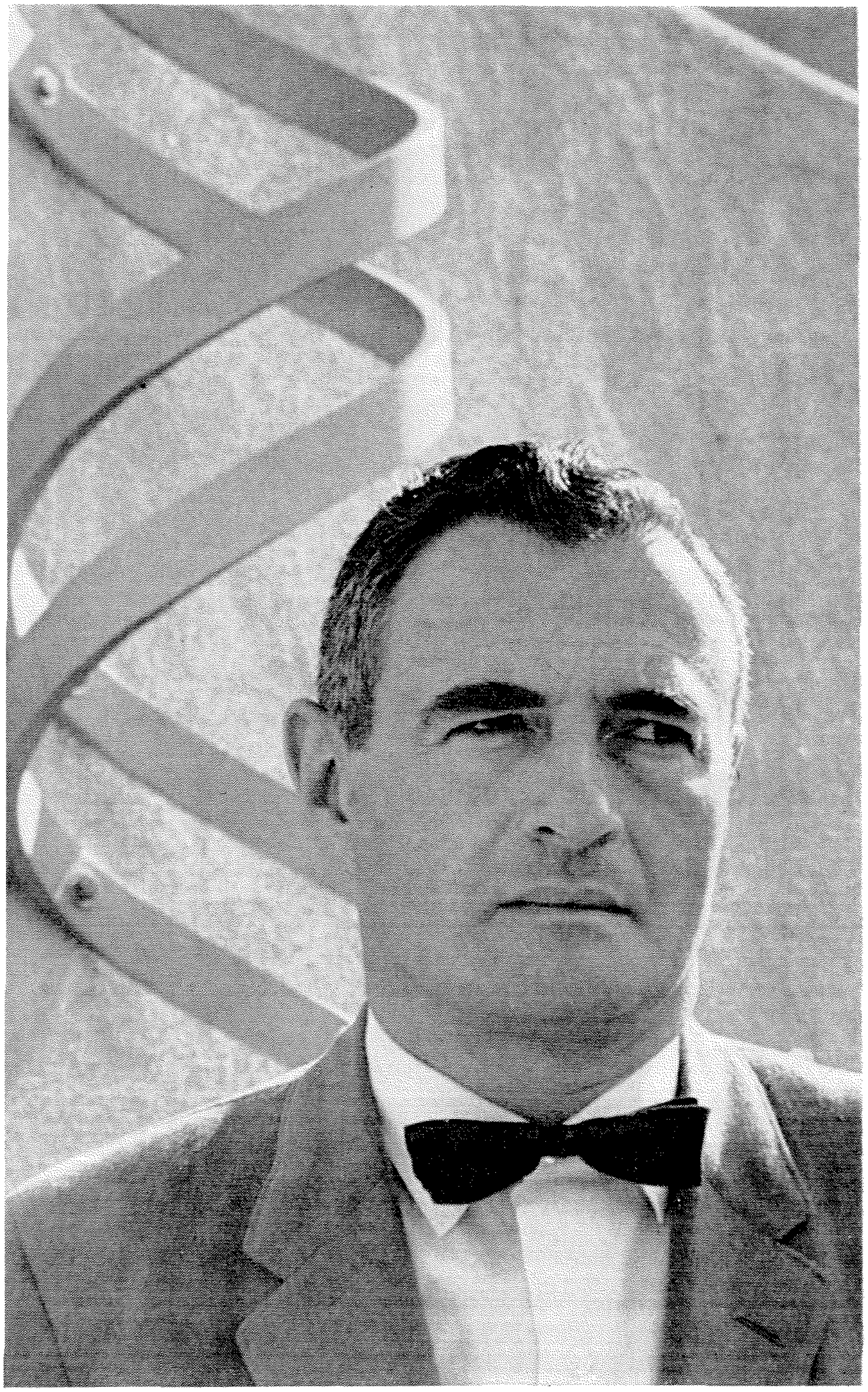
E&S
January 1968, Vol. XXXI, No. 4

New Understanding of the Chemical Basis of Heredity

In the past two decades biologists and biochemists have convincingly demonstrated that the genetic substance of all living creatures, from viruses to man, is nucleic acid—DNA (deoxyribonucleic acid)—and that the instructions in DNA are transmitted by messenger RNA (ribonucleic acid). The detailed structure of these substances and the manner of their function and reproduction are the primary concern of workers in the field of molecular biology today, a field in which recent progress has been particularly dramatic. On the following pages—three recent developments in which Caltech scientists have played a prominent part.



DNA –
A PERFECT COPY

Scientists at Stanford University and Caltech collaborate to produce DNA in the laboratory.

"The dramatic advances in molecular biology of the past few decades have laid bare the essential molecular mechanics of inheritance, and of the processes of cellular function and control. . . . In so doing, a secure base has been laid for further advances in our understanding of development and physiology and pathology—a base that can only be compared in this century with that which quantum mechanics provided for the development of modern physics and chemistry. And with this understanding will come the potentiality for intervention and the intelligent control of processes that have known only the mindless discipline of natural selection for two billion years."

—Robert L. Sinsheimer

DNA, the chemical material that controls the hereditary characteristics of every living thing, has now been successfully synthesized in the laboratory. Scientists at Stanford University and Caltech announced last month that they had produced a copy of the DNA of a virus that displays the full biological activity of natural DNA in living organisms; the synthetic DNA can infect bacteria and reproduce itself just as the natural virus does.

This is probably as close as anyone has yet come to creating life in the laboratory. The discovery should not only lead to better understanding of how viruses are duplicated when they enter cells, but also to new knowledge of what takes place when normal cells are changed into cancerous ones.

The team of scientists who collaborated on this research includes Arthur Kornberg, professor and executive head of the department of biochemistry at Stanford; Mehran Goulian, former postdoctoral fellow at Stanford, now on the faculty of the University of Chicago; and Robert L. Sinsheimer, professor of biophysics at Caltech.

Dr. Kornberg shared the Nobel Prize in 1959 for producing DNA from a mixture of inert chemicals. This synthetic DNA had all the physical and chemical properties of DNA found in nature, but it was not biologically active.

The DNA that has now been produced by the Stanford and Caltech scientists is a copy of the DNA of a natural virus known as Phi X 174, which attacks intestinal bacteria. Dr. Sinsheimer is a leading authority on the nature and behavior of this virus, which he discovered some 10 years ago.

Phi X, like all viruses, survives by attacking and infecting a cell that is thousands of times larger than it is. The cell in this case is the bacterium, *E. coli*, a common intestinal microbe. Phi X forces its DNA through the cell wall of *E. coli*, then directs the cell's metabolic machinery to manufacture almost 200 complete Phi X viruses within less than a half hour. The cell soon ruptures, freeing the viruses to attack other *E. coli* cells.

Using methods developed by Dr. Sinsheimer for growing and isolating DNA from Phi X, the Stanford researchers started by taking single rings of natural DNA from this simple virus, which consists of a DNA molecule surrounded by a protein sheath.

The rings were placed in a compatible solution simulating that of the interior of an *E. coli* cell. The solution was rich in the four chemical compounds called nucleotides, which are the basic building blocks of DNA. It also contained two enzymes which proved to be essential in carrying out what scientists know to be the first step in the infective process of this virus in nature. One of them, DNA polymerase, catalyzed the coupling of nucleotides in the building of the new DNA chain, using, at first, the natural viral DNA ring as a template. The second enzyme, DNA ligase, served the special function of closing the chain into a ring.

There were four major stages in the research. The ability of the Phi X DNA to replicate was tested at each stage and at several steps in between. Because DNA synthesis provides a complementary, or mirror-image, copy instead of an exact one, it was necessary to proceed through the several stages to achieve an artificial synthesis of the exact replica of the original, natural DNA ring.

The intensive phase of the research covered three and a half months during which the Stanford scientists, Dr. Kornberg and Dr. Goulian, induced the synthesis of various versions of the DNA of the virus, froze the samples to preserve them, and shipped each succeeding version to Dr. Sinsheimer at Caltech. He then carefully tested the ability of the DNA samples to replicate the complete viruses.

When the final version of the artificially produced DNA was put into living cells, they became infected just as they would from a normal virus. The viruses produced by the infected cells are indistinguishable from natural ones, and they infect in the same way.

The research represents an important step forward in understanding how viruses are duplicated when they enter cells and how DNA polymerase or similar enzymes make new DNA.

"If we know how to use this enzyme to copy this particular virus, then we can copy other viruses," says Dr. Kornberg. "And we can copy them in ways in which we can modify their structure by putting in alternative or fraudulent building blocks to create new forms of the virus. We can then use the synthetic virus to infect cells and produce altered responses."

"It opens a wide door to new discoveries in fighting disease and building healthier lives for mankind."

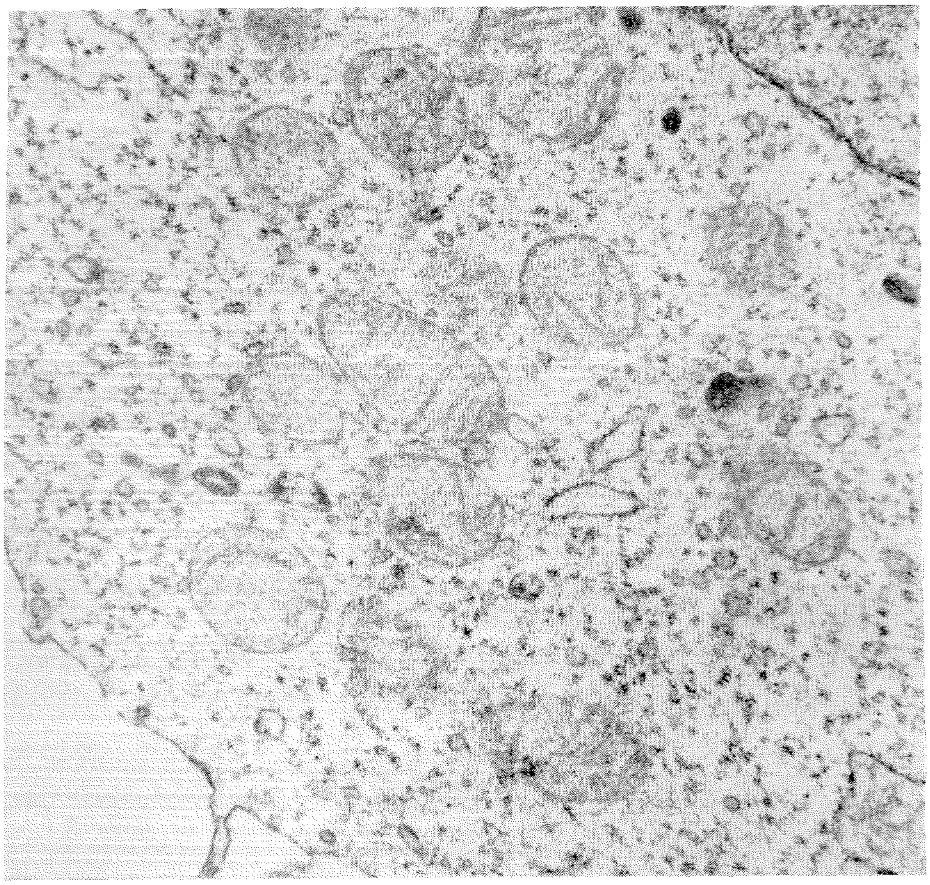
One possible future application is controlling certain forms of cancer. For example, DNA found in polyoma virus produces a variety of cancers in many animals. "I think it is reasonable to expect that the polyoma viral DNA will be synthesized by an enzyme system," Dr. Kornberg says. "With such a synthetic system we should be on our way toward figuring out what genes in the virus are responsible for the cancer response."

Another possibility in the far-distant future might be the careful manipulation of laboratory synthesis of DNA as a means of modifying genes.

The research has proved two things, according to Dr. Sinsheimer. First, it determined that there are two enzymes, DNA polymerase and DNA ligase, that carry out the first step in the infective process.

Second, considering that there are 5,500 nucleotides in the viral DNA, the work also demonstrated that the copying of the DNA blueprint in the test tube must have been very good. There could not have been many mistakes.

"It is an awesome accomplishment," President Johnson has said of this research. "It opens a wide door to new discoveries in fighting disease and building healthier lives for mankind."



This electron micrograph of a portion of a HeLa cell shows part of the nucleus in the upper right corner. The large oval-shaped bodies are the mitochondria in the cell's cytoplasm. Messenger RNA was found in the free polysomes (the clusters of tiny black dots) and in the vesicles of rough endoplasmic reticulum (the two dark elongated rings to the right of center). (Magnification 34,500)

A Second Genetic System

In the long and compelling search for an understanding of how life perpetuates itself, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) have been found to be at the basis of the processes involved. Cell growth and differentiation are known to be controlled by genes—represented by DNA segments—located in the nucleus of all animal and plant cells. A fundamental function of DNA is to serve as a template for the synthesis of messenger RNA, which carries coded instructions from the nucleus to the cytoplasm for the synthesis of proteins.

In addition to the nuclear genetic system, biologists have for some time had reason to believe that a second genetic system exists in the cytoplasm of molds, yeasts, protozoa, green algae, and higher plants. The presence of this second genetic system would account for certain phenomena of inheritance which do not follow the classical laws of heredity. This belief received scientific support recently when DNA was discovered in the cytoplasm of many kinds of organisms, in particular in the chloroplasts of plants and in the mitochondria (energy-producing organelles) of various organisms.

