Engineering and Science

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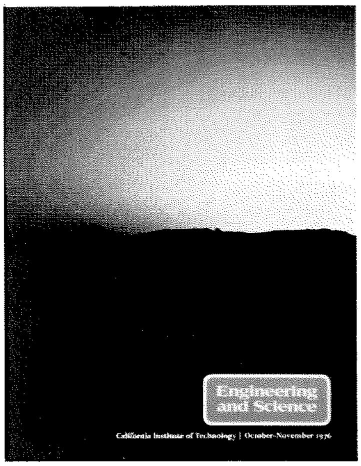
In This Issue



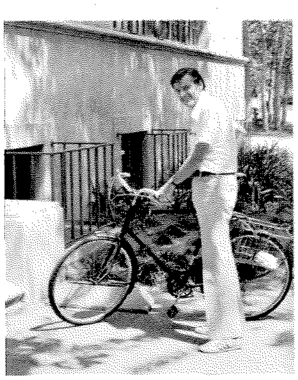
At Sundown

On the cover — the Martian sunset over Chryse Plain, photographed on August 20 by Viking 1. The camera began scanning the scene from the left shortly after the sun had dipped below the horizon. By the time the picture was completed the sun had dropped nearly 3 degrees below the horizon. About 5 degrees above the sharp line of the horizon the sky color grades from blue to red. This color variation is explained by a combination of scattering and absorption of sunlight by atmospheric particles.

Several more spectacular views of Mars taken by the Viking landers appear in "Mars — Up Close" on page 16.

Energy

Conservation of energy is so important these days that it is no surprise to find Robert H. Cannon Jr., chairman of Caltech's division of engineering and applied science, riding a bicycle to the campus — and pointing out that technology can make major contributions to solving the energy problem. Cannon is not only in an administrative position to be up on the latest in engineering research, he's done a lot of it himself — in such fields as the dynamics of rigid bodies and fluids, hydrofoil boats, automatic flight and space vehicle control, gyroscopes, and inertial guidance. He has served on the faculties of Stanford and MIT and has led research teams at the Autonetics Division of North American Aviation and at the Bendix Aviation Research Labs.



Cannon

From 1970 to 1974 Cannon was U.S. assistant secretary of transportation for systems development and technology. It was under his leadership that DOT established the Transportation Systems Center at Cambridge, Massachusetts, with projects that included studies of a new air traffic control system, high-speed ground vehicles, automated control of highway and ship traffic, aircraft and truck noise abatement, and stringent control of pollution of the stratosphere and of the oceans.

Recently Cannon put it all together in a Watson Lecture at Beckman Auditorium. "Smart Energy: A Key Role for Computers" on page 9 is adapted from that talk.

More Energy

The general session speaker for Caltech's 39th Alumni Seminar Day was Robert C. Seamans Jr., administrator for the U.S. Energy Research and Development Administration (ERDA). Introducing him, Caltech alumnus Carel Otte (MS '50, PhD '54) said in part: "Our speaker was born and raised in Massachusetts and went to school there, receiving a BS in engineering at Harvard, and his MS and PhD from MIT. We will forgive him for that.

"As an indication of the diversity of his interests, he serves on the Board of Trustees of the National Geographic Society; he has worked in industry for RCA; and he worked before that for NASA — both as associate and as deputy administrator. He's been a professor at MIT, was Secretary of the Air Force from 1969 to 1973, and has been president of the National Academy of Engineering.

"Since December 1974 he has been the administrator for ERDA, which combines the former energy research and development programs of the AEC, the Department of the Interior, and the National Science Foundation, and which also has the responsibility for nuclear weapons research, development, and production. We welcome Dr. Seamans to talk on 'Energy Realities for Tomorrow.'"

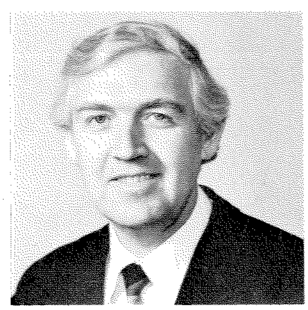
On page 13, *E&S* presents excerpts from that talk.

Groundwork

More than a hundred scientists and engineers from all over the world came to Caltech not long ago to attend a workshop on the use of centrifuges to test models of man-made and natural structures. The organizer of the meeting (which was jointly sponsored by Caltech and the National Science Foundation) was Ronald F. Scott, professor of civil engineering. An adaptation of Scott's lighthearted introduction to the proceedings, "Centrifuges in the Earth Sciences: A Revolutionary Idea," appears on page 18.

Centrifuges are an interest of Scott's because of their possible applications to research in his specialty — the mechanics of deformation and yielding in soils, which he has studied in almost every earthly condition and location — frozen, thawing, shaken by earthquakes, and on the ocean bottom, for example. Though he hasn't made any trips into space, he's also knowledgeable about extraterrestrial soils. He was principal investigator on lunar soil properties for the Surveyor spacecraft, and a member of the soil mechanics team for the Apollo manned lunar missions. Currently, he is a member of the physical properties team for the Viking missions to Mars.

Scott, a native of London, England, was educated at Glasgow University in Scotland and at MIT, taking his ScD there in 1955. He came to Caltech in 1958.



Scott

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Engineering and Science

October-November 1976/Volume XL/Number 1

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University of Washington, Seattle 98195
+ Bellevue Community College, Bellevue 98007 (GMC only)
+ Everett Community College, Everett 98201 (GMC only)

WEST VIRGINIA
West Virginia University, Morgantown 26506
+ Fairmont State College, Fairmont 26554

WISCONSIN
University of Wisconsin, Madison 53706
+ Madison Area Tech College, Madison 53703 (GMC only)
University of Wisconsin at Superior, Superior 54880

WYOMING
University of Wyoming, Box 3005, University Station, Laramie 82071

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Clarity of Thought and Higher Education

by JOHN H. KNOWLES, MD

As education focuses more narrowly on specialized vocations, we face the hazard of producing a nation of idiot savants

THE MODERN Western scholar traces his intellectual roots to Plato's school in the Grove of Academus in 397 B.C. (That's an opening sentence that's almost guaranteed to make heads bob!) It was here that the first learned group of pupils met to study under the great philosopher. And, to this day, "academy" refers to a collection of scholars, or a learned society. The word academic means "scholarly," but in more recent times it has also come to mean "impractical," or "not leading to a decision."

Perhaps this change in meaning is in keeping with the somewhat anti-intellectual tenor of the times. It certainly implies disaffection and frustration stemming from what is perceived as a failure of the modern university to meet urgent social needs. It is also a reflection of the sharpening differences between yesterday's university ideal of Cardinal Newman and today's vocational, pragmatic ideal of Clark Kerr's "multiversity" — that great conglomerate service station with as many roles as the colors in a pied coat.

The vocational, pragmatic ideal seems to have gained the upper hand, as more and more American universities have neglected the substance and purpose of an undergraduate education and the swollen tail of the graduate school wags the university's body, i.e., the undergraduate faculty of arts and sciences. Simultaneously the graduate school "tail" is pulled and twisted by the federal Leviathan. Reading and verbal ability scores have been falling steadily in secondary schools since the mid-1960's, according to the Department of Health, Education and Welfare; colleges and universities have responded by doing away with English and other language requirements.

It is very interesting to me that in some universities in the United States today about 70 or 80 percent of the students who graduate, graduate *cum laude* or above, and yet an equal percentage are unable to write a decent letter. The University of California at Berkeley had to institute remedial reading for 45 percent of its entering class, while 50 percent of the pre-journalism students at the University of Wisconsin fail to meet the minimal standards for competence in writing. The Modern Language Association has recently established a Committee on Public Literacy.

Now what is this due to? Can it be the emergence of the nonliterate television culture, the new emphasis on social problems in a sensate culture, or what? George Orwell, of *1984* fame, in a classic essay entitled "Politics and the English Language," said, "The fight against bad English is not the exclusive concern of professional writers. The slovenliness of our language makes it easier for us to have foolish thoughts, and to think clearly is a necessary step toward political regeneration."

Remember when one of our elected leaders said, "Now I want to make one thing perfectly clear" — when it was clearly his intention not to do so? Vagueness of language bespeaks vagueness of thought. Vocabularies of today's students are limited, and the lack of ability to think and communicate requires the increasing use of "ya know" and "like I mean" and "like I mean, ya know" to camouflage the general befuddlement. Is it possible to have intellectual and moral clarity of thought in the presence of a distorted language — swollen as it is with euphemisms, taradiddles, tautologies, inverted and subverted meanings stemming from Vietnam and Watergate, and perfectly horrendous grammatical bastardizations? Remember John Dean's memo about "maximizing the incumbency"?

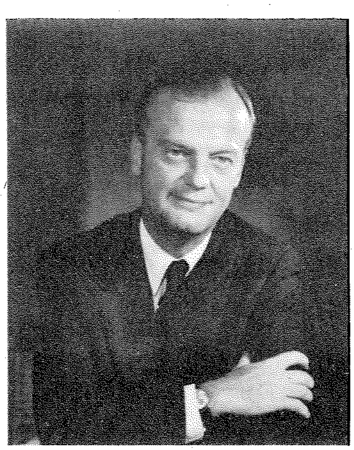
Governmental bureaucrats, singsong politicians, and businessmen — as well as foundation presidents — have all contributed their share to the destylization and confusion. Mark Van Doren put it well when he wrote: "The liberal arts are an education in the human language, which should be as universal among men as the human form, and yet is not. Saint Augustine paid his education the compliment of saying that as a result of it he could read anything that was written, understand anything he heard said, and say anything he thought. This is perhaps as much praise as education could conceivably desire."

Corruption and debasement, obfuscation and illogic abound. In a review of the Morrises' *Harper Dictionary of Contemporary Usage,* written, we are told, with the assistance of 130 distinguished consultants on usage, Joseph Epstein, an Englishman, writes in the *Times Literary Supplement,* "The battle for good usage is the best of all lost causes," and goes on to quote George Bernard Shaw, who described England and the United States as "one people divided by a common language." The attack is relentless, as he states, "American usage features the pompous at the service of the inane, the cumbersome in the cause of the confused." Many of us have suffered and winced when confronted with such phrases as *ongoing, felt needs, support structures, noise abatement, lifestyle, chairperson, Ms.,* and in the rush to rid ourselves of sexism in American life we have exchanged *charwoman* for *building interior cleaner, fishermen* for *fishers, busboys* for *waiters' assistants.* If we don't deplore these euphemistic clouds of foolishness, we should at least be able to laugh at them. As Epstein says, "One must step very gingerly to avoid the droppings left by advertising agencies, the media, and the social sciences."

The ultimate, of course, arrives in the form of the term *solid waste ecologist* for *garbageman.* The Morrises tell us that *concretize,* one of the most strident, harsh tones I think I have ever heard, is a favorite of businessmen, administrators, bureaucrats, and other semiliterates. The country would, in fact, appear to me to stand in need of a verbal waste ecologist.