Direct evidence for the existence of this separate genetic system, which sends messages to the cell's protein-synthesizing machinery in the cytoplasm of animal cells, has now been obtained by Giuseppe Attardi, M.D., Caltech professor of biology, and his colleague (and wife) Barbara. They have found that a fraction of the messenger RNA, the primary product of the genes, is synthesized in the cytoplasm. This indicates that genes exist and are switched on outside the nucleus.

The Attardis made their discovery by using two kinds of cells cultivated *in vitro*—HeLa cells, derived from human tumor, and a strain of mouse cells. They found messenger RNA in two fractions of the cell's cytoplasm—in polysomes (the protein-synthesizing structures) suspended free in the cytoplasm and in polysomes associated with a membrane fraction of the cytoplasm.

In order to determine the site of synthesis of

A Caltech husband and wife research team finds that a fraction of messenger RNA is synthesized in the cytoplasm of animal cells.

Barbara and Giuseppe Attardi isolate DNA from the mitochondria of the cells of human tumor tissue (HeLa cells) by collecting fractions of a cesium chloride density gradient. This will be used for experiments of hybridization with fractions of messenger RNA also extracted from the cell's cytoplasm.

these two messenger RNA classes, the Attardis carried out two types of experiments. In one they added a radioactive precursor (one of the building blocks) of RNA to growing cell cultures. This tracer appeared rapidly in the membrane-associated RNA, but somewhat later in the free-polysome messenger RNA. This suggested that the free-polysome messenger RNA was first synthesized in the nucleus and then transported to the polysomes, while the membrane-associated messenger RNA was synthesized in the cytoplasm itself.

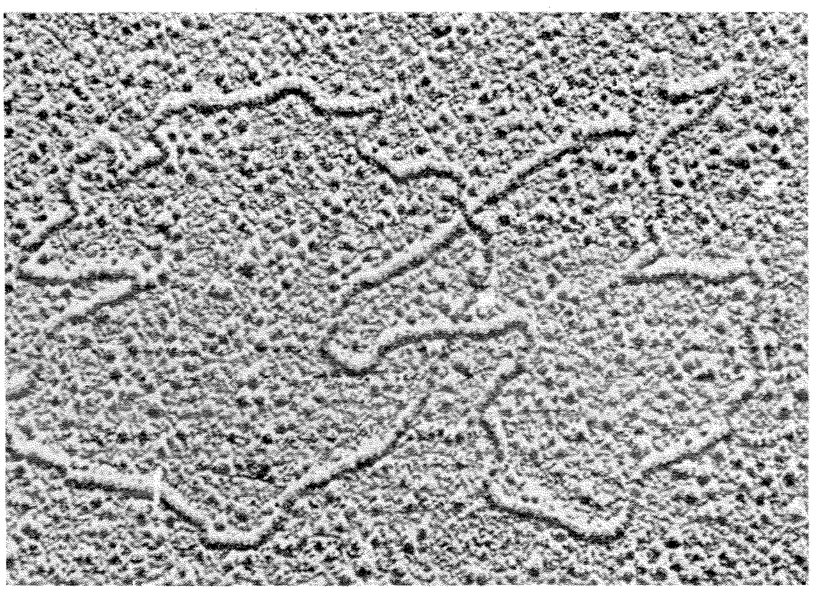
In order to obtain more direct evidence on this point, the Attardis extracted mitochondrial DNA and the two RNA fractions from HeLa cells. Each RNA fraction was incubated at high temperature in a salt solution with the DNA. The DNA formed molecular hybrids with the membrane RNA, but not with the free-polysome messenger RNA, indicating that the membrane messenger RNA is a "transcription" product (or complementary replica) of the mitochondrial DNA. Other evidence indicated that the major part of this RNA is associated with membrane structures outside the mitochondria, probably with the tubules and vesicles of the rough endoplasmic reticulum that electron microscopy has revealed in HeLa cells. The membrane messenger RNA would thus represent mitochondrial RNA which is exported to the rough endoplasmic reticulum. One fraction of it, however, presumably remains inside the mitochondria, since these organelles apparently are able to support protein synthesis.

The Attardis believe that the nuclear and cytoplasmic genetic systems are coordinated in some way. One possibility, suggested by other evidence, is that the cytoplasmic RNA carries instructions for the synthesis of structural protein components of mitochondria and other membranes of the cytoplasm. To test this hypothesis, the next step in their research will be to determine the nature of the proteins which are synthesized under the direction of this RNA.

Genetic Chains

Caltech researchers attempt to solve the chemical and biological mysteries of a new form of ring-shaped DNA

Scientists have known for some time that nuclear DNA in animal and plant cells exists as linear molecules. Several years ago, however, researchers found evidence that DNA in certain viruses and bacteria was ring-shaped. This form was also observed in the cells of mice, sea urchins, and men. Now Jerome Vinograd, Caltech professor of chemistry and biology, and his graduate-student colleagues David Clayton and Bruce Hudson have observed these rings in another form—in a series of loops connected like links in a chain. Genetic chains of up to seven links have been found. Located in the mitochondria of several kinds of animal cells, including human, these DNA circles seem to be capable of joining together to form new circles with twice the circumference or of forming interlocking circles in which one link (one molecule) threads through the other, perhaps exchanging genes in the process. The individual circles are generally five microns (1/25,000 of an inch) in circumference and have been found to occur in a variety of different arrangements. Thus a chain of four links can be either linear, as in a normal chain, or branched. There is also the possibility of a circular form, as in a necklace made up of small circles.



Photomicrograph of ring-shaped DNA in a new form—a series of loops connected like links in a chain. Chains of up to seven links have been found in the mitochondria of several kinds of animal cells.

The chain molecules are especially interesting because they contain a new kind of naturally occurring chemical bond. Two or more rings are bonded to each other without the customary sharing of atoms, yet they cannot be separated without breaking covalent chemical bonds.

The biological function of mitochondrial DNA is still essentially unknown. There is evidence that it contains the genetic information for the structural protein in the mitochondrial membranes.

Investigations of Vinograd's research group show that there is a difference in the distribution of the complex forms of mitochondrial DNA depending on the source. Some of the DNA studied came from human cancer cells grown in a tissue culture (HeLa cells) and some from human white blood cells from leukemia patients. The relative amounts of certain kinds of DNA molecules were observed to differ. In one leukemia patient the molecules were 10-micron circles—double the standard size circle. In the same patient only a small fraction of the molecules were linked to form chains of five-micron circles. On the other hand, in the HeLa cells interlocked five-micron circles were found almost exclusively. The next step in the research is to discover the origin of these unusual molecules, how they are formed, and how they affect the mitochondrion and the cell. The questions are difficult, but the answers may reveal new insights into the "code of life."

NUCLEAR POWER AND NUCLEAR PROLIFERATION

by Milton S. Plesset

The far-reaching benefits of peaceful uses of nuclear power go hand in hand with dangers of its potential misuse.

The materials necessary for producing nuclear bombs are spreading throughout the world. This will, of course, lead to an increase in the number of nations which have nuclear weapons. This is the problem of nuclear proliferation. The problem has three distinct aspects—technical, industrial-economic, and political—and these dissimilar aspects must be kept in simultaneous focus if a successful nonproliferation treaty is to be developed.

The formal source of treaty efforts is the Eighteen Nation Disarmament Committee (ENDC) which consists of the five NATO countries (United States, Canada, Italy, United Kingdom, and France), the five Warsaw Pact countries (Bulgaria, Czechoslovakia, Poland, Rumania, and U.S.S.R.), and eight nonaligned countries (Brazil, Burma, Ethiopia, India, Mexico, Nigeria, Sweden, and United Arab Republic). France, which is nominally a NATO country, has refused to participate. China was not invited to participate, presumably because of the close relationship of ENDC with the United Nations, so that the only members of the five-nation nuclear club which are participating are the United States, the United Kingdom, and the Soviet Union.

A number of technical and economic factors have led to the increased sense of urgency regarding the problem of nuclear proliferation. While it is clear that rapid diffusion of the materials from which nuclear weapons are made could result in a serious threat to world peace and stability, it is also clear that new developments of the peaceful atom have a great potential for large economic benefits on a worldwide scale.

Two kinds of nuclear weapons material play an essential role in the peaceful applications of nuclear energy: enriched uranium and plutonium. The first designs of power reactors were based on the use of natural uranium. In uranium the chain reaction and continuous energy production come from the rare isotope U^{235} which in natural uranium is only 0.7 percent of the whole, with the remaining 99.3 percent being the nonfissioning isotope U^{238}. Reactors using natural uranium are large structures, and, for special devices such as nuclear power reactors, large size generally implies great cost. Also, natural uranium reactors maintain power production in a rather marginal way; the auxiliary components must be made of special, costly materials which do not absorb too many of the fission neutrons—the particles which maintain the chain process.

In 1964 the nuclear power business emerged from a long period of depression in a spectacular manner. General Electric built a nuclear power plant for Jersey Central Power in which the utility was guaranteed a power-generating cost not to exceed 3.8 mills per kilowatt hour. While cost statements in mills per kwhr are an oversimplification, in the U.S. conventional plants fueled with coal or oil have costs ranging from 5 to over 10 mills. Costs in Europe are even higher.

The reaction of the electric utility industry in the United States has been enormous, as can be seen from the table below, which gives the status of the U.S. civilian nuclear electric power program as of September 20, 1967:

		Megawatts
In Operation	14 plants	2,800
Being Built	18 plants	11,600
On Order	36 plants	30,800
Announced	12 plants	9,800
		55,000
Total U.S. Electric Capacity		250,000

There are two striking characteristics of this latest and very successful generation of nuclear power plants. The first is that they have extremely large power capacities, ranging from 500 to 1,000 megawatts. The city of Los Angeles with its 2.8 million population has a total power capacity of 3,500 megawatts; the capacity of Hoover Dam is about 1,200 megawatts.

A world in which several little Nassers have enriched uranium at their disposal would be a most uncomfortable planet.

A second striking feature of the American design is that it uses enriched uranium. In natural uranium the content of the fissionable, energy-producing isotope U^{235} is less than 1 percent. The new U.S. reactors require uranium fuel in which the content of U^{235} has been increased to about 2 percent. This process is performed in enrichment facilities whose original purpose was solely to obtain weapons-grade uranium, which is very highly enriched material. Enrichment facilities have thus far been built in the U.S., the Soviet Union, France, England, and Communist China—those countries which have demonstrated their weapons capabilities.

The peaceful and economically significant use of enrichment facilities is a very recent development. There are many highly industrialized countries which do not have their own uranium enriching facilities; but they could build them. Then they would also have the capability of producing weapons-grade uranium. Here we have one kind of proliferation danger.

As an antiproliferation effort the United States has agreed to make enriched uranium available at an attractive price estimated to be about two-thirds of France's enrichment cost. (In the free world France has the largest existing facilities next to the U.S.). Some foreign spokesmen for the industry, such as those in West Germany, have expressed concern about becoming dependent upon the United States for a large segment of their power requirements, indicating some reserve about possible whimsical behavior at a future time by members of the American Congress which might cut off their supply of enriched uranium. Such an action would be a staggering blow to a nation's economy. The U.S. answer to this concern has been to give treaty status to an agreement on an enriched-uranium supply. The American view is that the abrogation of a treaty is a serious step that any country would hesitate to make. A further part of such a treaty would be that the plutonium produced, while belonging to the country owning the reactor, would be under international safeguards.

In spite of the treaty aspect, there are still some reservations on the part of the largest potential users of the U.S. type of reactor—West Germany and Japan. These countries are aware of the enormous world market for power reactors and are keenly interested in extending their foreign trade. They are reluctant to accept a secondary role for their own power needs as well as for their foreign trade. Their position is further weakened since they cannot supply enriched-uranium fuel even if they could compete on plant designs and construction.

The U.S. is thus far effectively the sole source for the supply of enriched fuel. It has established a price for the enrichment of uranium which has a direct effect on the cost of electricity generated from nuclear energy. Of course, the lower the U.S. figure is, the less—so the AEC believes—is the pressure for a foreign country to get its own enrichment facilities. Perhaps this attitude stimulated the AEC to lower the enrichment charge by 10 percent last September. This decrease means a further improvement in the competitive position of the enriched-uranium-fueled power reactor relative to the fossil-fueled power plant.

One point that the AEC has not made clear is the capability of our enrichment facilities for meeting the demand. The AEC has been steadily raising its predictions of the level of nuclear power production. In 1962 the prediction for 1980 was 40,000 megawatts. This is less than the nuclear power ordered or installed by 1967. The present AEC estimate for 1980 is 150,000 megawatts.

In any case, two important questions arise for the foreign operator of an enriched-uranium power reactor abroad: Will the existing U.S. enriching capacity meet the demands of the 1980s and later, and if it does not, will this capacity be increased sufficiently to meet the expected requirements? The AEC has just released information which indicates that our present enrichment capacity will barely meet the U.S. domestic needs. As for the second question, since foreign needs might be expected to have lower priority than domestic needs, foreign concern is entirely reasonable. The pressure for independent enriching facilities will certainly increase. Actually, the most efficient course is for the U.S. to increase its enriching capacity.

In every case so far the development of uranium-enrichment facilities has been motivated by a national drive toward nuclear armament. The economic value of an enrichment capability is of only recent importance. This economic incentive, however, may serve as a convenient excuse toward such a development. The AEC proliferation nightmare is that an enrichment method will be developed which will be so simple and inexpensive that any country would be able to develop it.