As grammar deteriorates, the critical ability to see through others' and one's own deceptions atrophies. Just what in heaven's name does *consciousness raising* mean? Or *creative associations with our environment?* Or *selfhood?* When Professor Reuben Hill, an expert on the American family, on the faculty of the University of Wisconsin, is quoted in the *New York Times* under the headline "New Lifestyle Said to Bolster Family," see if you can tell me what he means: "The dual pattern fits nicely our ideology of equality of opportunity, full utilization of education, equalitarian ethos, and the push toward symmetry of the genders." I, for one, do not want symmetry of the genders. I rather enjoy the symmetrical differences between men and women.

A rash of *with-it* expressions (so-called *with-itry*) despoils the verbal landscape. *Low profile, bottom line,* being *into* something, and *meaningful* are barbarisms that refuse to leave and more often than not are shorthand deceptions. A leader of American medicine speaks of the *one-on-one physician-patient interaction* when referring to the relationship between physician



A COMMENCEMENT SPEAKER is supposed, somehow, to inspire and inform a very mixed audience — one that is likely to be at least restless and at worst blasé. So it was Caltech's good fortune at its 82nd commencement on June 11 to have a speaker who brought both wit and wisdom to the occasion. He was John H. Knowles, MD, president of the Rockefeller Foundation, and, said Stanton Avery, chairman of the Institute's board of trustees, in introducing him, "We can be sure that whatever Dr. Knowles has to tell us this morning will be expressed in his own words, because he has said that he would no more ask somebody else to write his material than Maria Callas would let someone else sing for her."

Dr. Knowles earned his AB degree at Harvard in 1947. He says he spent all his time there playing baseball, hockey, or squash, and writing music for the Hasty Pudding show with Jack Lemmon. Nevertheless, he was accepted by the Washington University School of Medicine and graduated first in his class. Eleven years later he was named, at 35, the youngest director in the 150 years of Massachusetts General Hospital. In 1972, he became the Rockefeller Foundation's eighth president.

Herewith, his Caltech commencement address.

and patient. (We can only hope that they are, in fact, not *on* each other.) *Subclinical* is another favorite. *Clinical* comes from the word that means *bed;* therefore a subclinical disease, or a patient with a subclinical disease, means that the patient and the condition are under the bed.

Lionel Trilling said, "A specter haunts our culture; it is that people eventually will be unable to say, 'They fell in love and married' — let alone understand the language of Romeo and Juliet. But they will as a matter of course say, 'Their libidinal impulses being reciprocal, they activated their individual erotic drives and integrated them within the same frame of reference.' "

There is humor on one side of this, and coming to southern California, I can't resist the recitation of a few Sam Goldwynisms. He is, of course, the man who said, "I don't think anybody should write his autobiography until after he's dead." And, "Keep a stiff upper chin." Or, his most famous one, which is in Bartlett's *Familiar Quotations:* "Include me out." Another is, "I can tell you in two words, 'Im Possible.' " When asked whether some of the papers in his bulging files could be destroyed, he answered, "Sure. But just be sure to keep a copy of everything."

A complete list of Goldwynisms would have to include, "I read part of it all the way through." And also, "The trouble with this movie business is the dearth of bad pictures." When told an employee had named his new baby "Sam," he said, "Why do you want to do that? Every Tom, Dick, and Harry is named Sam."

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Finally, when telling a friend about his new knowledge of the atomic bomb, he said, "It's dynamite!"

Now, in addition to the misuse, abuse, and nonuse of the language, the College Entrance Examination Board reports that SAT test scores on developed reasoning ability have fallen almost 10 percent over the past 10 years. As a result of testing nearly 100,000 elementary and high school students, the National Assessment of Educational Progress reports that students know significantly less science today than they did just three years ago. Ignorance of history also abounds. We seem to have forgotten the admonitions of Louis Brandeis who said, "One page of history is worth a volume of logic." And of Santayana who said, "He who knows no history is doomed to relive it." New on the scene in our country is a dispiriting, self-flagellating churlishness that prevents us from confronting without embarrassment the values that make for greatness in a people and a nation — specifically, our own.

Cardinal Newman's university was a collection of scholars who believed that "knowledge is capable of being its own end," and "knowledge is its own reward." But the Oxfords and Dublins of Newman's age were to be overcome by the development of science and research, which were to be firmly established in the German universities in the latter half of the 19th century. The gentleman scholar, the wealthy Renaissance man, at home in and in control of his own world, and indulging in so-called purely academic discussions, was soon to become specialized and vocationalized. The dilettante was one interested in art

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and science as a pastime, but the word was finally to be used in a derogatory manner indicative of a lazy amateur. This is a pity, for as Pascal said, "It is far better to know something about everything than to know all about one thing."

The natural scientist and the research ideal contributed enormously to the advance of knowledge and, with it, the advance of civilization and improvement in the quality of life. But something was lost in the process. As knowledge expanded, superspecialization took hold, and the modern university was forced to rigidly compartmentalize its disciplines. At the present time, in many universities in our country, the undergraduate years have become a necessary bottleneck, or a way station, en route to the specialized vocations of the graduate schools. As the focus becomes progressively narrow, we face the real hazard of producing a nation of idiot savants, highly knowledgeable in depth and technically proficient but abysmally deficient in breadth and the ability to synthesize knowledge and integrate its disparate, atomized parts — so that the true purpose of all study, i.e., to be at home in and in control of the modern world, can be realized.

(Parenthetically, let me say that the critical mass of the California Institute of Technology, the capacity for its wide variety of disciplines, and the excellence of its faculty allow the interdigitation of many different disciplines bearing on the complex problems of today. They cannot be solved in isolation by one set of experts alone.)

But why should the phrase "purely academic" now carry with it the connotations of irrelevancy, impracticality, and inaction? Perhaps it is because the intellectual isolation of specialism may in fact be an attempt on the part of the academy and its scholars to escape responsibility. (Here again, the California Institute is heavily involved in local, regional, and national issues.) The wish to acquire special knowledge and salable skills may have diverted us from our civic responsibilities and the necessary moral commitment to the whole — whether in terms of knowledge or with reference to our country, its culture, and its form of government. Every interest seems to be vested, and none encompasses the interdependent whole. Granted that the pull and tug of special interests define the democratic process, to whom will fall the special responsibilities of leadership? We hope the question will be answered in November. To whom do we look for those qualities of the true intellectual who integrates and synthesizes disparate knowledge into a coherent whole and then can transmit it to the nonexpert but educated listener? And who will tell us what *should* be done humanistically, as well as what *can* be done scientifically and technically? And who will follow the leader if either he or they are incapable of understanding the language?

One of the great discontinuities in contemporary intellectual life is the now fully institutionalized belief that knowledge and the students thereof are neatly

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divisible into two bodies — the one scientific, the other humanistic. C. P. Snow, as you know, popularized the cleavage between the "two cultures," noting its dismal results, and rejuvenated the search for continuity. Science systematizes knowledge logically, seeks analytic generality, abstracts what is quantifiable, and forms general laws which can be verified and then amended by the accretion of further knowledge. The humanities have no single methodological strategy and rely on speculative thought and normative judgment. John Higham has said that "humanistic approaches predominate in all efforts to preserve the complexity of experience instead of abstracting verifiable regularities from it. These efforts include the use of expressive rather than technically precise language, a greater interest in individual events than in general laws, a reliance on qualitative rather than quantitative judgment, and a subjective grasp of a totality in

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preference to a dissection of its parts."

In the rush to be scientific, we have denigrated the literary, the romantic, the subjective, the impressionistic, the anecdotal. If not armed with questionnaires, tape recorders, computers, and the language of the social sciences, the results are clearly invalid. In between humanist and scientist sits the social scientist, a relatively recent arrival on the university scene. John Dewey saw the domain of the social sciences — history, sociology, political science, and economics — as bridging the gap between past and present, culture and science. Since the turn of this century, most universities have subdivided themselves into the natural sciences, the social sciences, and the humanities. The social scientists wanted to become pure scientists and in the process demanded complete separation from the value-laden speculations of the humanists, preoccupied with the past. Scientism and antihistoricism were natural bedfellows. The humanists rose up and established their defense. Their common concern was with values. The humanities would offer a liberating knowledge of choice, preference, and taste. But their claims paled when viewed in the light of the Second World War, Vietnam, and then Watergate.

The separation of these three divisions of scholars, while rational, is also artificial. To say that the social sciences are not value-laden, and — particularly in recent times — not using increasingly a historic dimension, is to say that you are not familiar with the works of Kenneth Boulding, David Riesman, Seymour Lipset, and Erik Erikson. To say that the humanities have not become more hospitable to methodological diversity is to ignore the recent developments in linguistics and in analytic philosophy and the work of

Chomsky and Quine, for example. However, one can only agree with John Higham when he says, ". . . we still assign much too low a priority to evaluative finesse in the social sciences and to criteria for measurement in the humanities. Consequently, we have too little 'art' in one camp, too little 'science' in the other, and not enough breadth of mind in either."

To say that the natural sciences can exist and reach full flower in the service of human needs, without the historic perspective of the human condition offered by the humanities or the quantitative knowledge offered by the social sciences, is to belie the meaning of the word "university" and to cast the ultimate irony at its door. Alas, the Carnegie Commission on Higher Education, begun in 1967, headed by Clark Kerr, financed by over $6 million from the Carnegie Foundation, and productive of 20 volumes of its own reports and additional scores of essays and research reports, does not answer or resolve the controversy surrounding education; namely — as defined by Robert Hutchins— ". . . how

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to maintain its critical function, how to regain community (or cohesion), how to repair the ravages of specialization, how to have a university rather than a series of unrelated autonomous technical schools called departments, how to force the confrontation of the disciplines, and how to tame the pretensions of the experts."

If ever-increasing public support for higher education is to be obtained — and by public support I mean both voluntary for the private universities, and by taxation for the public institutions — then answers to society's questions must be provided. In 1900 only 4 percent of the college-eligible age group went to college; in 1970 over 40 percent attended — the highest percentage in any country in the world. At the same time, one must ask: How can the nation support an enrollment of over 9 million students in higher education when there is no consensus about what ought to be taught, and why, to candidates for bachelor's degrees?

The three major purposes of education — to develop the intellect, to transmit the culture, and to acquire marketable skills — have been so heavily weighted toward the pragmatic ideal of "making a good living" that the undergraduate curriculum today is a mishmash of electives and pre-graduate school requirements. The idea of knowing a little about everything; integrating and synthesizing knowledge in the attempt to gain understanding of both self and life's problems; strengthening the culture and its values; acquiring aesthetic and ethical sense in choice, preference, value, and style; and being able to read anything written, understand anything said, and say anything thought has been lost to the pomposity of idiot savant professionals, technicians, governmental bureaucrats, and to a rigidly compartmentalized faculty which has lost its sense of community and deals with everything but its universal purpose.