Actually, the realities of the enrichment situation are somewhat different. The scientific and technical procedures for enrichment are well understood, and there is no particular need for secrecy. The actual design and construction of an enrichment facility, on the other hand, require an engineering and industrial base of appreciable extent.

The pressure for enrichment facilities is only a part of the concern over nuclear proliferation. A very great concern is with the production and use of plutonium. This element did not exist until the advent of the nuclear age, and it is now produced in large quantities in nuclear reactors. Plutonium has outstanding fissionability, which means that it is an outstanding material for nuclear bombs. Less than 10 kg (22 lbs) of plutonium are sufficient to produce a nuclear weapon. Plutonium is always being produced in a reactor since U^{238} is a fertile material; that is to say, when a U^{238} nucleus captures a neutron, a fissionable nucleus, plutonium, can be produced. In a 1,000-megawatt nuclear plant, sufficient plutonium is produced to make more than 20 nuclear bombs per year. Furthermore, the separation of plutonium from nonfissionable materials is not a difficult physical process, like the one required for uranium enrichment. Rather, it is a simple chemical process, since plutonium is obviously a different chemical element from uranium.

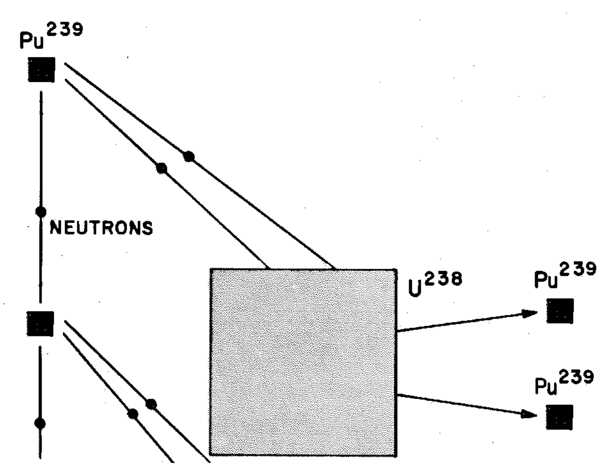
The U.S. and the U.S.S.R. have proposed that inspection and verification of the fissionable materials uranium and plutonium be made by the International Atomic Energy Agency (IAEA). The European Community group, for which West Germany has been the active spokesman, has strongly objected to this inspection proposal. It points out that Euratom, the atomic energy division of the European Economic Community, already has an extensive and capable inspection system of its own. Further, it is clear that France, which accepts Euratom inspection of its civilian nuclear installations, would refuse to accept inspection by IAEA. West Germany and Japan also would probably be unwilling to accept IAEA. They already feel they have lost out to the United States in the first great stage of economic development of nuclear reactors—those based on slightly enriched uranium. As great industrial powers, they feel it is essential for them to have an independent role in the next stage of nuclear power development. West Germany is already making an important investment in this next stage and genuinely fears that its developments will be stolen by Russian or other inspectors from IAEA.

The rapid growth of nuclear power production in the world means that the output of plutonium from the conversion of enriched uranium will be huge. By 1980 the world supply will be over 100,000 kg. This figure translated into an equivalent number of nuclear bombs (over 10,000) is truly awesome. Yet, in spite of this enormous production there is universal agreement that the shortage of plutonium will be acute until at least the year 2000. This shortage will result from the increased need for plutonium for nuclear power production in the new type of reactor to come.

The implications for the proliferation problem of large amounts of plutonium in several places throughout the world are almost too obvious, and the existence of an acute shortage at the same time may seem paradoxical. To understand this situation it is necessary to consider the next stage in the production of electric power by means of the plutonium fast-breeder reactor. Here we are talking about developments which will take place by the early 1980s and will rapidly become large scale. The physical and engineering principles which are the basis for the plutonium fast-breeder reactor are already well known. What remains is only a technological and manufacturing development that requires experience with various prototypes already operating or now being built in the United States, in the U.S.S.R., in England, and in West Germany.

The plutonium fast-breeder reactor is a compact structure which will have a power density of the order of a megawatt per liter—1,000 times greater than the power density in the gas-cooled natural-uranium reactor and more than ten times greater than in the enriched-uranium reactor. The fission energy comes from the plutonium; natural uranium will be included in the reactor to be converted to

THE PLUTONIUM FAST BREEDER



The plutonium fast breeder, the electrical power producer of the future, uses a costly fission energy fuel (Pu^{239} at \$40 a gram), but it will actually produce more Pu^{239} than it uses. Neutrons given off from the fission of one unit of Pu^{239} will not only keep the energy-producing chain reaction going, but, when combined with uranium 238, will produce two new units of Pu^{239}.

plutonium. So, while plutonium is consumed in the reactor, it is also being produced by the conversion of uranium. Actually, more plutonium will be produced than is consumed.

An important characteristic of the breeder is the so-called doubling time—the time required to replace the initial charge of plutonium and to produce an additional amount equal to the initial charge. The design objective is a doubling time for plutonium which is shorter than the doubling time for installed electric power; that is, the breeder doubling time should be less than 10 years. We must understand that uranium is consumed, but it is of the utmost significance that the U^{238} which is converted is 99.3 percent of the total. We are then freed of the need to buy 140 pounds of uranium to get a pound of the fissionable U^{235}.

The direct economic result is that the cost of the natural uranium being consumed becomes an entirely secondary matter. One can go to quite poor sources of uranium and still have an economic fuel. The kind of poor source that is pertinent here is, for example, the low concentration of uranium dissolved in the oceans. The total amount of dissolved uranium is in excess of a billion tons.

The plutonium breeder reactor means that the electric power needs of the world can be met for thousands of years at a fraction of the present cost. A greater and growing share of the electric power production will certainly be nuclear. It is projected that between 2020 and 2040 essentially all of the electric power in the United States will be produced by plutonium fast breeder reactors. We can therefore be certain that the great expansion in the world's energy needs will be met without the world suffocating itself by the combustion of fossil fuels.

Evidently a kind of millenium is near in which the world's electric power can be generated at extremely low cost. We have at hand unlimited resources for power with negligible fuel costs. The efforts of Project Sherwood, the AEC project to attain low cost energy from the controlled fusion of hydrogen, so far unsuccessful, is no longer justifiable as necessary to meet the world's energy requirements now that these requirements will be met by the plutonium fast breeder.

One cannot anticipate all the benefits that will come from the availability of cheap electrical energy in large packages. One such use, however, is the desalination of sea water. We can surely expect others. The development of the plutonium fast-breeder is proceeding even more rapidly than was anticipated two or three years ago. The next generation of mankind, we hope, will adjust calmly to the fact that there will be hundreds of plutonium power reactors scattered around the world.

But the following questions will surely be raised. In view of the danger from nuclear power, why bother with it? Why not continue with fossil fuels as sources of energy? We must appreciate the tremendous growth in power demands not only in the highly industrialized countries but in the less developed countries as well. Fossil fuels will continue to be used for power generation for some time, but their share of the total will be a decreasing one and should be decreasing because of the air pollution problem, if for no other reason. Further, the nuclear power plant has an important flexibility in that it does not need to be located in a way which is convenient for receipt of fossil fuels in bulk.

In view of the economic benefits on the one hand and the threat of a spread of nuclear weapons on the other, we might expect that it would not be too difficult to draft a treaty which would receive ready acceptance by most of the nations of the world. Actually, there have been many difficulties and delays in the development of a treaty.

One source of difficulty comes from the basic feature of the proposed treaty. The nuclear powers who sign the treaty promise that they will not assist any non-nuclear power to acquire nuclear weapons. Since none of the nuclear powers had any intention of doing this in any case, it should be easy for them to accept such a treaty. On the other hand, the non-nuclear powers who sign the treaty *do* give up something quite concrete since they are asked to renounce any attempt to acquire nuclear weapons. Many countries that do not now have nuclear weapons could acquire them with no help from the present nuclear powers. Non-nuclear powers such as Sweden, West Germany, Canada, or Japan are well aware that they could, without outside help, have a more efficient nuclear weapons program than has France or China. There is an even longer list of countries which could develop nuclear weapons—less efficiently perhaps, but still effectively.

Nontechnical people frequently believe that there are scientific facts which may be held secret and which will thereby effectively inhibit the development of nuclear weapons in a country which does not have them. The actual situation is that the scientific, physical principles at the basis of nuclear weapons are very widely known and available. What are not generally available are the engineering and technical procedures which facilitate the manufacture of nuclear material and devices. To secure these techniques takes time and effort. The necessary techniques are, of course, made easier to develop when there is a sophisticated engineering base in industry, but many countries *do* have this base already.

The non-nuclear powers can reasonably feel that they are making a positive contribution to world stability by signing a nonproliferation treaty. A similar positive contribution from the nuclear powers seems lacking in the eyes of these have-not countries. The reluctance of the non-nuclear powers is understandable as is their demand for some kind of *quid pro quo.*

It is necessary to have most of the countries of the world not only accept a nonproliferation treaty but to do so with real enthusiasm.

The United States and the Soviet Union are in agreement on most points of the proposed treaty, and any agreement between the superpowers is an item of the greatest importance. Yet, I believe that it is necessary to have most of the countries of the world not only accept the treaty but to do so with real enthusiasm. I should like to make the following proposals which I believe would greatly improve the response to the nonproliferation treaty.

First, the United States should not insist that the inspection and monitoring of fissionable material be done *solely* by the IAEA. The IAEA inspection capability is appropriate to the pre-industrial era and is adapted to a relatively low-level stage in nuclear power. The IAEA cannot claim to have a higher level of inspection competence than Euratom. The nations in Euratom announced last November that they are united in their rejection of IAEA inspection as provided in the draft treaty. They will allow inspection only of fissionable materials, enriched uranium and plutonium, but not of power reactors and related plants. Further, they demand that IAEA and Euratom negotiate on a free and equal basis on inspection procedures. The U.S.S.R. will not be enthusiastic about this possibility, but it is worth pressure from the United States in its favor. For purely technical reasons no inspection procedure is going to be entirely adequate to guarantee that *no* diversion of fissionable material takes place. The essential inaccuracies in control will always be equivalent to enough material for quite a few nuclear weapons. The success of a nonproliferation effort must be based ultimately not on elaborate surveillance or inspection but rather on the development of some kind of responsibility of nations. Technical developments have made *certainties* in the world impossible to obtain.

Second, the United States should terminate completely, and make a strong effort to get the U.S.S.R. to terminate, its program for the development of peaceful applications for nuclear explosions. Peaceful nuclear explosions, if we may use such a term, for making canals or for underground mining, differ only in intent from military nuclear explosions. The loophole provided by such programs is too large, and the potential economic gain from these applications is too small to justify acceptance.

Third, the United States and the Soviet Union should extend the test-ban treaty to include underground tests. This step will make their test ban complete. Actually, the gap between the United States and the Soviet Union on this point during the original treaty discussions was not so large as might be supposed. Underground explosions were not included because the Soviet Union would not accept the number of on-site inspections of suspicious seismic events within its borders which the United States felt would be necessary. Since the execution of the original treaty there has been some improvement in the Soviet attitude regarding foreign surveys, and there has been a significant improvement in the techniques of seismic measurements which would aid in the discrimination between earthquakes and underground nuclear explosions. A nominal inspection privilege would be an entirely adequate safeguard against the possibility of cheating. Again, we must realize that we cannot demand *certainties* in a technically complex and politically involved situation.

While all three of these steps would increase the acceptability of a nonproliferation treaty to the non-nuclear powers, the completion of the test-ban treaty would be the most significant contribution to their enthusiastic acceptance and support of the treaty. The international moral pressure on France and mainland China would be correspondingly increased. These two countries could very well discover that their second-rate nuclear arsenals represent a net loss in national prestige.

The world needs a good nonproliferation treaty, but the moment is gone when it would have been easy to get a good one. We have been technically inventive; now we need to be politically and organizationally inventive. In spite of the potential dangers of the widespread diffusion of nuclear materials, perhaps the great economic benefits will confine the use of nuclear materials to economic applications. The revolution in energy supply will be just as available in an underdeveloped part of the world as it is in a highly industrialized country. It is inevitable, perhaps, that it will come more slowly in the areas of the world which need it most. But it will come.