If the bugle sounds an uncertain note, who will do battle? Where and who are our leaders? Do we understand them and will they understand us? To quote Mark Van Doren, "The human language, once it is admitted to be complex, reveals itself as cogent. But bad education does not assist the revelations; it leaves us, on the contrary, chronically misunderstanding our enemies and our friends."

The university's role is to be a university. The complex problems of this rapidly shrinking, interdependent world require clarity of intellectual and moral thought for their solution. Such clarity can be achieved through the integration and synthesis of humanisitic and scientific knowledge and the methodological disciplines of both. In the act of discovery, the student will be freed to pursue the lifelong joys of learning and understanding, for "the art of being taught is the art of discovery, as the art of teaching is the art of assisting discovery to take place" (Van Doren). In the process, the individual acquires hope, will, skill, purpose, fidelity, love, caring — and in the end, authenticity, and integrity — the highest virtue of them all.

Paul Tillich said we shouldn't lose our sense of humor. We're now in the midst of our bicentennial, and you are the favored, special class on our 200th anniversary, and I think the country is beginning to regain its sense of humor. And that makes me happy because of Tillich's statement that "humor is a prelude to faith, and laughter is the beginning of prayer." All you good folks about to graduate, may your reach always exceed your grasp, and remember that the journey is the thing — not the arrival. And always remember that statement on the great seal of the California Institute of Technology, "The truth shall make you free."

Thank you, and good luck.□

Smart Energy

A Key Role for Computers

The miracle of the digital computer is giving us the opportunity to employ new levels of care and skill in solving our energy shortage problems

by ROBERT H. CANNON Jr.

In working out our energy shortage problems we may make more progress with finesse than we do with brute force — finesse in managing the energy we use in machines and processes, and finesse in understanding ahead of time what all the consequences are likely to be of choosing one or another course of action. Finesse in managing, finesse in understanding.

The new technology that is giving us the opportunity to employ this care and skill — this finesse — is the miracle of the digital computer.

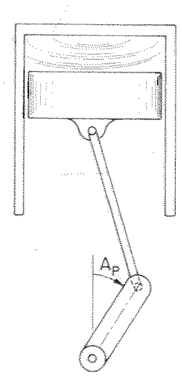
Computers can help us get more from our energy at three levels. Level I is machines and processes, like automobile engines and glass factories. Level II is major operating systems, like regional power networks or the national air traffic control system. Level III is understanding whole segments of the economy, like transportation, or the complex of major industries involved in producing electric power from coal.

The opportunities are pervasive. For every example that space permits there are a dozen or two it does not.

LEVEL I: MACHINES AND PROCESSES

Example 1 is about smarter automobile engines. There are many ways to improve automobile fuel economy; one where finesse can really count is computer control of ignition.

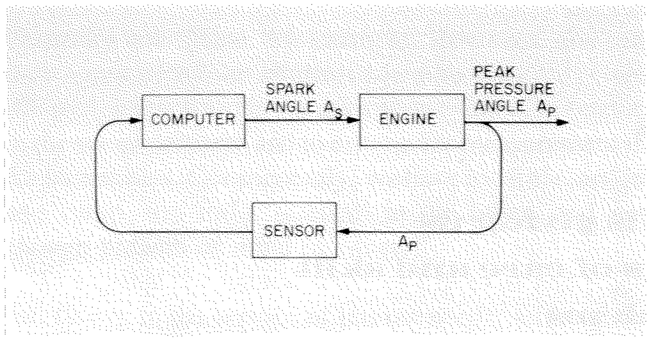
The amount of power that gasoline delivers when you burn it in your engine depends on the particular crank angle (A_p) at which *peak pressure* is reached — at which maximum force is exerted on the piston by the exploding fuel mixture (just as pushing a child high in his swing depends on pushing at just the right time in each cycle). Angle A_p depends in turn on the *earlier* crank angle (A_s) at which you fire the spark plug to ignite the fuel. For good performance, peak pressure occurs after dead center (as in the child's swing), and ignition before dead center. But it is angle A_p that determines power; angle A_s merely controls A_p.



It turns out that (as with the child's swing) the angle A_p for best power is nearly the same for all operating conditions. The spark angle to produce it, however, varies greatly with temperature, altitude, fuel content, and humidity, as well as with engine speed. In automobiles, from the beginning, the right spark angle has had to be guessed at — first manually, using the little lever under the steering wheel on the Model T, and since then by using an automatic adjustment with engine speed, which guesses wrong a lot of the time. That's the problem.

The solution is to quit guessing at spark angle and to control A_p itself, using a simple sensor to measure angle A_p directly and a computer to continually adjust spark angle A_s until you get the A_p you want. This is what Professor David Powell and his colleagues at Stanford University have done. By measuring and controlling A_p directly, Powell's system always fires at exactly the right time, hot or cold, rain or shine, mountain or seashore, fast or slow, man or boy.

What would such a system cost? If you already have electronic ignition, you just add a peak-pressure sensor and a tiny computer chip that costs a dollar or so. The sensor Powell has designed fits inside a spark plug.



An inexpensive solution to the problem of getting maximum power from exploding fuel in an automobile engine — a sensor to measure crank angle A_P so a computer can continually adjust spark angle A_S.

(Notice that you don't need to know the pressure itself, only the crank angle at which pressure is maximum.) So, replacing one of your spark plugs with one of Powell's would perhaps cost less than five dollars. The whole system can then be very cheap.

Another part of the auto-engine efficiency story is, of course, fuel/air ratio. How lean a mixture can you burn with smooth performance? Here again a tiny computer can provide the precision control needed, and many laboratories are working on one. (In this case it is oxygen in the exhaust that is sensed, and the zirconia sensor needed will cost a little more than Powell's pressure sensor.) The payoff is not only the obvious reduction in gasoline needed when you use a lean mixture, but a major reduction in emissions as well. Precision control lets you operate safely very close to the lean limit, where emissions are low. Without such precise control you must use a much richer mixture (making emissions several times higher than necessary) in order to be sure that excursions around the nominal operating point never get you below the lean limit, where you will encounter nasty misfiring.

So, with two little computers you can provide yourself with an engine that is not only operating very efficiently when you get it back from a garage tune-up, but operating efficiently all the time, under all conditions. I expect to see Detroit including these computers as standard equipment before long.

Now you don't produce successful systems, even simple ones like these, by just thinking about them. First you make many measurements — many experiments — until you understand the nature of the system you're trying to improve. Next you try to evolve a quantitative description of how things seem to behave — a *model* of the system. Then you test the model with more experiments to be sure it is valid. That's the experimental method.

In addition, before you build your whole new system, you can do an inexpensive intermediate step, called *simulation*. This consists of putting your mathematical model on a general-purpose computer so that it behaves like the real system. You can then do preliminary experiments on this computer — much faster and much cheaper than you can do real experiments. And from them you can predict what will happen later with the real physical system. This is finesse in *understanding*. (Powell did this extensively for the automobile engine.) Then finally, with the detailed understanding you have thus developed, you can build the actual control system with much more confidence.

These two concepts — (1) the importance of experiment, and (2) the use of one kind of computer to manage energy (in machines and processes and operations) and another to model and *simulate* that performance (to gain understanding about it) — are common to all the examples we'll be discussing here, particularly as the systems grow more complex.

Example 2 is glass-making, a typical energy-intensive industry where, in fact, energy is more expensive than the raw materials.

Glass is made in a large vat. Across the top of the vat heated air flows from many orifices to melt, in just the right way, the incoming batch of constituents that will form the glass. At the bottom, molten glass is drawn off and sent to molds to make drinking glasses, or windshields, or building glass, or the myriad other glass things in our daily life.

The efficiency of the process depends critically on the distribution of temperature *all along* the top of the vat. And this whole temperature *distribution* is what must be controlled. To do this, many air flows must be controlled separately in the right proportions, based on many temperature measurements throughout the vat.

What has led to improved efficiency here is successful three-dimensional simulation, on a general purpose computer, of the heat and liquid flows and currents in the cauldronous glass-making vat. From this simulation has come the design of another, operational, computer to control air and fuel flows to optimize those distributed temperatures. This analysis was done by Professor Eugene Goodson's team at Purdue University. The computer uses finite element techniques to solve simultaneously a set of partial differential equations — a new and important achievement.

The glass industry produces about 13 million tons of glass per year. The 10 to 15 percent improvement in overall efficiency expected from computer control could save about half a million gallons of oil per day.

Example 3 is deep ocean mining. As we reach farther and farther for our energy resources, we're going to have to operate with machines where men cannot go — searching, probing, extracting, harvesting — all by remote control. A current example is the *Glomar Challenger,* a ship designed to drill holes in the bottom of the sea, to learn how the sea floor was formed, to learn more about the plate tectonics puzzle, and to learn where minerals and resources may be.

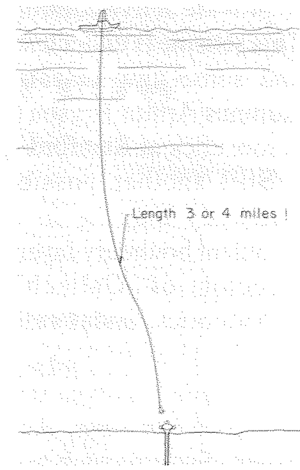
This means controlling, from the surface, a submerged drill string three or four miles long, threading a needle underwater by pushing on the other end of the thread about four miles away. The really interesting problem here is to reenter the same hole after you've broken a drill bit — or after you've been away for a week. Without this reentry capability, you can drill only as deep as one bit will take you. With reentry, there's no such limit.

The *Glomar Challenger* team solved this central problem with a sonar sensor on the end of the drill string, and a managing computer to operate the ship so it would move in just the right way to drop the drill string into the hole. Around the hole there are three sonar transponders on a 15-foot cone. The computer compares the three signals to determine where the drill bit is in relation to the hole. The computer on the ship must have built into it a full understanding of the dynamic response of the ship and its four-mile-long piece of spaghetti, so it can figure out how to have the ship move around on the surface to just drop the drill bit into the hole.

The computer can do it. Making many reentries, the *Glomar Challenger* recently drilled a hole 1,000 feet into the sea bottom in 15,000 feet of water.

Harvesting oil in water that deep is another interesting challenge. In fact, there are many things to be done on the ocean floor. That's the new frontier — and we'd better learn to operate there, for energy, for food, and for resources of all kinds.

Sometimes, unmanned, untethered vehicles will have to do things for us at great depths, in contact with people on the surface only through underwater sound communication. This adds to the problem of manipulation at a distance the problem of having to wait as long as eight seconds after you send the command before you see that command obeyed — because sound signals take four seconds to travel from the surface to the bottom and from the bottom to the surface. It is like trying to drive your car with the arrangement that after you turn the steering wheel there will be an eight-second delay before the wheels turn. Experiments show this is truly impossible.