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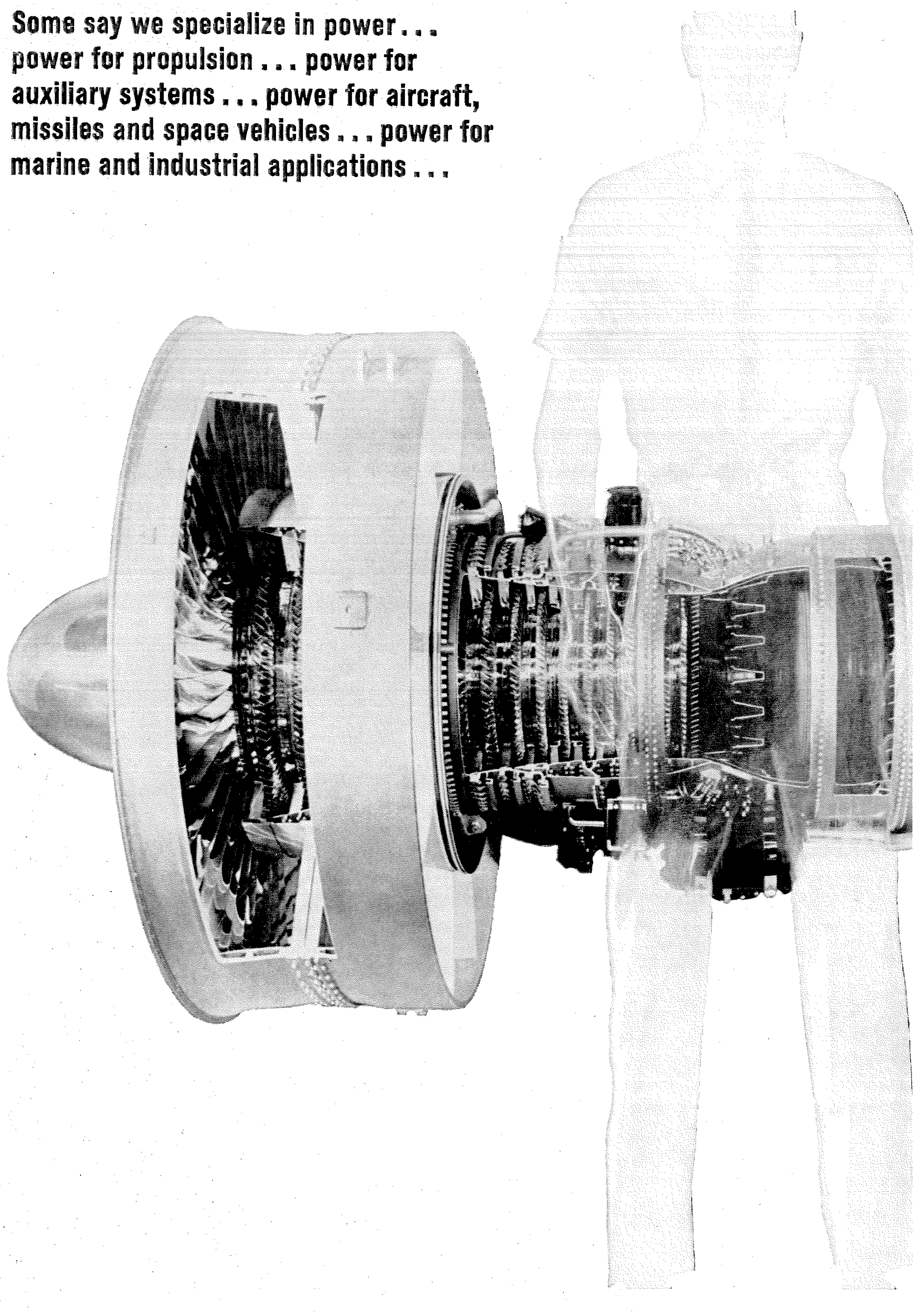
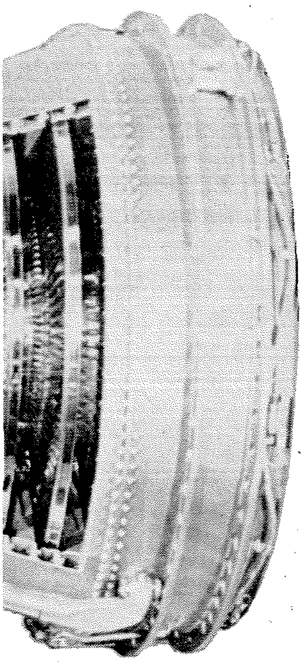


. . . they're right. And wrong.



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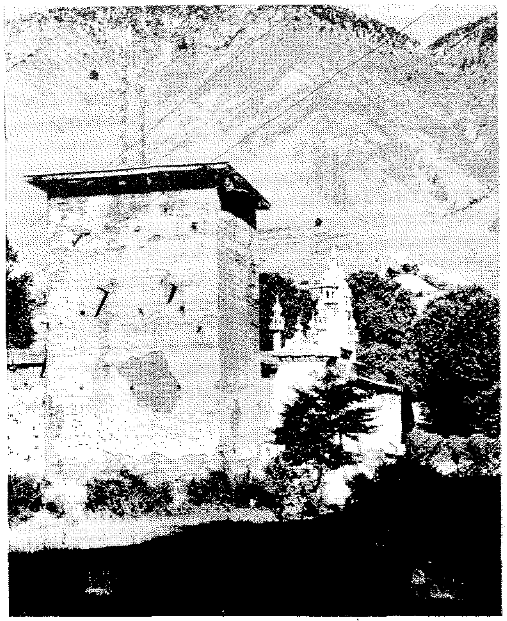
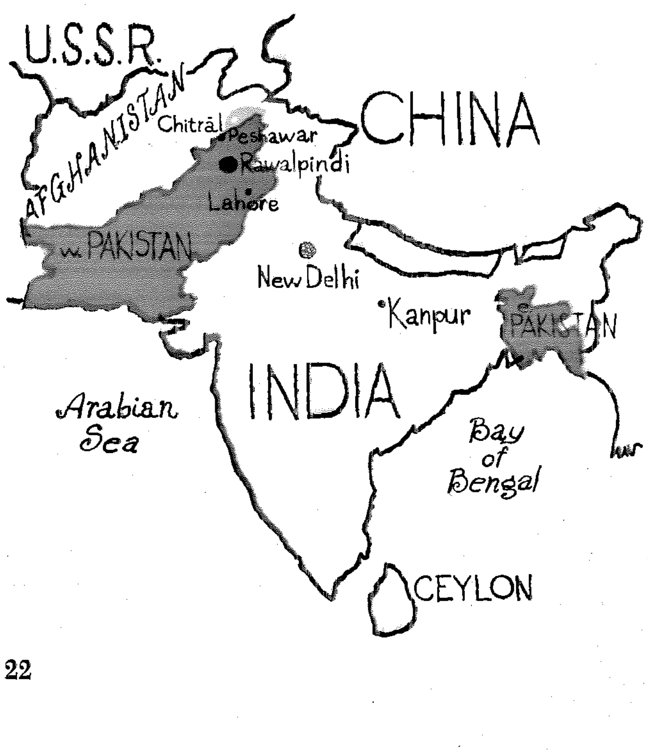


Chitral Revisited

by Robert Huttenback with Peter Fay

Early in 1895 Umra Khan, an ambitious Pathan ruler fishing in the troubled waters of succession controversy on India's northwest frontier, besieged 500 British troops under the command of George Robertson, MD, at Chitral, a princely state astride the route by which many British statesmen anticipated the Russian hordes would debouch out of central Asia. Robertson's men, who were mainly Sikhs and Kashmiris under British officers, held off the enemy for 46 days until the relief column arrived. The siege attracted almost as much attention in Britain as had Gordon's defense of Khartoum ten years before, and the story of Chitral entered the folk literature of the day as one of those edifying tales which once again proved that British phlegm and the strength of heart that God had reserved for the Anglo-Saxon race always triumphed in the end. In *The Relief of Chitral,* the Younghusband brothers wrote:



> .... The British forces came on triumphant; and once again in our fair island's story it was shown that British officers, even though they had not a single British soldier by them, and had only to trust to their own stout hearts and strong arms, and to the influence they could exercise over the men of subject races, and to the feeling of loyalty they could evoke from them, had been able to uphold the honour of the race; and the story of the defence and relief of Chitral will be handed down to posterity as one of the most brilliant chapters in the annals of Indian military history.

Some 70 years after these words were written, I was spending the summer searching the archives of India and Pakistan for materials dealing with Kashmir, the subject of a historical study I was writing. As Chitral had played an important role in the history of that state, I decided to visit it with my Caltech colleague Peter Fay. If Chitral contained no relevant records, at least I would gain that feeling for the area which is so vital for the writing of readable history.

The Younghusbands would no longer recognize the India of today. Gone is the British raj, so firmly

A history professor's research sometimes takes him farther afield than he ever intended to go.

in the seat of power in 1895 that no one seriously contemplated its demise. Gone too are most of the princely states, though in the part of the subcontinent that is now Pakistan a few are still preserved in some degree of autonomy. Chitral is one of these. But the siege is almost totally forgotten. No longer is Chitral considered a vital defensive position astride the route likely to bear invading Russian legions southward. Nevertheless we wanted to see the place.

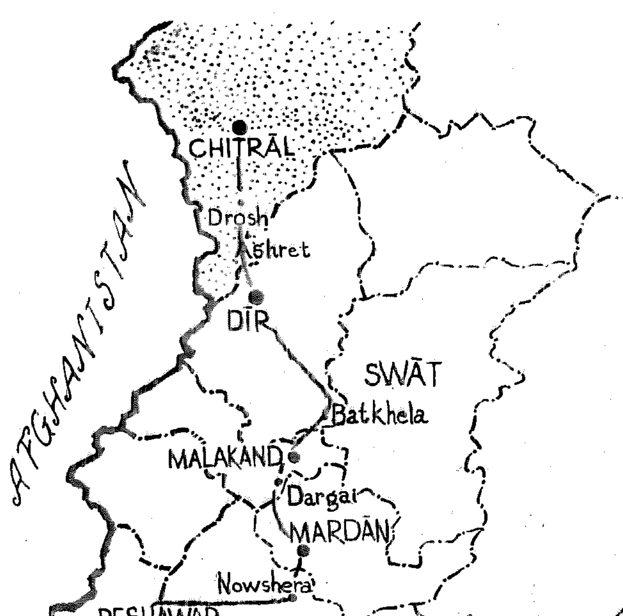
We left our families in Fay's bungalow in Kanpur, where he was on detached service from Caltech teaching at the Indian Institute of Technology. We obtained the necessary visas in New Delhi and, early in July, flew by way of Lahore and Rawalpindi to Peshawar.

In Peshawar, at the very limit of the great north Indian plain and from that circumstance the historic gateway to Afghanistan and the northwest frontier, we put up at Dean's Hotel and sought out the government tourist officer whose permission had to be obtained for any journeys to the northern regions. It was evening, but he obligingly reopened his office and issued the necessary permits.

Our problem was, however, how to get to Dir, capital of the princely state of that name, situated at the southern end of the Lowari Pass, and we solved it by reserving at the Khyber Express agency two seats on next morning's run to Swat, still another princely state which lies well to the southeast of Chitral but is approached by the same road from Peshawar. Edward Lear immortalized its ruler with:

> Who, or why, or which, or *what,*
> Is the Ahkond of Swat?
> Is he tall or short, or dark or fair?
> Does he sit on a stool or sofa or chair,
> or Squat,
> The Ahkond of Swat?

At eight on the morning of July 4 we took our seats in what proved to be an ordinary, somewhat battered American sedan. Our fellow passengers were a surly Pathan, a woman in a burkah (face covering), and the woman's husband. We had suitcases and bedrolls. They had at least the equivalent.



It wouldn't all fit in the trunk, and there was a good deal of arguing and shouting. In the end a second car was produced and we were off.

We did not, of course, head northwest into the low hills that almost touch Peshawar on that side and in which the Khyber Pass lies. Instead we turned east and drove for several dozen miles across the flat, irrigated Peshawar plain, past occasional sugar mills, through Nowshera and Mardan. On the far side of Mardan we left the plain at last and began to climb toward the Malakand Pass. The road, narrow but paved, wound back and forth up rocky and bitterly arid slopes. Occasionally we met a bus, and halfway up we came across one lying empty and deserted on its back just below the curve it hadn't negotiated.

At the top we passed between Beau Geste-style forts connected by crenellated walls. There were two lines of them along the heights, one facing north and the other south, for they had been built as much to bar the way to the plains behind us as to protect the gateway to Pathan tribal territory ahead. The Pathans are an independent and warlike people, and once over the Malakand Pass, at the Dargai Barrier where cars are halted and papers checked, the influence of the Pakistani government is greatly reduced, and tribal law prevails.

In Batkhela, a collection of shop stalls strung along both sides of the paved highway, we left the Khyber Express. It went on to Swat, but we had to turn left for Dir and Chitral. Westerners who tarry in this unlovely spot are still sufficiently rare to cause some stir. Several young boys adopted us at once. They seemed to have charge of a stall selling motor parts and quickly found us a couple of chairs and a small table, produced tea and *tanduri roti* (unleavened bread), and took an enthusiastic and distracting interest in our efforts to find a way of reaching Dir, still 70 miles away. As our Pushtu (the local language) wasn't much and our Hindustani little better, this took some time. In the end we found a bus—or rather, a truck with a bus body entirely filled with cross benches. On these benches sat a number of bearded men in the rough grey cotton pajamas which are the standard dress of the area. They were talking, laughing, and spitting out the window. Their tin trunks, boxes, bedrolls, livestock, and whatnot lay in a heap on the roof. We saw our bedrolls and incongruous airline suitcases to the same place, bought tickets for Dir at the deluxe rate of four rupees, eight annas (95 cents) each, and took our seats on the front bench beside the wheel. By then the bus was entirely full and obviously ready to start. But nothing happened, and nobody but us seemed impatient. Our fellow passengers joked and sang. It was our first lesson in the vast good humor of these frontier people and in their total lack of a sense of time.

"Gradually the country rose, the ridges became hills and even mountains, the appearance of rifles became less . . . . ."

We had left Peshawar at 8 a.m. It was now 2 p.m., and we had covered only 50 miles. To make matters worse, we suddenly discovered that we were on the wrong bus. But, actually, it was of no matter. We were shifted to another similar conveyance equally reluctant to get under way. Finally our driver approached—a natty chap with sparkling eyes and rakish mustache, dressed in the usual salwa and camise and wearing the furled-edge wool hat of the frontier. He carefully hung his pistol over the steering wheel and prepared to depart. A push got us under way, but after no more than ten feet we broke down—a pattern that was to continue for the eight hours it took us to go the 70 miles to Dir.

The Pathan country through which we drove at first was essentially foothill terrain—small, flat, stony valleys among ridges too low to support trees. The dirt and gravel road crossed washes, some of them wet. In one of them the bus stuck and had to be pushed. We passed little forts and were stopped at check posts manned by irregulars carrying rifles and cartridge belts. In fact, nearly every man we passed carried a rifle. At one of the clusters of stalls where the bus from time to time stopped for tea, we saw one fellow with a submachine gun. Women we rarely saw. The few we encountered turned their backs as we drove by.

Gradually the country rose, the ridges became hills and even mountains, the appearance of rifles became less. We were leaving Pathan country. But the bus wasn't emptying. On the contrary, it got fuller and fuller, until the roof carried almost as many passengers as the benches. Still they were continuingly amiable. One in particular adopted us; plied us with cucumbers and tea, shouting throughout, "Thik hai? Thik hai?" (Okay, is it?). As he seemed to be related to everyone we encountered, we dubbed him "Uncle Thik Hai."

We reached Dir a little after 10 p.m. It was pitch black. Our luggage was unceremoniously dumped in the road. Fortunately the bus driver took us in hand and led us several hundred yards down dark alleys to a large, two-story building which turned out to be a sort of caravanserai filled with tribesmen

Where snowdrifts block the road, passengers and porters carry the luggage over the 10,500-foot Lowari Pass.

and students in transit. We ate a greasy supper next to a table of West Germans—technicians of some sort on holiday from their jobs in West Pakistan—and went to bed by the light of a kerosene lamp in a little room that smelled of urine.

Bed meant spreading a bedroll over the mattress on the bedstead; but the bugs were not to be stopped by mere canvas, and by morning I was trying to sleep sitting bolt upright on the only chair. At first light we left and took a look at Dir. Despite a rushing river, it was a mean and ugly little town without a single building of consequence.

To reach the Chitral Valley from Dir, we had to cross the 10,500-foot Lowari Pass whose approaches began just beyond the town. There is a good gravelled road over the pass which is usually open by July. So it was with confidence that we rented space for ourselves and our luggage in a jeep already carrying about ten other persons. After an hour of climbing, the jeep stopped at a little village which turned out to be the end of the jeep line; for, though most of the snows had melted, hardpacked drifts as much as ten feet deep still covered parts of the road above us. It would be another week or two before the work of shoveling cuts through them would be completed and Chitral opened to the outside world.

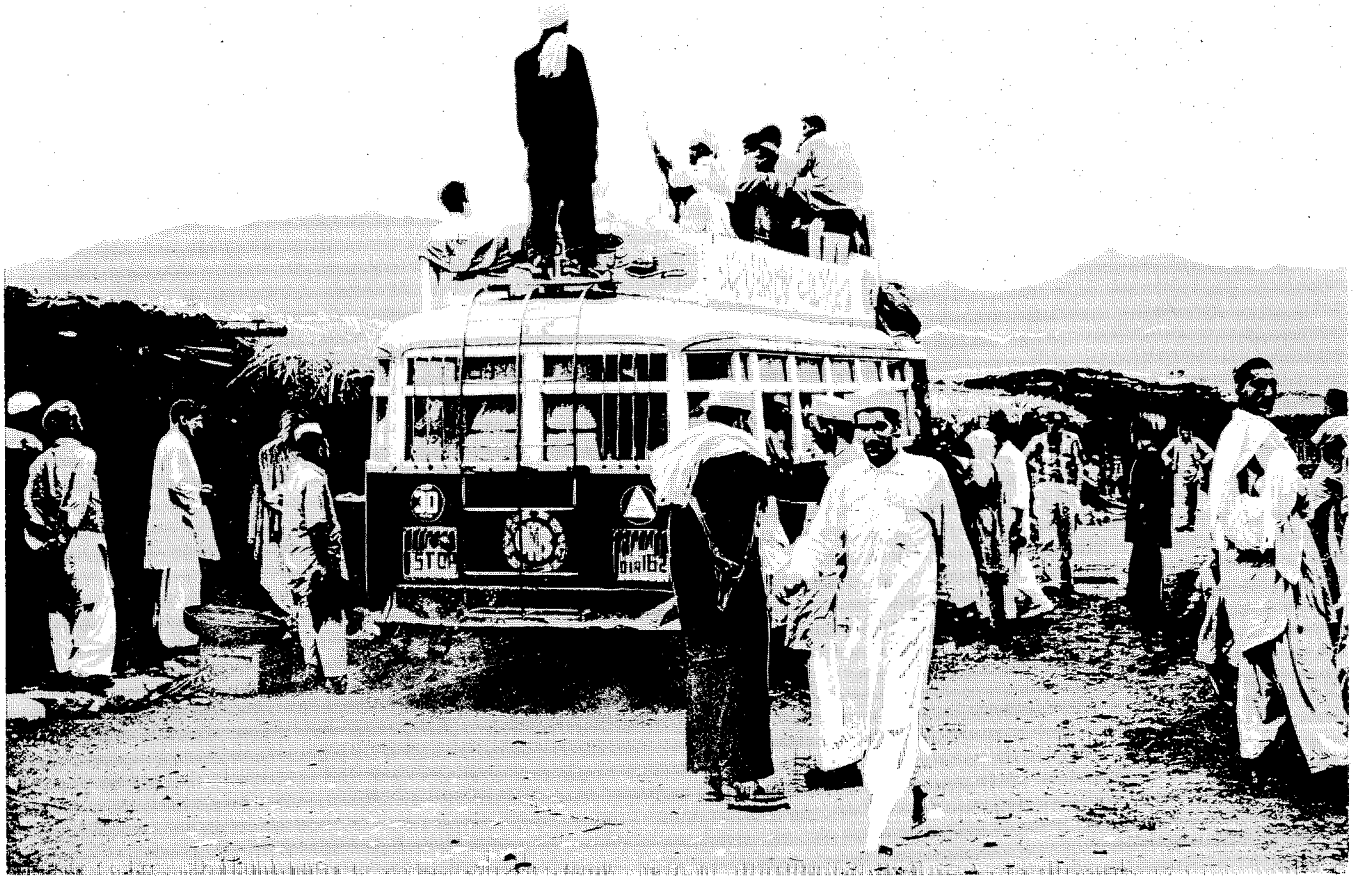
We were determined to proceed on foot. So, by the usual process of inquiry and advice—you ask in English, you ask in broken Hindustani, ten bystanders give you ten different answers in Pushtu—we hired two porters, and off we went.

The porters were soon out of sight—ahead of us, that is. It was a lovely walk, moderate grade, only occasional snow, a small stream below us to our left, and high up on the mountainside beyond it some interesting food for thought: the pieces of the last Pakistan International Airlines DC-3 which had tried to fly into Chitral.

About eleven we reached the top of the pass, an event we celebrated with the usual cup of tea from one of the "hótels" that welcome the weary traveller. The tea came in brand-new cups recently imported from China. A number of porters passed us carrying tea boxes containing miscellaneous goods going into the valley. Small mules carrying triple a human load went by on the same errand. They had a dozen miles to go before what they carried could be transferred back to jeeps or trucks. And so did we.

The downhill walk on the Chitral side was even pleasanter than the ascent from Dir had been. There were many more pines and in the distance, looking north, an alpine landscape very different from what we had seen in the lower, harsher, Pathan country.

We were overtaken by Uncle Thik Hai, with his nephew who was returning to his Chitral home for the summer after a year of teaching school at Pesh-



The "Dir Express" makes one of its numerous tea stops on the road through Pathan country from Dir to Ashret.

awar. Most of the people going north that day were going home on vacation after a winter's work somewhere in West Pakistan.

Down we went with Uncle and Nephew. Most Indian roads must have been much like this one in the early 19th century. The only modern touch, if you except our suitcases now far out of sight, was someone's transistor radio screeching popular music, and, at intervals, bad news from Vietnam in a perfect imitation of the BBC accent.

We reached Ashret and the once-more-negotiable road early in the afternoon, paid our porters the agreed price of 15 rupees ($3), and recovered our baggage. Only 40 miles lay between us and Chitral proper. Uncle negotiated a ride for us all and four or five other men on top of a loaded truck. About four, the driver, who looked rather like Gregory Peck, finished his tea, waved us all to our posts on the top of the tea boxes which entirely filled the little pre-war Chevy, and away we went.

The road wound first along the side of the valley of a tributary to the Chitral River, then of Chitral Valley itself. Below us, for the road kept well up the hillsides, were cultivated fields of barley and millet or rice, in places to which water could be brought from the river. From time to time we passed a tribal chieftain's fort. "Gregory" drove with enthusiasm and without brakes. We rode on the very top of the cargo, higher than the roof of his cab, hanging on to the tops of the tea boxes, each other, or air. But nobody lost his good humor. I was on the left side and had a splendid view of the river swaying far below. Fay crouched on the right, with an equally exciting prospect of onrushing, overhanging rock.

From time to time something went wrong with the truck. Or so Gregory evidently decided, for he would stop, get out, and go under the hood. Someone always shoved a large rock under one of the rear wheels just in case.

About dusk we reached Drosh, the second town of the state of Chitral. Like most towns in this part of the world, it consists almost entirely of stalls with sod roofs. It is also, however, the headquarters of a first-rate military unit, the Chitral Scouts. Once raised as local levies by the British, the Scouts now form a part of the regular army of Pakistan. Chitralis are not as martial as Pathans. But their Scouts looked much more military, at least in a spit-and-polish way, than the irregulars we had seen the previous day. We observed officers and men playing soccer near their immaculate encampment and wandering among the stalls in starched khaki shorts of British cut. No baggy pajamas for them.

After the usual delay for tea and the checking of papers, on we went again—Gregory driving faster than ever with the smell of home in his nostrils. We thought sure to be in Chitral by nightfall. Unfortunately there were delays at any tributary of the river that required a bridge. The bridge was invariably of the suspension type and so rickety, hung from cables so mean, that everything in the truck had to be taken out on one side and put back in on the other. Coolies stationed at each bridge did the carrying. Passengers took advantage of the interruption to pray, sleep, or relieve themselves.

Dusk caught us still 25 miles from the promised land. To our utter astonishment and apparently no one else's, as the sun went down we pulled up at a cluster of huts in fields near the river's edge and everyone climbed down. We saw no profit in arguing. By silently pulling the rank of our foreignness, we obtained, through Gregory, two charpoys (wooden cots with rope webbing). These we heaved up on the flat, sod roof of one of the houses.

The night was cool and pleasant. As we rested and drank from a bottle of Scotch secreted in one of the bedrolls, the moon rose over the mountains revealing a lovely muted picture of river, mountains, and cultivated fields. Supper consisted of two great plates of rice cooked in what surely must have been axle grease with an egg on top of each. Soon the exertions of the day caught up with us, and we slept on our rooftop surrounded by comrades who had more or less dropped where they had a moment before stood.

At five the next morning we were again on our way. The night halt had not improved the disposition of our conveyance, and repair stops were more frequent than ever. But there was a compensation. We began to see, at first occasionally and then almost continuously, a mountain. Not an ordinary mountain, but over 25,000 feet of one, conspicuous in its perpetual ice and snow, massive, towering high above everything around it. At every turn in the valley, which grew somewhat wider and gentler as we went north, we expected to confront it base-to-summit. At every turn it was as far away. It lay in fact almost 40 miles beyond Chitral. Lambent in the early morning sun, Tirich Mir fully answered its description as the most imposing mountain in the world.

At 11 a.m. we crossed the final bridge and at last entered the town of Chitral. We found it, despite the beauty of its setting, a rather poor place. The valley, twisting another 200 miles northwards to the Afghan border, is narrow, and there is little arable land. The town consists largely of sod roofed stalls, although the Scouts' camp is more substantial. Near the Mastuj River there are some lovely green fields dotted with huge chinar trees. The old fort still stands on the banks of the river, much as Robertson left it in 1895. No one today knows of its history. Everywhere in the town there is rushing water in streams, channels, and irrigation ditches.

We moved into the Government Rest House. As usual it was clean and comfortable, with a lovely garden. After a few moments the lieutenant of the local police arrived to register our papers. He insisted that we take his picture, and before departing stuck out his tongue to show how ill he was and that he needed medication. It is an oft repeated myth that the people of these northern mountains enjoy boundless good health and live to a very ripe old age. Almost the opposite is true. They suffer from a multitude of diseases and from chronic malnutrition.