The solution to the time-delay problem has to be to place tactical control in a local computer. The commands that you send must be strategic ones only. You cannot say, "Turn left — quick!" but "Go around that rock," or maybe "Go from point A to point B and don't run into any rocks." The only thing that makes this conceivable is, again, the miracle of the minicomputer, which has such enormous amounts of computing power in a tiny space, and *in situ*.

Interestingly, the ocean-bottom remote control problem is apt to get solved by the space program. William Whitney and his team at JPL have the problem of controlling an exploratory vehicle on Mars. The communication-time delay (in a radio signal, in this case) from here to Mars and back is many minutes. As on the ocean floor, the task is to probe, manipulate, and examine. One difference is that on Mars the light is going to be better.

There are, of course, many energy-related requirements for fail-safe remote manipulation. Handling toxic materials such as plutonium is one. Mining coal is another.

Example 4 is aircraft efficiency. About 10 percent of all transportation oil is used by aircraft. That percentage will probably go up. So reducing aircraft drag can save important amounts of oil.

Part of airplane drag comes from the large vertical tail. Now you do need such a tail for feathering — so the plane will be stable and always point in the direction you want to go. One way to reduce drag is to replace the large vertical tail with a much smaller tail; but if you do only that, you get an unpleasant fish-motion ride. On the other hand, you can replace the large tail by a small tail, plus a sensor of yaw motion, plus a computer to control that motion by operating the rudder in just the right time sequence to give you a very smooth ride indeed. This system is known as a yaw damper, and there is now one on most commercial aircraft — to make your ride more comfortable and to save some fuel by not having to add that huge tail.

Another way to reduce aircraft weight, and hence fuel consumption, is by controlling the flutter of aircraft wings. The wings can be made amply "stiff" with considerably less structural weight if you use feedback to provide active control of their up-and-down motion. This scheme is under test for military aircraft at Boeing, and some new research is under way by Caltech alumnus Arthur Bryson (MS '49, PhD '51), who heads aeronautics at Stanford.

Still another possibility for improving aircraft efficiency may lie in controlling, by feedback, the turbulent boundary layer on the wing. Hans Liepmann, director of Caltech's Graduate Aeronautical Laboratories, is currently addressing this possibility.

Example 5 is about simulation in aeronautics and the energy it can save. Aeronautics is where simulation began. Systems such as the yaw damper and automatic pilot are always tested extensively, using computers to simulate the aircraft's dynamic response under the whole range of flight conditions, before the planes are ever flown.

Another example of simulation that saves energy is the program for familiarizing commercial airline pilots with airports they have not landed in recently. Before really good simulation was available, flight crews made large numbers of practice landings with full-sized, empty commercial aircraft. The economic penalty of tying up the capital investment in an empty airplane, compounded by the rapidly rising cost of jet fuel, motivated vigorous development of the art of simulating these landings so that pilots can practice without limit in a special room on the ground, with all the realism of actual flight.

The result is pretty impressive. What the computer does is generate, for the pilot, a three-dimensional picture of the airport, complete with approach lights, runway and taxi markings, and even lighting from the airport terminal. The system is so realistic, including the motions of turns, banks, and runway touchdown, that the FAA has approved it for use in all pilot proficiency training. United Airlines, for example, has installed the system on its 737 and DC-8 flight simulators in Denver. This one company says it saves about 55 million gallons of jet fuel each year with its flight simulator pilot training.

Here again is computer finesse at work. One of the designing geniuses behind this particular computer simulation and display is Ivan Sutherland, who has just joined Caltech as professor of computer science.

LEVEL II: LARGE OPERATIONAL SYSTEMS

Example 6 is the National Air Traffic Control System. Air traffic control began with the Berlin Airlift where, in zero-visibility weather, controllers on the ground used radar to talk the pilots down to the runway. Since those days much operational development and much research have been done. Recently the FAA installed it in its Third Generation Air Traffic Control System, a major computer achievement now in use throughout the country.

Before the new computer was in, each controller had to keep track of all the blips of light on his radar screen and figure out which aircraft was which — and remember them all as he directed their movements. As the number of aircraft mounted, pressure on the controllers also mounted until the problem began to reach a crisis level around 1969. There was anxiety for safety; and droves of aircraft were kept orbiting airports for hours (burning fuel the while).

What the new computer does is tag each aircraft on the controller's radar screen. It provides a picture not only of the raw radar return but also of much other information, including each aircraft's identity, altitude, speed, and heading. With this information the controller is relieved from routine pressures and is free to lay out his strategy and manage the group of aircraft in his area with certainty and safety — and minimum expenditure of fuel.

In concert with surer control of aircraft in the vicinity of the airport, en route control is also being improved now to take advantage of computer-maintained, up-to-the-minute knowledge of where the winds aloft are, and of where thunderstorms are, so that safe, minimum-fuel routes can be laid out (with safe spacing between aircraft). That's why, when you fly across the country, you may take any of several different routes, depending on what the computer has determined is the most fuel-efficient one.

This capability will continue to improve. There will come a time fairly soon when commercial aircraft will be controlled gate-to-gate. An aircraft will not leave the passenger gate until its entire path all the way to the passenger gate at its other terminal is cleared. It will be controlled on the runway, on takeoff, throughout the flight, and all the way to the next gate, to minimize fuel consumption. This, finally, is the full *systems* approach, completely eliminating the fuel waste due to flying under adverse conditions, due to waiting in the landing pattern, and due to waiting on the ground with the engine running.

The ultimate air traffic control system will probably use satellites instead of radar. Three satellites (at 22,000 miles altitude) can pinpoint simultaneously the location of all the aircraft over the country to about 50 yards and can provide all the information in a single computer (with fail-safe redundancy added, of course,

continued on page 28

Energy Realities for Tomorrow

by ROBERT C. SEAMANS

No limited mix of energy technologies can provide our country with the flexibility to meet our needs ....

IT'S UNDERSTANDABLE that we've long taken energy for granted, because it was not until the 1950's that we lost our self-sufficiency. Our reaction to this development was simply to import what we needed — mostly crude oil and petroleum products, but gradually some limited amounts of gas as well. By 1970 we were spending about $3 billion a year on imported oil; $7.5 billion in 1973, and — in the face of post-embargo OPEC price rises — an astounding $27 billion in 1975. This massive outflow of dollars not only aggravates our balance of payments, but eventually can also influence the global balance of power. Here at home, it translates into jobs lost and higher rates of inflation.

Internationally, our percentage of world oil production has dropped precipitously. Before World War II we were producing about 60 percent of the world's crude. Last year we accounted for a mere 16 percent. By 1974 the Soviet Union had overtaken us as the world's Number One producer. And their production curve is moving upward as ours slopes downward. During 1974 and 1975 they boosted oil production by a little over 7 percent, reaching a peak daily output last December of more than 10 million barrels. We have not seen that kind of production for six years in this country, and we are now down about 16 percent from that peak value.

Reduced to its barest essentials, America's energy problems (some prefer to call it "crisis") are that we are now 75 percent hooked on oil and gas energy; domestic production is dropping while necessary imported supplies are costing us dearly; and at the same time both domestic and foreign supplies are destined to run out in the early decades of the next century. That is only 30 to 40 years away, which is not much time for making fundamental changes in the production and utilization of energy to run our economy.

I always like to take a short look at history and point out that in 1850 we relied almost entirely on wood for fuel; in 1910 we relied for most of our energy on coal; and now it's oil and gas. So in the past we've been dealing in 60-year cycles. We don't have 60 years in the future to shift to other forms of energy. To correct this situation, the President has proposed a comprehensive program to move toward energy independence. A major part of this program deals with energy research, development, and demonstration, as reflected in the national plan that the Energy Research and Development Administration (ERDA) first issued at the end of June last year and recently updated. One of the fundamental conclusions of the updated version is that no single or limited mix of energy technologies can provide our country with the flexibility required to meet our growing needs. A large part of the problem is that we must increase the use of energy in the next 25 years by the equivalent of 25 to 45 million barrels of oil per day. The higher figure results from a growth rate of 3 percent per year, which will be needed to satisfy our population growth by the year 2000 — unless we can mount a major conservation effort. These figures are based on statistics from the Department of Commerce, on looking at our population growth curves, and on information from groups in our country that are not satisfied with the status quo and so are trying to build in some hope for economic growth.

To reduce our needs in the year 2000 by 20 million barrels a day, we have singled out conservation for greatly increased attention. Each barrel of oil saved is one less that has to be imported. Furthermore, it often costs less to save a barrel than to import one, and conservation usually reduces the burden on our environment while at the same time preserving for future generations the limited, irreplaceable legacy of fossil fuels and uranium left us by nature.

The primary responsibility of bringing into use new technology for energy conservation and for expanding domestic energy production rests with the private sector. The federal government's responsibility is to assist the private sector in the development of new energy technologies and markets for them by establishing appropriate policy environments, sharing risks, and conducting complementary research and development.

Along with our conservation efforts, we must increase the utilization of major existing resources of coal and uranium. We must also seek further yields from so-called depleted oil and gas fields, using new, enhanced extraction technologies.

This is a fascinating area. Not long ago I went to Bartlesville, Oklahoma, where we have a small research lab. I went into Osage County — the home of the Osage Indians — and met there with the chief, with whom I went to the area where we're going to try some new techniques that involve drilling down several miles, and pumping in certain solvents (which have been tested in the lab but never on a large scale) to see if they will penetrate and loosen up the oil that still remains in the sandstone at those depths.

I asked the chief where all the Indians were, and he told me that this particular tribe was very clever; they occupied that land back in the 1880's, and they struck oil there in 1920. Since then, they have been quite prosperous because they get a seventh of all the profit from those fields. It's very difficult, the chief said, to actually screen all those who claim they're Osage Indians to make sure that only the genuine Osages get payments.

...and no nation, however well endowed, can face the world alone

American energy problems, serious though they may be, pale beside those of other industrial nations. We have vast coal deposits, many of outstanding quality; most of those countries do not. We have adequate uranium resources; others have none. We possess numerous geothermal sites waiting for exploitation and new technologies; most countries don't. And we still enjoy extensive, though dwindling, oil and natural gas reserves — a luxury in the eyes of our friends overseas.

A little over a year ago President Ford spoke of America's commitment to an interdependent world and of the vital importance of cooperating with other nations in the field of energy. At the same time he warned that the fate of all cooperative international energy programs depends crucially on what we do at home. The energy interdependence and cooperation the President is talking about comes down to shared responsibility. No nation, however well endowed, can face the world alone. We all share the planet and its resources, and we all share responsibility for them. When traditional energy sources no longer suffice, new ones must be developed, and as this happens, producers and consumers alike must cooperate to be sure of their adequacy, their safety, and their environmental suitability.

Many nations are making heroic efforts to locate oil in increasingly inhospitable places. Just last fall I took a helicopter two hundred miles out to the middle of the North Sea to view one of the very large operations being run there by Phillips Petroleum. They have four very large platforms from which they drill, and there are drill rigs around them at a radius of about 20 miles that feed in to this central location. From there, the pipe goes under the floor of the North Sea to England. And when they really get going, they plan to deliver of the order of a million barrels a day. One of the things that really fascinated me was the catwalk from one platform to the next about 110 feet above the surface. The waves of the previous winter, they said, on occasion hit those catwalks. So we're learning how to operate under very stringent and difficult conditions.

Despite all that can be done to locate offshore oil, limitations do exist. It's going to become more and more difficult to carry out the drilling and the operation. International surveys of supply and demand tell us that nuclear energy must play an increasingly important role.

For many nations nuclear energy offers the most plausible route toward energy independence. Among such nations are even those of the Middle East. Recently, when I visited Iran, the Shah emphasized to me that "oil is a wasting asset." Recognizing this fact, he is determined to utilize many of his petroleum dollars to build a nuclear capability in anticipation of the time when Iran's oil reserves become depleted. The Shah and many others are also questioning whether we should be burning our irreplaceable oil for fuel rather than conserving it for use as a feed stock for tomorrow's petrochemical industries. The French have determined to go ahead in a major way in electrifying with nuclear energy. So have the Japanese and many others.

When the U.S. inaugurated the atoms-for-peace era in 1953, we offered to share our atomic know-how with the rest of the world. At the same time this country took the lead in developing controls designed to minimize the possibility of diversion of nuclear materials for unauthorized uses. In the early years of this program the International Atomic Energy Agency was also established as a result of our initiative. In this agency we strongly advocated the development of an international safeguard system to encourage other nuclear nations to provide for safeguards during the course of their nuclear transfers to other nations. We also called upon the users to voluntarily submit their nuclear programs to international surveillance. Persuaded that a universal safeguard system was both preferable to and more credible than a multiplicity of bilateral arrangements, the U.S. progressively transformed its bilateral agreements into safeguard arrangements, using the IAEA as the responsible agent.

With the advent of the U.S.-inspired treaty for non-proliferation of nuclear weapons in 1968 we took further steps to universalize the concept and application of international safeguards. Among other things we offered to place all of our commercial nuclear activity under IAEA safeguards. Today we have with the IAEA an international system that covers the nuclear program of over a hundred nations.

Now in view of the fact that certain stages of the nuclear fuel cycle are more vulnerable to proliferation, or theft, than others — in particular reprocessing of spent fuel — the U.S. government has been exploring ways to limit reprocessing centers. This includes the concept of developing multinational reprocessing and enrichment centers that could reduce the potential spread of weapons capability.

Disposal of radioactive wastes accumulated as a normal by-product of the generation of nuclear energy must also be considered. We know it is scientifically and technically feasible to manage these radioactive wastes in a safe manner. This assurance is based on the know-how and technology we have amassed through research, development, and demonstration, and have documented in a recently issued report. This document explains the technological options available to achieve multiple-barrier isolation.

The record in managing radioactive wastes over the last 30 years in our weapons program includes both favorable experience and instances where problems have occurred. But there have been no discernible health or safety ill effects on the public from this activity, and the experience gained has benefited future planning and should minimize problems when large-scale commercial operations begin. We estimate that, given the estimated growth of nuclear power by the year 2000, the total cumulative high-level solid waste from all nuclear stations would fill a cube 70 feet on a side. This, we think, is an entirely manageable volume.

The IAEA is already a useful forum and an important audit agency, accounting for nuclear materials worldwide. We are also active participants in the International Energy Agency (IEA), which includes all European countries, Canada, Japan, New Zealand, and Australia. Our objective in the IEA is to be mutually supporting in a variety of ways, including research and development. We have 17 different R & D program areas to which the members can contribute, ranging from the use of peat (in which Ireland has the lead) to solar, geothermal, and direct coal combustion. In this latter area, we have a joint experimental project in Great Britain, funded by the United Kingdom, Germany, and the U.S., in which all members of the IEA can participate.

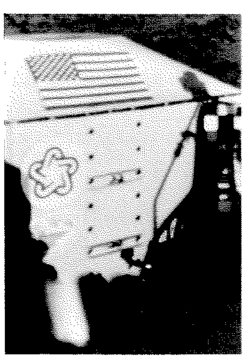
Separate from these two international organizations (IAEA and IEA), we have bilateral programs with over 25 nations, including the Soviet Union. And we are studying ways to work more closely with underdeveloped countries. As we work for a better balance between our domestic supply and demand for reasons of our own economy, we will also reduce our demand on world energy markets. It is essential that we recognize the interdependence of all nations in the requirement to satisfy world energy needs if we are ever to approach world stability.

In summary, to help us achieve these national and international objectives, we will be looking to the university community, which can assist us with basic research and with creative and innovative ideas, and in educating the scientific and technical leaders who will be coping with these complex problems in the years ahead. We are not going to solve these problems soon; they are going to be with us for tens of years.

We are also counting on the universities to provide broad analysis and counsel regarding the social, economic, legal, regulatory, cultural, environmental, behavioral, esthetic, managerial, and other aspects of the transition from dependence on oil and gas to alternate sources of energy. The nontechnical issues turn out to be even more difficult in my mind to resolve than the admittedly complex scientific and technical problems that we are addressing today.

Let us resolve to participate thoughtfully and responsibly in domestic and worldwide energy commerce. Let us recognize that all energy sources have risks and benefits. Each has environmental factors that must be thoroughly addressed. Let us use and share all appropriate technologies for energy generation and conservation, since no one approach can satisfy our needs. Only in this way, I believe, can we have optimism for man's survival in the world of tomorrow. □

This spectacular picture of the rock-strewn Martian landscape surrounding the Viking 1 lander shows a dune field with a number of features remarkably similar to many seen in the deserts of Earth. Viking scientists have studied areas very much like this in Mexico, and in California — specifically in Kelso, Death Valley, and Yuma. With maximum contrast the dramatic early morning lighting — 7:30 a.m. local Mars time — reveals subtle details and shading. Taken on August 3 by the lander's camera no. 1, the picture covers 100°,



On Mars — the U.S. flag.

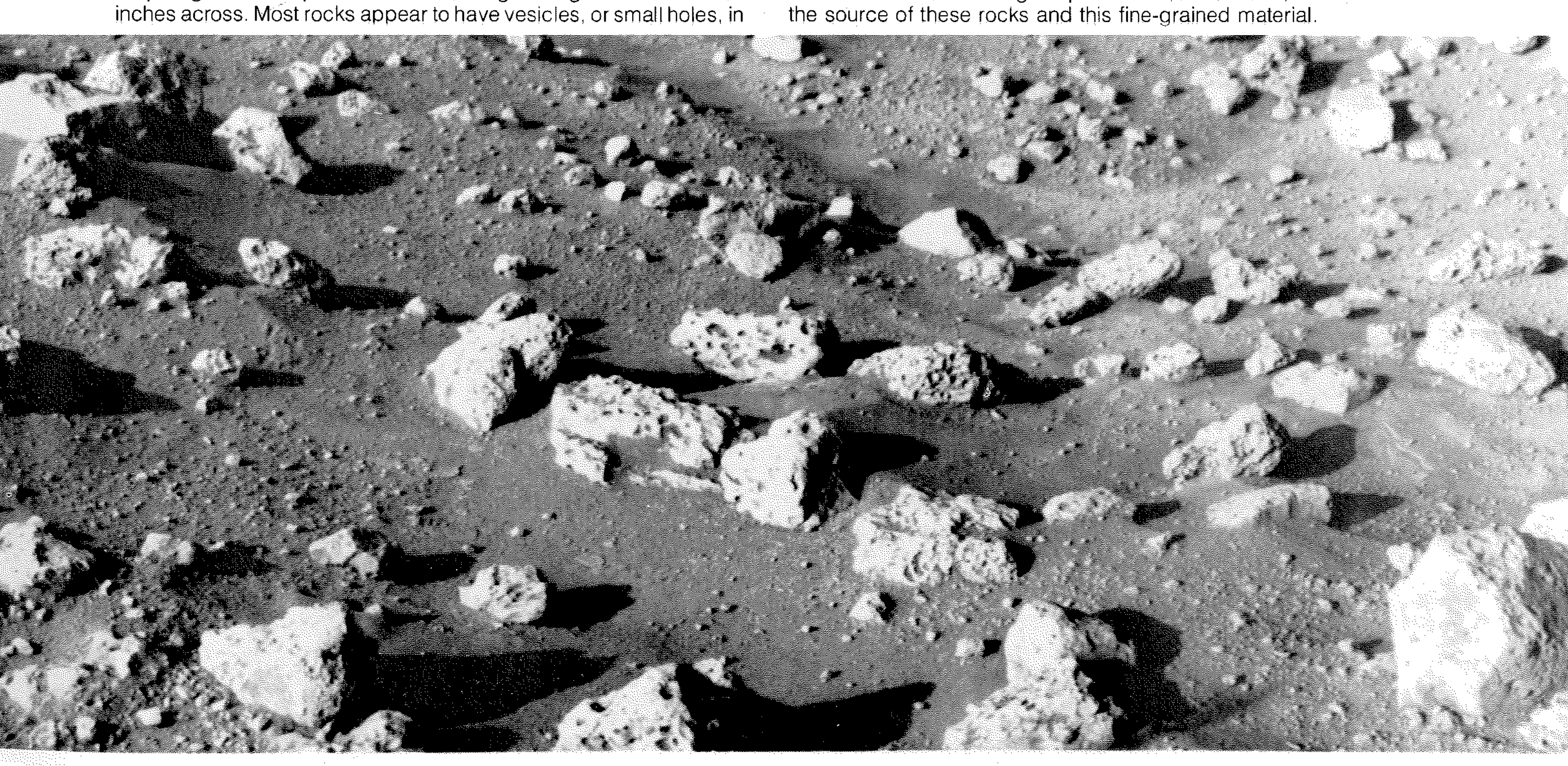
MARS – UP CLOSE

AFTER a journey of 213 million miles that took eleven months, a U.S. spacecraft set down on Mars on July 20. While the Viking 1 orbiter continued to photograph the planet from above, the 1300-lb. Viking lander began taking pictures of its surroundings — besides performing a series of intricate scientific experiments. On September 3 a second scientific station went into operation on Mars when the Viking 2 lander was brought down 4000 miles from the landing site of Viking 1. On these pages — a small sample of the exciting pictures coming back from the Viking vehicles.□

Viking 1 took this high-resolution picture on July 22 — its third day on Mars. The photo shows numerous angular blocks ranging in size from a few centimeters to several meters. The surface between the blocks is composed of fine-grained material. Accumulation of some fine-grained material behind blocks indicates wind deposition of dust and sand downwind of obstacles. The large block on the horizon is about 13 feet wide. The distance across the horizon is about 110 feet.

looking northeast at the left and southeast at the right. The sharp dune crests indicate that the most recent wind storms capable of moving sand over the dunes did so in the general direction from upper left to lower right. Small deposits downwind of rocks also indicate this wind direction. The large boulder at the left is about 25 feet from the spacecraft and measures about 3 feet by 10 feet. The meteorology boom, which supports Viking's miniature weather station, cuts through the center of the picture.