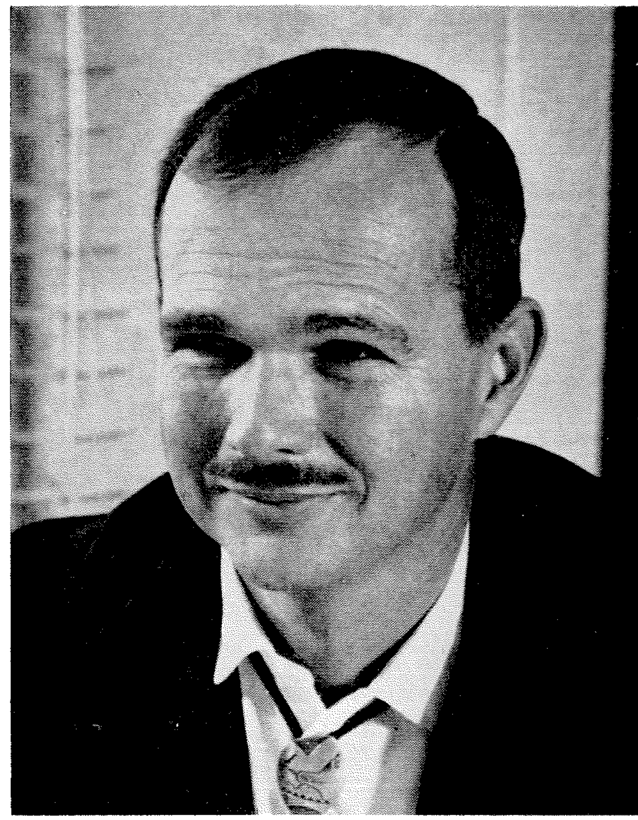
"Supper consisted of two great plates of rice cooked in what surely must have been axle grease with an egg on top of each."

We paid a courtesy call on the Assistant Political Agent, who was the Pakistan government officer in charge of the state. Mohamad Tariq was a sophisticated young man with a law degree from Lincoln's Inn and experience in the USA. He had just received orders to go to Oxford for further study and could not have been more delighted. He did not know whether he could have stood another winter in Chitral. At the first snow the road closes and the telegraph line ceases to operate. Only the radio provides sporadic contact with the outside world. And, he said, there was no one to talk to in Chitral.

Our stay in Chitral itself lasted scarcely more than a day. I found no records, no papers, but was left with an indelible impression of a land of which Robertson has left us this memorable description:

> The dominant note of Chitral is bigness combined with desolation; vast silent mountains cloaked in eternal snow, wild, glacier-born torrents, cruel precipices, and pastureless hillsides where the ibex and the markhor find a precarious subsistence. It takes time for the mind to to recover from the depression which the stillness and melancholy of the giant landscape at first compel. All colour is purged away by the sun-glare; and no birds sing. Life is represented by great eagles and vultures, circling slowly or poised aloft, and by the straight flight of the hawk . . . .

THE MONTH AT CALTECH



Eugene M. Shoemaker

INTERNATIONAL HONORS

Max Delbrück, Caltech professor of biology, recently received two European honors—the Gregor Mendel Medal from the German Academy of Natural Scientists, Leopoldina, and membership in the Royal Society of London.

Dr. Delbrück notes that there was quite a contrast in the ceremonies in Halle, East Germany, and in London. "One was marked by an academic procession, classical music, and speeches laden with politics . . . the other by a tea, a brief formula spoken by a lord, and the signing of a venerable book."

Dr. Delbrück is the first recipient of the German medal. The creation of the award is notable because the Academy's membership represents in part a geographic-political area where, until very recently, genetics and Mendel have been considered "decadent capitalist theory."

The Royal Society, Britain's top scientific body, which dates from the time of Charles II and claims Sir Isaac Newton as one of its early presidents, elects only four foreign members a year. Other Caltech faculty who have been honored by membership include Richard Feynman and the late Theodore von Kármán, who is reported to have especially cherished his Royal Society membership because it was the only honor he had that wasn't also held by Robert Millikan.

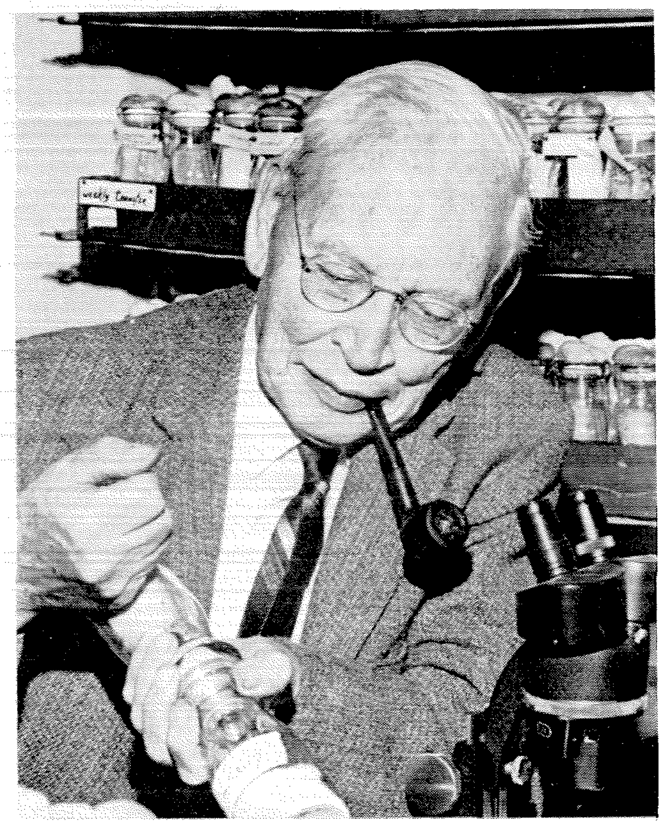
DIVISION CHAIRMAN—1969

Eugene M. Shoemaker, chief scientist of the United States Geological Survey Center of Astrogeology in Flagstaff, Arizona, and a Caltech research associate in astrogeology, has been named chairman of Caltech's division of geological sciences, effective January 1, 1969. Clarence Allen, professor of geology and geophysics, will continue as acting chairman of the division through 1968.

Dr. Shoemaker began his association with Caltech in 1943. He received his BS here in 1947 and his MS in 1948. His PhD came from Princeton University in 1960.

Early in his career he did geological studies of the Colorado plateau country, and in 1957 he began to specialize in the study of impact structures and the mechanisms of meteorite impact processes. In 1963 he organized the Manned Space Sciences Division of NASA and established the United States Geological Survey Observatory in Flagstaff. Two years later he organized the Astrogeology Center there.

Dr. Shoemaker served as an investigator of the television picture experiment for the Ranger spacecraft series and is now principal investigator of both the Surveyor moon television experiment and the geological field investigations of the Apollo lunar landing program. All in all, a busy man.



Alfred H. Sturtevant

THE NATIONAL MEDAL OF SCIENCE

Alfred H. Sturtevant, Caltech's Thomas Hunt Morgan Professor of Biology, Emeritus, has been named a recipient of the President's National Medal of Science for 1967—the nation's highest government award for distinguished achievement in science and engineering. He will receive the honor in ceremonies at the White House in February, along with 11 other U.S. men outstanding in their various disciplines of science and engineering.

Dr. Sturtevant, whose major contributions have been in the field of genetics, is the second Caltech faculty member to receive the medal. The award was established by an Act of Congress, and Caltech's Theodore von Kármán received the first National Medal of Science from John F. Kennedy in 1963.

Dr. Sturtevant came to Caltech when the biology division was founded in 1928. He became professor emeritus in 1962.

MORE SPACE IN THE LIBRARY

An extensive collection of published material on space technology, astronomy, and science fiction has been presented to Caltech's Millikan Library by the widow of Alvin W. Kunke. The Kunke Space Archives, which comprise one of the most comprehensive collections ever to have been assembled by an individual, include a wide range of material, beginning with very early imaginative works attributed to Cyrano de Bergerac, Bishop Godwin, and Johannes Kepler. The collection also contains original publications by writers who entertained fantasies of space exploration long before there was a profession devoted to rockets or space flight. There are historical treatises on astronomy, ancient astronomical maps, and some scare copies of *Pacific Rockets*, a journal of the Pacific Rocket Society, an early group of experimentalists based in South Pasadena. The collection is in the humanities and social sciences division of the library.

SECRETARY OF THE BOARD

Theodore C. Combs has been named secretary of the Caltech board of trustees, succeeding James N. Ewart who retired January 1 this year. Mr. Combs, who graduated from Caltech in 1927, joined the Institute development staff in 1964 as associate director of corporate relations and has been director of alumni relations in the development division since 1966. Mr. Ewart served as director of personnel at Caltech from 1946 to 1964 and as secretary of the board from 1964 until his retirement.

HONORS AND AWARDS

Frederick C. Lindvall, chairman of Caltech's division of engineering and applied science, has been named a fellow of the American Society of Mechanical Engineers, an honor reserved for members of more than 25 years standing who have made significant contributions in their profession.

Caltech's Beckman Auditorium has received an Esther Award from the weekly newspaper, the *California Jewish Voice*, in recognition of outstanding programming. The award was presented to J. Kent Clark, Caltech professor of English, by Henry Roth, music editor of the paper, acknowledging the concert of soprano Shirley Verrett as the outstanding voice recital in the Los Angeles area last season.

Aron Kuppermann, Caltech professor of chemical physics, has been awarded a National Science Foundation senior postdoctoral fellowship to pursue research on the dynamics of molecular collisions. He will spend a year studying at the Weizmann Institute of Science in Behovoth, Israel, and at the Institute for Atomic and Molecular Physics in Amsterdam, beginning in September 1968.

H. Russell Bintzer, vice president for development at Caltech, has been appointed to a four-year term with the Community Redevelopment Agency by the Board of Directors of the City of Pasadena.

continued on page 30

"Dear Papa,
I will be a good boy. I will save my money and buy food for my dog and give some money to the missionaries.
Your little boy, Robbie."

This note, written by four-year-old Robert A. Millikan in 1873, is among the memorabilia that were placed in the cornerstone of the new Caltech library, named in his honor, at ceremonies on December 6. Other possessions belonging to the Caltech physicist which were placed in the cornerstone cache were a pair of his spectacles, a handwritten report card from Macquoketa High School in Iowa, two poems written to him on his 85th birthday by his wife and son, and some of his most significant writings and publishings.

Lee A. DuBridge, president of Caltech, and Arnold O. Beckman, chairman of the board of trustees, officiated at the ceremonies attended by the library donor Seeley Mudd and community leaders and guests of the Institute. The occasion was the latest in a long line of library "occasions," which began in May 1965 with an interhouse tree-chopping contest run by Caltech undergraduates to clear the site for the then prospective library. Other occasions included the ground-breaking ceremonies that same month, and another cornerstone-laying a year ago this month. That pseudo-ceremony was conducted by pranksters who, in the dark of the night, put the cornerstone in upside down.

SAVE STAR TREK

Although the hallmark of today's college campus is protest, Caltech students have been distinguished by their indifference to the causes that convulse other campuses into rallies and marches. This month, however, this dispassion came to an end.

A CAUSE emerged with which Teckers could identify, and they marched—200-strong and armed with torches and banners—on the NBC television studios in Burbank to present a petition signed by 600 students who decry the rumored cancellation of the program "Star Trek."

Now the ball is rolling, and students are considering another protest—this one against bad reporting. The *Los Angeles Times* reported that the Caltech demonstrators carried signs for "Dr. Benjamin Spock." As any "Star Trek" fan knows, it is *Mr.* Spock, who is chief science engineer of the United Space Ship Enterprise.

Caltech students and sympathizers rally at NBC studios to save Star Trek.

Psychology professor John Weir meets with students in the experimental classroom.

ROOM FOR IMPROVEMENT

Human subjects are rarely used in experiments at Caltech. Yet there is definitely human involvement in a special study being conducted by John Weir, Caltech professor of psychology, for which he has established what he calls an *experimental classroom*. His purpose is to experiment with different physical settings for a classroom and discover any direct relationships between a student's classroom environment and his attitudes, opinions, and learning ability. This information, with some interpretation by Dr. Weir, will then be handed over to Caltech's consulting architects, Robert E. Alexander & Associates, with the hope that some improvements can be incorporated into the classrooms of new buildings.

Dr. Weir started with a standard classroom in Mudd Laboratory and, through the use of vibrant colors, draped windows, and special floor coverings, has turned it into a totally new environment for learning. He is not the only professor who uses the room, however. There are currently classes in logic, math, English, and biology, also.

The most obvious difference in this room is felt with the first step onto the lush gold carpeting that not only flows underfoot but creeps 36 inches up the walls. The walls are painted with several colors, which will be changed periodically according to student response. Adjustable lighting, a lowered ceiling of alternating orange and yellow panels, and *optional* chairs complete the feeling of informality; and the hope is that students will pick up more in this room than lint off the carpet.

Dr. Weir's project is in the infant stage, and he is still distributing questionnaires about the new room to his students. But when all the results are in, this study may help students eventually to escape the clinical, traditional classroom.

AUFS RETURNS

The first of four American Universities Field Staff lecturers scheduled to visit the campus during the winter quarter arrived on campus January 9. James Rowe, who is returning from a study period in Brazil, will spend 10 days in lectures and discussions with Caltech students. Roy Lockheimer, a specialist in Japanese politics and history, will be on campus from January 23 to February 1; Charles Gallagher, authority on North Africa and Islam, from February 13 to February 22; and Edward A. Bayne, who has been to Israel since his visit to Caltech in October, from February 27 to March 7. The AUFS, sponsored by Caltech and 11 other colleges and universities, sends representatives to specific areas to study and report on current conditions.

VISITOR FROM OUTER SPACE

Gerald Wasserburg, the Colomera meteorite, and Hermogenes Sanz.

A 290-pound meteorite from outer space arrived at Caltech last month, via Spain, for a ten-month period of research. The object of the research is the 4.6 million-year-old iron Colomera meteorite discovered near Granada, Spain, in 1912 and taken to the National Museum of Natural Science in Madrid. There it remained until last December when the museum permitted it to be shipped to Pasadena, via air freight, to be studied for information it can reveal about its formation and possible alteration.