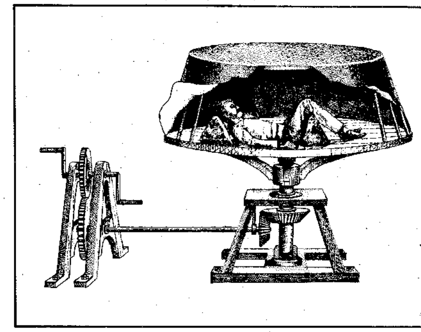
This high-resolution photo of the Martian surface near the Viking 2 lander shows a few square yards at one of the possible spots for acquiring a soil sample. The rock in the right foreground is about 10 inches across. Most rocks appear to have vesicles, or small holes, in them. On Earth such rocks can be produced by either volcanic processes or hypervelocity impacts of meteorites, and near this Martian site there is a large impact crater, named Mie, that could be the source of these rocks and this fine-grained material.

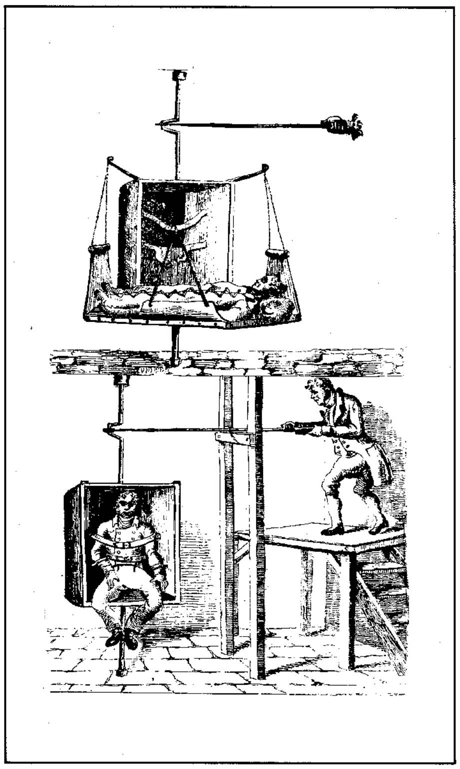


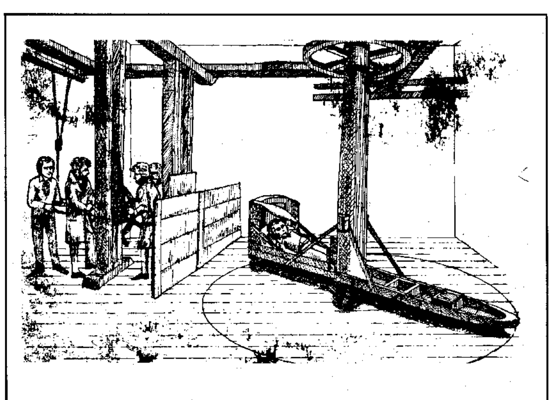
Centrifuges in the Earth Sciences:

A Revolutionary Idea *

by RONALD F. SCOTT







A NUMBER of materials, primarily geological in nature, such as soils and rocks, but also including other granular substances, have physical properties which depend on the stresses induced in them by the density of the overburden in the earth's gravitational field. It is frequently necessary to build structures on or in these materials, or to dig holes in or through them. These structures or cavities must be designed to have adequate factors of safety under the imposed loads.

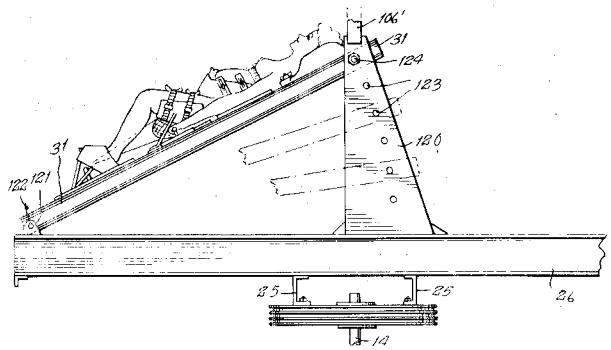
While there are various analytical or computer methods available for use in problems involving soils or rocks, the heterogeneity or anisotropy of the natural material is such that field tests of prototype structures are very desirable. In many cases models are constructed and tested. However, field tests are hard to perform (how do you impose loads of hundreds to thousands of tons on a full-scale structure?), and model tests on soils at earth's gravity are not scaled correctly, because the stresses and forces in the model are much smaller than in the prototype. As a consequence, the model material behavior is not correct.

When the model scaling relations are established for soils or rocks, it turns out they can be satisfied if a particular scale model is subjected to a high enough acceleration to impose stresses in the model the same as those in the prototype at similar points. Thus a 1/100 scale model should be subjected to 100 times gravity (100 g). The only practical way of doing this is to test the model structure in a centrifuge.

*The reader is invited to follow his bent in picking other titles to this discussion. Phrases such as "Soil Testing: Let's Give It a Whirl," "Circular Thinking (Arguments in Geotechnology)," and "Around the Lab in 80 Milliseconds" come readily to the right kind of mind.

This method of testing has assumed considerable importance in Europe and the Soviet Union in recent years, but has not been employed extensively as yet in the USA.

Recently I received a grant from the National Science Foundation to organize and hold a workshop conference in December 1975 on the centrifugal approach to testing to apprise U.S. research workers and engineers of the potential of the method. In my introduction to that workshop, I traced a brief history of the development of certain kinds of centrifuges. An abbreviated version follows:



The 1965 Blonsky Spin-It — an ingenious, and patented, idea for medical use of the centrifuge.

I did a minimal amount of research on centrifuges to find out where they came from and how they got started. The most significant thing I learned was that they were *not* invented by Leonardo. The original idea appears to have developed about the middle of the 18th century, probably in France, in the form of carnival amusements — carrousels, or merry-go-rounds. ("Carrousel" comes from an Italian word meaning a demonstration or parade of horses in a circle.) Probably the reason there were no substantial developments until the 1750's was a lack of machines to power them. Muscle power alone couldn't turn the centrifuge fast enough to give an interesting enough sensation to a rider to induce him to pay for it.* The introduction of steam power in the 18th century gave the impetus to the centrifuge concept in the area of entertainment.

Shortly thereafter the medical profession picked up the idea, particularly for the treatment of the mentally ill. This approach gave rise to a series of centrifuges, some illustrated on the opposite page. The pictures come from various pieces of medical literature beginning roughly in the 1790's. At this time Erasmus Darwin, the grandfather of Charles, first made some comments about using centrifuges in the treatment of mental patients. The idea caught on and there are a number of references in medical books of the 19th century to apparatus designed to spin mentally ill people in the hope of effecting cures. It is not very clear whether it was the spin or the threat of it that was efficacious; a certain amount of progress was reported.

One thing that interested me was that Darwin apparently started the medical merry-go-round (which continues) because of a conversation he had with a famous civil engineer of his day, James Brindley. Brindley had made the observation that some farm workers would lie across a rotating millstone (they got stoned) to induce sleep. I suppose it was a variation in their daily round. An antic high. In point of fact, as the aviation people learned, the farm hands were experiencing negative g's and were actually losing consciousness.

Interest in centrifuges in the medical business continues. The example above is from a 1965 U.S. patent obtained by a New York mining engineer and his wife. They devised this equipment for facilitating birth by centrifugal force. The prospective mother, waiting for life's cycle to be repeated, is placed on the revolving platform and whirled around under the direction of an obstetrician. It's not quite clear where he would stand* and what he would do. Perhaps he jogs, keeping abreast of the patient, and of course counting the laps. Alternatively, he remains stationary, inspecting the mother's condition briefly by synchronized stroboscopic flash as she zips by. There is always closed-circuit television of course.

George E. and Charlotte B. Blonsky called their machine the Spin-It. Smooth rotation is assured by the use of water ballast, and the baby is received in a padded net. Girl children inevitably become spinsters. Boys are well rounded. In this day of automation, of course, there is one final touch: The baby's arrival switches off the motor and rings a bell. I could see a problem develop were the occasion one of multiple births (circlets). One more instance of spiraling population increase.

In the 20th century the effect of acceleration on the human body became of importance to the aviation and, later, space fields. Many large centrifuges have been built and operated in a number of countries to study the response of human and animal subjects to acceleration loads.

*After this talk I learned that in India a man-powered device like a Ferris wheel carrying a number of riders has appeared at village festivals for centuries. It is driven by a number of men who run up a plank to the horizontal axle, mount a spoke of the wheel and walk out to the end of it. There they drop off and repeat the process.

*"Obstetrician" means "one who stands before."

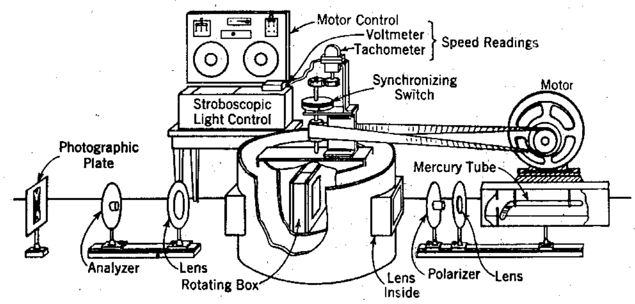
If the scaling relations developed for soils and geological materials apply to biological organisms, then the movements of, say, a human being of normal size in a 2 g field simulate those of a similar organism of twice the linear dimensions in a normal 1g environment. During our meeting in December, one of the engineers from Ames Research Center said that a number of generations of rats had been bred there in a continuous 4 g centrifugal condition. On being asked what were the obvious physiological manifestations when later generations were brought to 1g, he said, "They are good jumpers." It seems to me that this would have a useful application in Calaveras County, or, at a more ambitious level, to steeplechase racing.

Apart from medicine, centrifuges have, of course, proliferated in a variety of fields. They are used in sedimentation studies, biological work, and in industry for separation in chemical applications, and in metal and concrete casting. I will proceed, however, to the application of interest to us.