Caltech's Gerald Wasserburg, professor of geology and geophysics, Donald Burnett, assistant professor of nuclear geochemistry, and Hermogenes Sanz of the Spanish National Commission for Space Research and the Spanish Atomic Agency will conduct the research in a project supported by the National Science Foundation and NASA.

When the Caltech team of Burnett and Wasserburg was doing research on a number of iron meteorites last year, Dr. Wasserburg visited the National Museum of Science in Washington, D.C., where he found a small piece of Colomera that the museum has owned for a number of years. Dr. Wasserburg requested and received pieces of it for study in his Caltech laboratory. He and Dr. Burnett found that their analyses of Colomera did not fall into the regular pattern that other iron meteorite analyses did—a pattern which usually makes it possible to calculate the time of a meteorite's formation.

Because of the unusual nature of the Colomera results, the men wanted an opportunity to dig deep inside the meteorite body and to compare analyses with those they had made from the outer fragments. The techniques for carrying out this type of experiment exist in only a few places in the world.

The Caltech men will slice the meteorite, taking sample crystals of silicate from it. The initial experiments will investigate the isotopes of rubidium and strontium using a new computerized mass spectrometer developed by Dr. Wasserburg, which will determine the exact balance between radioactive rubidium-87 and its strontium-87 daughter. This information will indicate conclusively whether this meteorite has experienced serious alteration since its formation. Such alteration could be caused by heating or by collision of the meteorite with other objects in space prior to falling on the earth.

When the experiments are finished in about eight months, Dr. Sanz will return to Spain with the main mass of the meteorite. Then Colomera will again take up residence in the National Museum, having played an important role in the acquisition of knowledge about the creation of our solar system.

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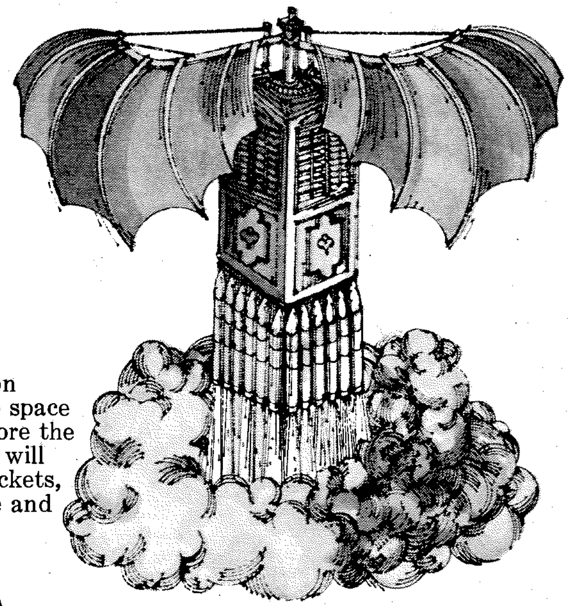
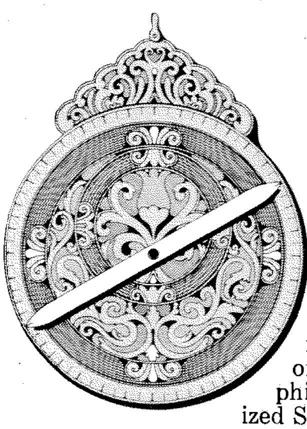
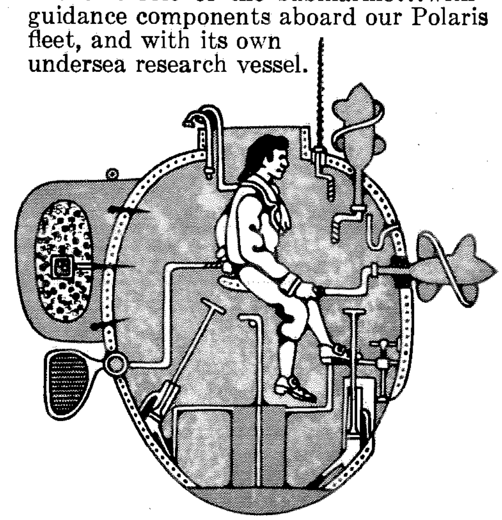


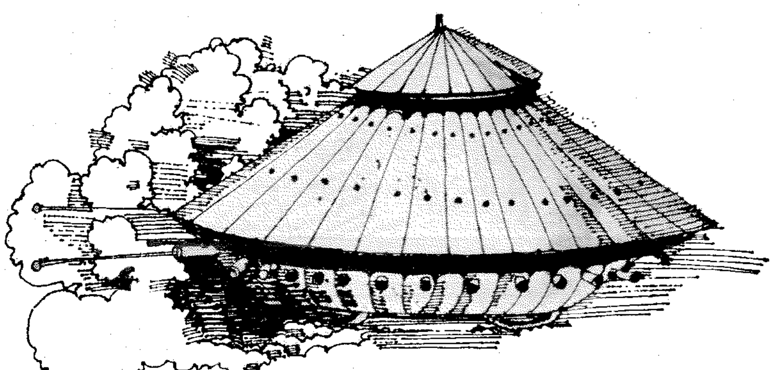


17th-Century Space Flight. Cyrano de Bergerac's science fiction fantasy about a box propelled into space by rockets came close to fact. Before the end of this decade, Apollo and LM will indeed be thrust to the moon by rockets, guided by AC Electronics guidance and navigation systems.

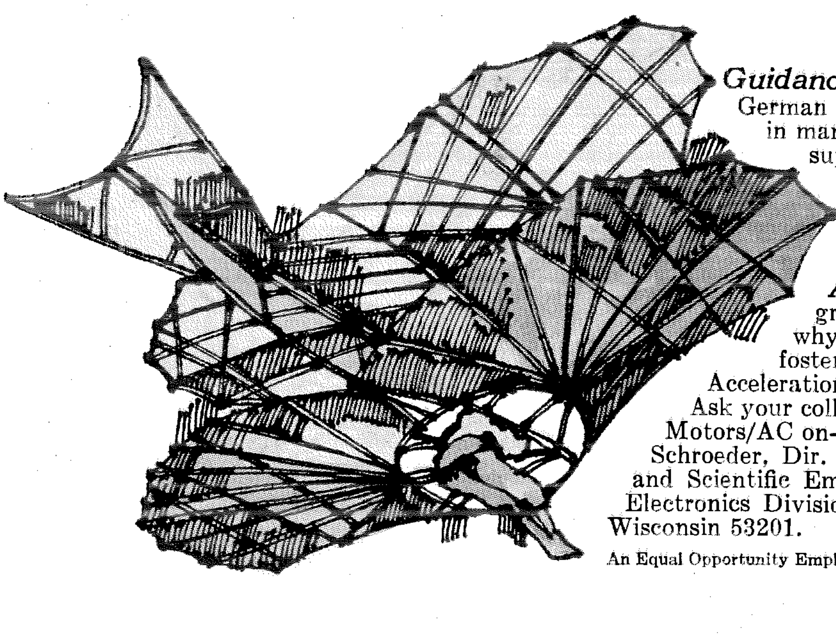
Navigation, Second-Century B.C. Hipparchus's second-century astrolabe was used for celestial navigation until the mid-18th century. Today, ships still depend on stars for guidance . . . through such sophisticated help as AC Electronics' computerized Ships' Self-Contained Navigation System.

Turtle vs. Eagle. In 1776, the American "Turtle" attacked the British flagship "Eagle" in the first wartime submarine action in history. Today, AC Electronics contributes to both the defensive and the scientific role of the submarine...with guidance components aboard our Polaris fleet, and with its own undersea research vessel.





Leonardo's Tank. Leonardo da Vinci was one of the first to envision the use of tanks in warfare. Contributing to the advanced state-of-the-art in tanks, today, is AC Electronics, with a computerized fire-control system for military land vehicles.



Guidance Gets a Lift. Otto Lilienthal, 19th-century German glider, proved that the future of flight lay in man's ability to guide the aircraft. Tomorrow's superjets will be guided inertially . . . by systems like AC Electronics' Carousel IV, chosen for the Boeing 747.

At AC Electronics we believe every great achievement starts with an idea. That's why we put a premium on creativity, and foster it through such innovations as our Career Acceleration Program which lets you learn as you work. Ask your college placement officer about a General Motors/AC on-campus interview. Or write: Mr. R. W. Schroeder, Dir. of Professional and Scientific Employment, AC Electronics Division, Milwaukee, Wisconsin 53201.

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- Components & Materials Engineers
- Circuit Design Engineers
- Product Design Engineers

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Hughes Aerospace Divisions
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CAMPUS INTERVIEWS

February 14

Contact College Placement Office to arrange interview appointment.

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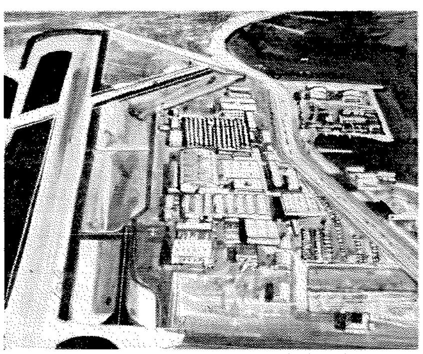
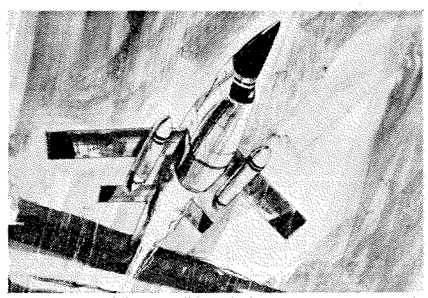
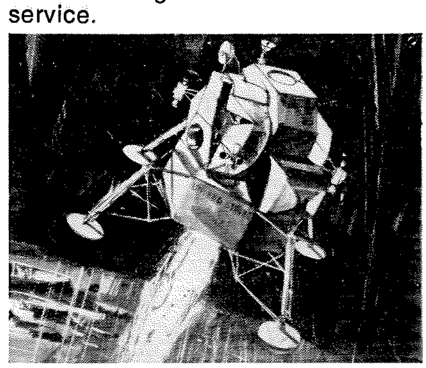
We mean that a pioneer aerospace company still headed by the man who founded it 45 years ago has *got* to be a company that cares about its people. T. Claude Ryan, founder and chairman, is still at the office every day. To him, Ryan employees are friends. Old ones and new ones alike. Ryan headquarters, combining engineering and manufacturing facilities, are on the shores of San Diego bay, where it all started in 1922.



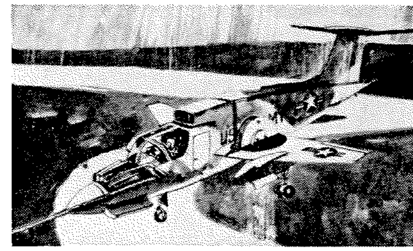
We mean that a company so rooted in aviation history is bound to be a leader in vitally important defense/space programs. The outgrowth of the original Ryan Airlines, Inc., that built the "Spirit of St. Louis" in 60 days from a standing start will always be ready to accept impossible challenges. And ready to listen to young men of vision who can dream up answers to those challenges. Ideas are given a chance at Ryan. So are the men who come up with them.



We mean that a company which led the world in the conception and development of jet-powered target drones is the kind of company where daring and untried ideas come to life. Over 3,000 Ryan Firebees, the most versatile aerial targets ever conceived, are in use with all three branches of our armed forces, helping to train our defenses against any airborne threat. A super-sophisticated, supersonic Firebee II will soon be flight tested and enter service.



We mean that a company whose heart has always been in the wild blue yonder would just naturally be there when man reached for the stars; that the products of its scientists, engineers and technicians would naturally play a key role in our race for space. Ryan landing radar systems made possible the first soft landing on the moon. And an advanced Ryan system will assure a soft landing for the first manned lunar visit. The men at Ryan already have their eyes on the space beyond the moon.



We mean that a company made up of men who taught themselves to fly straight up, while others said it couldn't be done, is the sort of place that puts no strings on a man's imagination. Or barriers in the way of way-out thinking. For over twenty years Ryan has been amassing an unmatched fund of technology in vertical and short take off and landing (V/STOL) aircraft. The list of accomplishments is long: Dragonfly, 1940. Vertijet, 1957. Vertiplane, 1959. The present day XC-142A tilt-wing and the XV-5A Vertifan. Ryan products can fly straight up. So can the men who work there.

We mean that a company with a strong and capable management—whose business success has led to majority ownership of large related companies — is the kind of concern that can match challenges with permanent opportunities. Ryan Aeronautical is majority owner of Continental Motors Corporation and its subsidiaries, suppliers of primary power for both piston and jet aircraft and agricultural, military, marine and industrial equipment. There is nothing provincial about Ryan. Including subsidiaries, it operates 16 manufacturing facilities in the USA and Canada.

We mean, also, that *San Diego* is a better place to work—because it's a better place to *live*. It's the surfing, sailing, deep-sea fishing and golfing capital of the country. It's clean, uncrowded and friendly and you can lead the good life year 'round. Its great universities make education one of its largest industries. Ryan is an important and respected member of this dynamic community . . . a community on the move.