The idea of using a centrifuge in the testing of engineering models seems to have originated with the Frenchman Edouard Phillipps. In 1869 a short paper by him appeared in the *Comptes Rendus* of the French Academy of Sciences, suggesting that a model of a recent and controversial British bridge, the Britannia, be tested in a centrifuge at somewhere around 50 g in order to determine the effect of gravity on the deformations and stresses in the bridge. Gravitational loads are, of course, the most important factor in bridge design. At the time, the Britannia was the second and largest example of a wrought iron tubular bridge. It was originally proposed to support it by suspension chains, but the designers decided to omit them on the basis of model tests performed on a variety of tubular beams. There was a considerable amount of discussion at the time on the wisdom of this decision and regarding the strength and flexibility of the structure. Phillipps's remarks had apparently been stimulated by a discussion in the minutes of the British Institution of Civil Engineers. It is not clear why it occurred to him to do a centrifuge test. Perhaps a friend had been centrifuged.

It would have been very difficult with the technology of the 1870's to have conducted such a study in a centrifuge. However, with their ingenuity in mechanical gadgets, I think they would have obtained some useful information out of it on, for example, displacements, if, in fact, Phillipps's idea had been implemented.

By the 1920's the whole business of model studies had been placed on a firm foundation with the similarity and dimensional analyses of E. Buckingham and P. W. Bridgman. There seem to be no other references to the technique until the late 1920's or 1930's.



A diagram of the centrifuge built by P.B. Bucky in 1930 for use in testing mining models.

In 1930 an American investigator, P. B. Bucky, at Columbia University, built a small centrifuge and used it for testing some mining models. He examined the stability of tunnels and cavities, using the apparatus pictured above.

About a year or two later, investigators in Russia, apparently independently, took up the same idea, as happens so commonly. Davidenkov proposed the use of a centrifuge in soil studies, and the notion was developed by Pokrovsky and Fedorov. Their area of interest was primarily soil mechanics, and in succeeding years Pokrovsky built more centrifuges and performed many tests in them. They are quite well reported in the European literature in the 1930's. The papers do not seem to have received much attention by Western engineers; it could well be argued that they did not receive the recognition they deserved. Subsequently, the business of centrifugal testing of geotechnical models proceeded in the USSR to an extent which was not followed in Europe or the United States except by Bucky, who pushed on with his mining studies. Following his lead, some work was done by the Bureau of Mines in this country up to the 1950's, but then apparently the centrifuge method was dropped.

In the early 1960's H. Ramberg in Sweden started work on the behavior of geological models in centrifuges, to study the processes of instability in various earth crustal structures. Recently he has examined plate tectonic processes. At about the same time in South Africa, E. Hoek took up the centrifuge idea and began rock mechanics and mining investigations there.

In the 1950's at Cambridge University, England, A. N. Schofield edited a translation of a Russian plasticity book by Sokolovsky. In the book there is a reference to

Pokrovsky's work with centrifuges, which is described by Sokolovsky as "well-known." It certainly was not very well known anywhere else but in the Soviet Union. This remark sparked Schofield's interest, and he followed up by first building at Cambridge a small centrifuge for soil studies. The results were interesting, and he and his colleagues went on to tests on larger specially designed and built centrifugal machines.

The centrifuge is a uniquely useful tool for testing materials such as soil and rock, whose mechanical properties depend on the pressures to which they are subjected. However, the full-scale problems of interest involve structures such as earth dams with dimensions of hundreds of feet. If they are to be brought to manageable size, scaling factors of the order of 100 to 500 are required. At these scales, the larger models are a few feet in size and weigh up to two or three tons. As we have seen, a linear scaling ratio of 100 requires that the model be subjected to 100 g. Consequently, for large tests a centrifuge is required that will bear a payload of a few tons at accelerations of up to a few hundred g. The axial force in the centrifuge arm is then several hundred tons. In a centrifuge rotating at a constant speed, the acceleration at a point in a specimen depends on the radius. This means that different parts of the model are subjected to different accelerations, which violates the similarity conditions and is therefore undesirable. A large radius (a few meters) minimizes the effect.

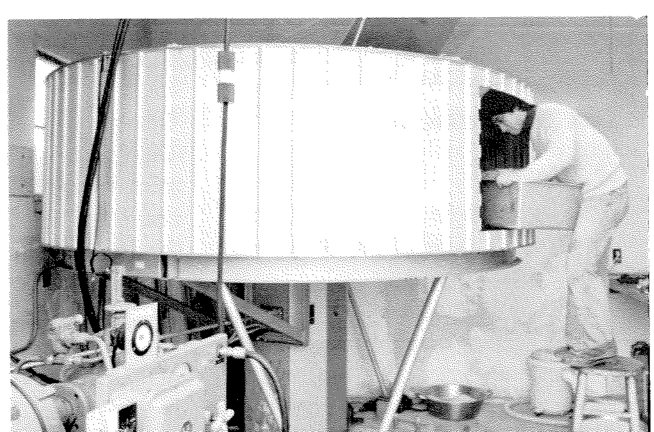
The result of all these considerations is that centrifuges designed for geotechnical testing are large and potentially dangerous. Careful checking procedures to ensure adequate balancing and structural integrity are required. In practice, the large machines are usually constructed in concrete-lined circular pits. At present in England there are large machines at the University of Manchester, University of Manchester Institute of Science and Technology, and at Cambridge University, as well as a few smaller machines. A recent Russian paper mentions "several dozen" centrifuges in the Soviet Union, where they seem to be employed in relatively routine testing applications.

Interest in the centrifuge as a geotechnical testing device seems to be stirring again in the United States. If we get back into the technology that Bucky pioneered here in 1930, one could say that we have come full circle.

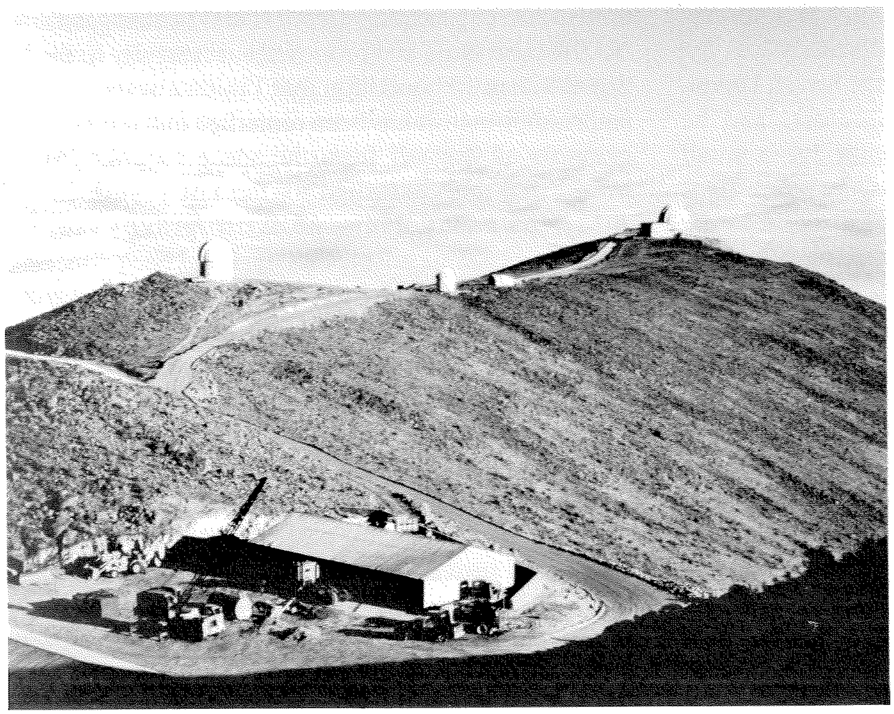
I spent the year 1972-73 at Cambridge, and while I didn't work on the centrifuge they were using, I was interested in what was going on there. It seemed it might be a useful tool for dynamics studies in the earthquake engineering area. I found I could get a small NASA centrifuge and proposed successfully to the National Science Foundation that I initiate some dynamic soil studies in it. It has been remarked that this is a good example of spin-off from the space program. We've been using this centrifuge for the last year or so.

My own involvement with gravity in soil experiments came a little earlier. I had been concerned in the early 1960's with the question of how soil would behave under lunar gravity (about one-sixth of earth's). Apart from a purely scientific interest, there was a great curiosity at the time in certain circles as to how far various lunar vehicles and astronauts would sink into the lunar surface. With the surface sampler on the Surveyor unmanned spacecraft, I was concerned with obtaining the mechanical properties of the lunar surface material to answer such questions. The interpretation of the tests that were carried out depended on a knowledge of soil behavior at lunar gravity.

There were two ways of going about obtaining experimental results: One was to mount full-scale apparatus including soil in an airplane equipped to fly arcs at one-sixth gravity. A graduate student, Dr. T.-D. Lu, and I did this. The other was to perform model tests at earth gravity. This method required the apparatus to be one-sixth the scale of the full-size lunar surface equipment. In this instance, the earth acted as our centrifuge. I also suggested at that time that some tests be carried out at accelerations greater than that of earth's gravity, so that interpolations and extrapolations could be made with greater confidence. However, it would have been quite complicated to operate appropriately scaled experimental equipment in a centrifuge at the time, and I did not pursue the thought further.□



Caltech's recently acquired centrifuge is nine feet in diameter and is capable of spinning two 100-pound models at 100 g. The test material in this case is sand.



A New Observatory In Chile

Las Campanas joins Mount Wilson and Palomar

IN 1903 the Carnegie Institution of Washington seriously considered a proposal to establish a major astronomical observatory south of the equator. The project was set aside, however, in favor of one at Mount Wilson in California. Under the guidance of George Ellery Hale, a pioneering series of telescopes resulted: the 60-inch reflector and the 100-inch Hooker Telescope at Mount Wilson, followed by the 200-inch Hale Telescope and companion instruments on Palomar Mountain. Together, they have made possible great advances in astronomy, including much basic knowledge of the universe.

The early idea of an observatory south of the equator was realized on October 6 with the dedication of Las Campanas Observatory in Chile. It joins Mount Wilson and Palomar to become one of three major observatories that will be operated as a group with a combined scientific staff. The joint sponsors are the Carnegie Institution of Washington and the California Institute of Technology.

The project that resulted in this new observatory had its beginnings in 1961, when the trustees of the Carnegie Institution, reviewing the possibilities for new scientific ventures, decided that the most promising approach centered on a large new telescope that might be built in the Southern Hemisphere. It was evident from the start that favored locations would be on coastal mountains of moderate altitude on the western edge of a continent in latitudes about 30° south. Essential requirements were clear skies, stable atmospheric conditions, a congenial relationship with the host country, and freedom from artificial sources of pollution such as dust or the glare of city lights. Site investigations were conducted in Chile, New Zealand, and Australia, and reports of conditions in South Africa and on various islands were carefully studied. It soon became clear that the Norte Chico region of Chile offered advantages superior to those that could be found anywhere else.