RYAN

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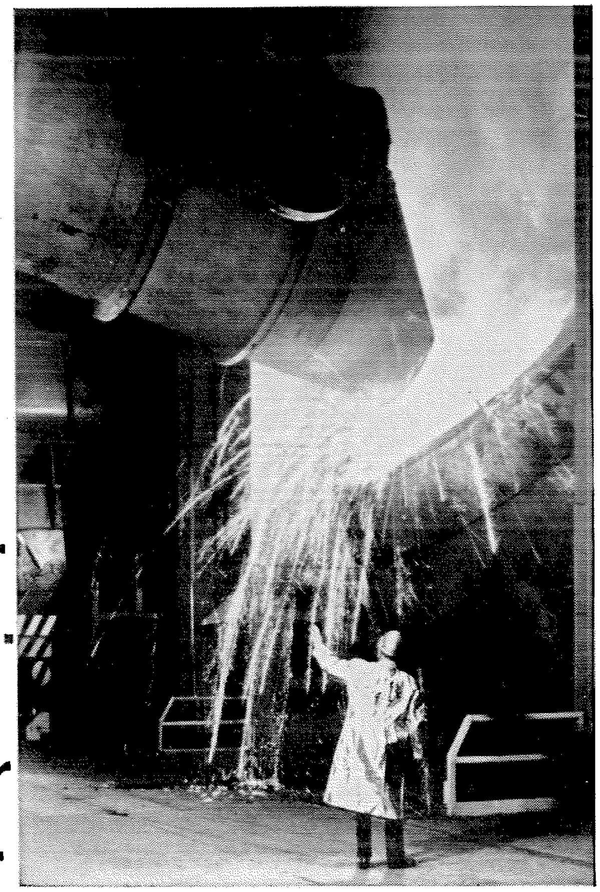
This is what we mean when we say, "Ryan is a better place to work." The 4,500 men and women now at Ryan know it is. And they invite your inquiry. Check with your placement office for our campus visit, or write to Mr. Harlow McGeath, Ryan Aeronautical Company, Lindbergh Field, San Diego, Calif. 92112.



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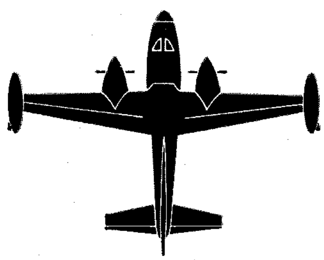
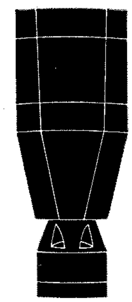
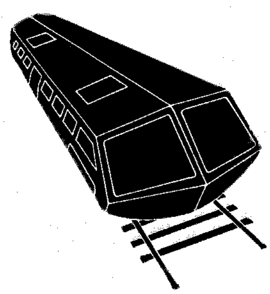


Turboprop engines for business and military aircraft

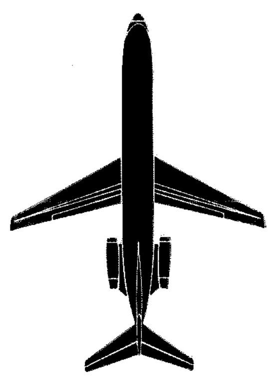


Nuclear turbo-electric power systems for space

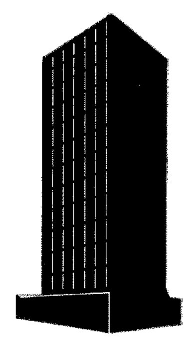
Valves and control systems for space vehicle boosters



Gas turbine propulsion systems for high-speed rail cars



Onboard turbines and control systems for jetliners



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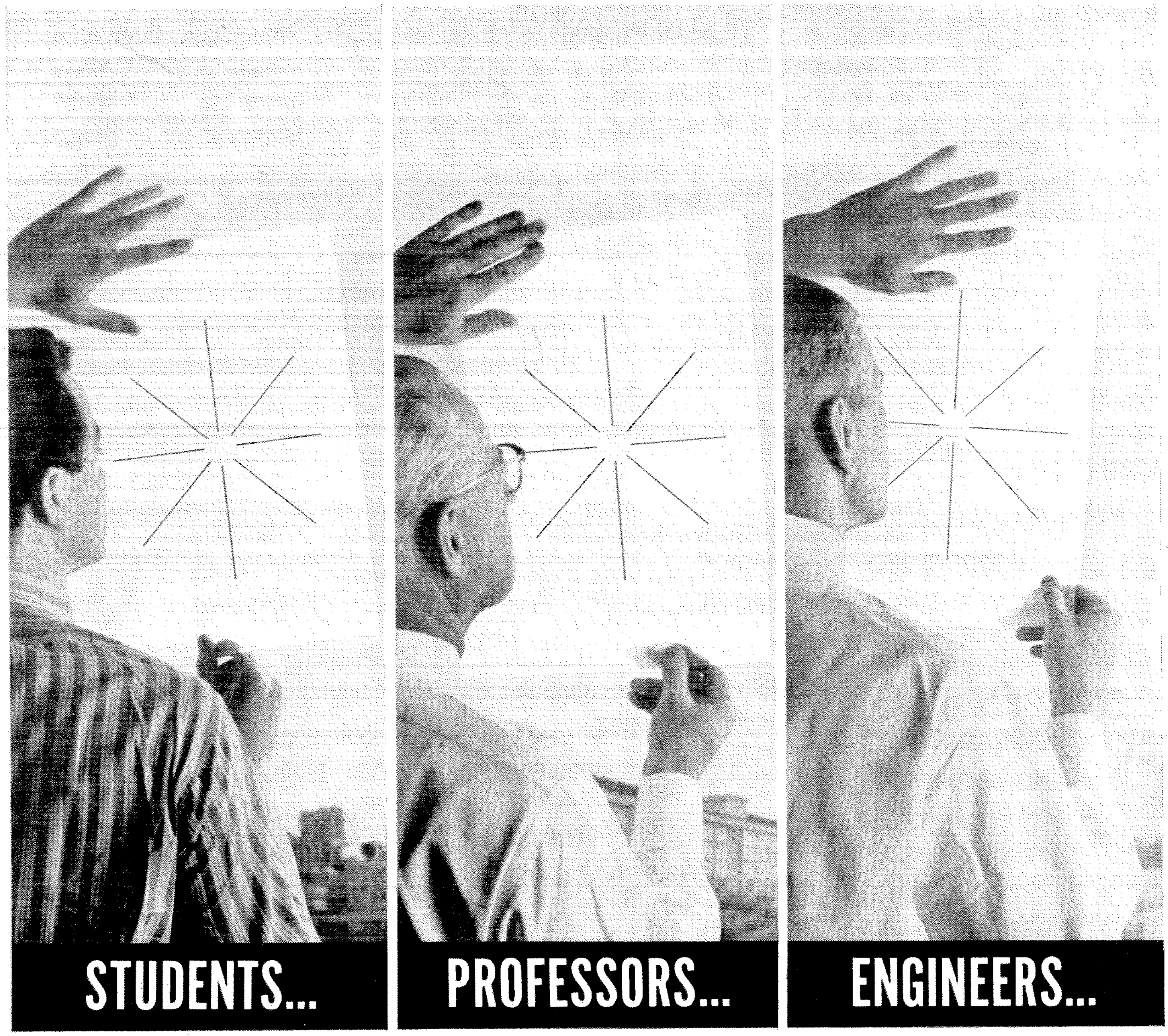

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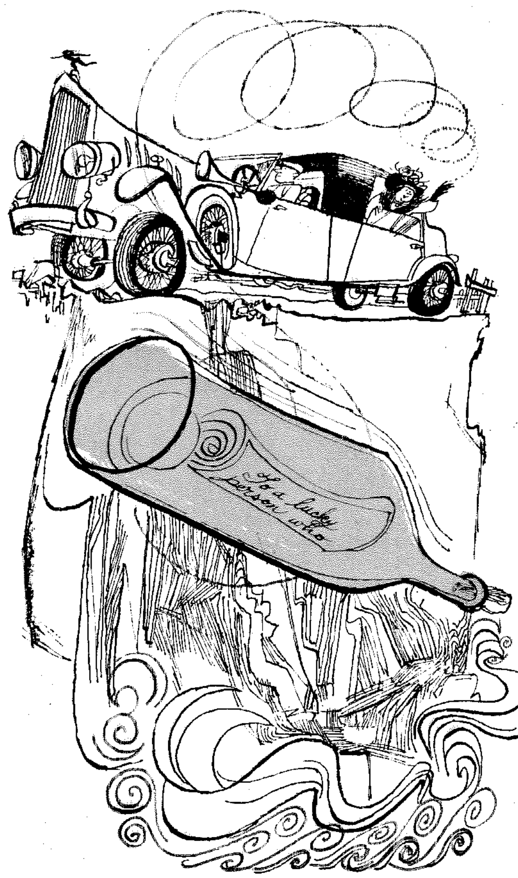

*Mrs. Alexander wrote a will,
put it in a bottle,
and tossed it in the ocean.
It said, in part,
"... to avoid confusion
I leave my entire estate
to the lucky person
who finds this bottle
and my attorney
to share and share alike."*

Not only was Mrs. Alexander wishy-washy, so were the tides. By the time her bottle had washed ashore, eleven years later, the courts had some questions.

You may have some questions about providing for Caltech in your will or through a life income trust or annuity. If so, don't be wishy-washy, contact:

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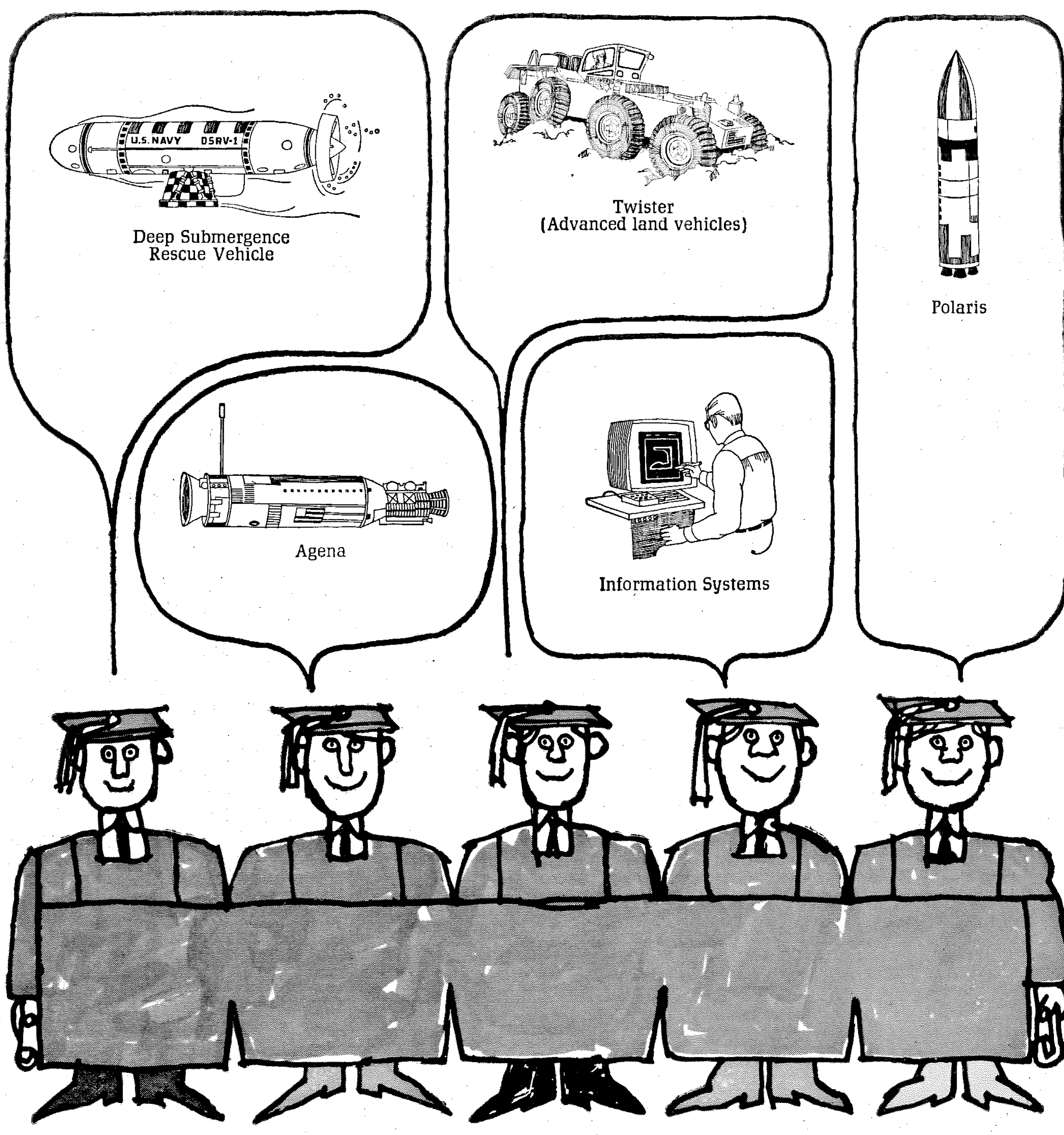

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". . . Accident in the left hand lane of the Queens-Midtown access ramp. Right lanes moving slowly. Fifteen minute delay at the Brooklyn Battery Tunnel. Lincoln Tunnel backed up to the Jersey Turnpike. Extensive delays on Route 46 in the Ft. Lee area. That's the traffic picture for now, Bob."

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