Beginning in 1963, successive administrations of the Chilean government have welcomed the Carnegie Institution's observatory project and provided substantial assistance. Site investigations and observatory construction have been conducted with the cooperation of the University of Chile. Assistance has also been rendered by the Associated Universities for Research in Astronomy and by the European Southern Observatory, both engaged in observatory development in the same general region.

Portable site-testing equipment developed in California was used for testing the quality of the astronomical seeing at numerous mountain locations before Las Campanas was chosen in 1968 on the basis of good topography, an exceptionally high percentage of clear nights, an adequate water supply, freedom from both present and future sources of artificial light, and immediate availability.

Las Campanas is in the Sierra del Condor on the boundary between the provinces of Coquimbo and Atacama. The mountain is approximately 40 kilometers from the coast, with a ridge 5 kilometers long and summits ranging from 2290 to 2540 meters above sea level.

The Carnegie Institution originally

planned a 200-inch (5-meter) telescope in Chile, but for economic reasons it was postponed. By 1969, however, it was evident that it would be advantageous to go ahead with the development of the site and to install an initial telescope of more modest size. This crucial step in the development of the project was made possible by means of a substantial gift to the Institution from Henrietta M. Swope, a member of the scientific staff of the Hale Observatories from 1952 to 1968. By her wish, the gift remained anonymous for a number of years.

Essential steps in the development of the Observatory involved construction of an access road from the valley to the west and of a water supply system. Other facilities include an astronomers' lodge, diesel-electric generators, warehouses, and maintenance facilities. Administrative and logistical support is provided through an office at Colina el Pino in the coastal city of La Serena.

The first astronomical instrument of the Observatory was a 40-inch telescope, which has been in operation since June 1971. Observations with it have confirmed the excellence of the site. A 10-inch photographic refractor, long used at Mount Wilson, has also been erected at Las Campanas. In 1970 an agreement was reached that enabled the University of Toronto to install and operate a 24-inch telescope on the ridge.

In December 1970, Mr. and Mrs. Crawford H. Greenewalt made a gift of $1,500,000 to the Carnegie Institution to initiate construction of a 60-inch or larger telescope to be designed by the staff of the Hale Observatories and constructed at Las Campanas. The Institution decided to provide the funds necessary to make this a 100-inch instrument. The telescope was to be named for Mrs. Greenewalt's father, the late Irénée du Pont.

In January 1971 the Observatory staff began work on the design and development of this new instrument. The optical design was the work of Ira S. Bowen, former director of the Mount Wilson and Palomar Observatories, in collaboration with Arthur H. Vaughan (who has been named assistant director for the Las Campanas Observatory), and the Hale staff. The special coudé system was devised by Horace W. Babcock, the present director of the Hale Observatories. Bruce H. Rule, project officer and chief engineer, assembled an engineering group to design the telescope and oversee its construction. He also directed installation of the instrument in its dome in 1975.

The design of the Irénée du Pont Telescope incorporates many concepts that have been evolved from its predecessors at Mount Wilson and Palomar: a short, stiff tube structure using the Serrurier truss, a fork mounting for compactness and convenience, and thin-film pressurized oil bearings for low-friction support of the polar axle, to mention a few. It also has many new features such as a special Ritchey-Chrétien optical system with a Gascoigne corrector that gives an exceptionally wide field (2.1° in diameter) for direct photography at the Cassegrain focus, a radically new coudé optical system to provide maximum efficiency for observing the south polar region of the sky, and an electronic control system employing programmable microprocessors.

The large coudé laboratory room will be fitted with a 10-meter spectrograph, interferometers and special photoelectric receivers, and Schmidt cameras.

The primary mirror is a solid disk of fused silica, 101 inches in diameter and 15 inches thick. The disk was supplied by the Corning Glass Works. It was optically figured under the general supervision of the Hale Observatories at the Optical Sciences Center of the University of Arizona.

Every effort has been made to match the quality of the telescope to the unsurpassed natural conditions at Las Campanas. Because of the excellent atmospheric conditions, star images as small as one arc-second are frequently obtainable, and it is expected that on rare occasions images one-third that size may be encountered.

The microprocessors of the telescope's electronic control system interact with the many switches, motors, encoders, and indicators that set the telescope accurately, move the dome and windscreen automatically, provide correct rates for driving the telescope, and assist the astronomer with data acquisition. Automated controls and sensing devices will permit much of the observing to be done remotely, with the astronomer in the control room adjacent to the observing floor. An integrated closed-circuit television system permits guiding on very faint objects.

The Cassegrain focus, where a great deal of the observing will be done, is equipped for direct photography with plateholders of various sizes up to 50 centimeters (20 inches) square. An instrument adapter accommodates spectrographs and photometers.

Every large telescope needs an ongoing program of auxiliary instrument development. Two of the basic auxiliaries for the du Pont Telescope are a fast spectrograph and a digital photometer. The fast spectrograph, a grating instrument offering intermediate and low dispersions, has an image tube that can be interchanged readily with other devices such as a SIT (silicon intensifier target) Vidicon system. The photometer is a multi-filter, two-channel digital instrument designed for star-sky switching. A special system for observing at infrared wavelengths from 1 to 20 microns is being constructed.

A "flip-top" at the upper end of the telescope permits quick changes between the Cassegrain secondary mirror and the smaller coudé secondary. The telescope's unique design provides a coudé system with only three reflections for the southern part of the sky instead of the usual five. It should make the system unusually efficient.

The du Pont Telescope is an important addition to the worldwide array of large reflectors. With its very wide field and its ability to record faint limiting magnitudes, combined with its eventual coudé capability, it is especially suited to tackle certain problems related to the chemical history of galaxies, particularly of the Magellanic Clouds. These problems, in turn, are related to the understanding of galaxy formation in an evolving universe. □

In Memoriam

James Olds
1922-1976

A Tribute by Mila and Arnold Scheibel

James Olds, Bing Professor of Behavioral Biology, died in a swimming accident on August 21.

WE FIRST got to know Jim Olds against the background clatter of half a hundred rats seeking heaven or risking hell, and, to our unaccustomed ears, his self-stimulation laboratory sounded like nothing so much as a great secretarial typing pool whose staff had reverted to hunt and peck.

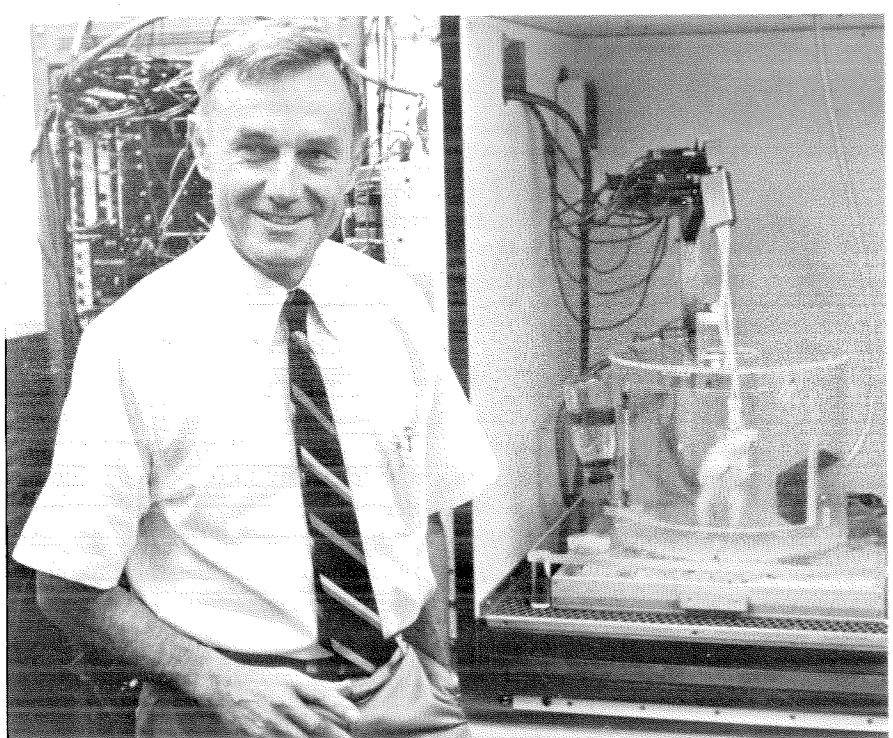
It was 1956, and the place was a one-story, frame, ex-bachelor-officers' quarters on the Brentwood VA Hospital grounds — one of the innumerable "temporary" buildings whose status had become uncertain and whose term was open-ended. We found that Jim had been given the west wing, as we had the east wing, and biochemist Sam Eiduson, the north. Our laboratory environment cycled with the season, murderously hot in summer, frigid in winter, uncomfortable always but, at least, plenty of space to be uncomfortable in. And we found that Jim and Nicki could be quite as uncomfortable as we; so misery's bond developed first, soon to be replaced by other bonds more enjoyable and meaningful.

Jim thought hard and moved fast, and we wondered at the almost machine-gun rate at which he turned out implanted rats to join the performing flock and give him further data points.

Jim's coming had been much heralded among the small UCLA neuroscience community, still under the thrall of the epochal discoveries by Magoun from the previous decade. Much was expected of the new psychologist from the North, this "Elvis Presley of Neurophysiology," as Robert Heath had called him. And Jim was no flash in the pan. His lab materialized quickly and his operation grew, and students and technicians were soon working the same long hours as the young master.

We often talked to Jim in those days, sprawled on the laboratory steps in the early evening, drinking coffee after midnight, or cussing mutually over a central animal room that always smelled like one. Little was understood about his discovery at the time. While many of us saw it as a fundamental element in a new psychophysiology of hedonism, there were some to whom it seemed more like an electrode artifact, or perhaps the result of a local epileptic seizure.

Mila and I were involved in a study of the longitudinal systems of the reticular formation, and we stressed — although we needn't have — the importance of understanding the phenomenon within the matrix of its substrate structure. We needn't have, because Jim was already asking the same question of us. And while we hadn't gotten that far rostral at the time, we promised to show him what we saw at the mesodiencephalic junction and beyond.



With a lengthy detour through the structural and functional basis of neural maturation in the kitten, it was to take us almost six more years to reach that portion of the brain stem with our structural studies. And by that time Jim was long since gone, attracted to Ann Arbor by a dynamic neuroscience program and the chance to be his own master. Temporary building T-45 was never quite the same without Jim's quick step and contagious laugh and — perhaps in part as a result — the area is now just one more VA parking lot.

Thinking of Jim, and trying to integrate the loss we all have suffered, it's easy to say that he was bright, fast thinking, a sparkling wit, and a tender friend. But one has to stop a moment to appreciate the enormous insight involved in making the right deduction and taking the appropriate action on the chance observation that an implanted rat returned by choice to the same spot in the cage where he had received a brief electrical stimulus to his brain. From the beginning, his work had elegance and there were few lost motions. In fact, we doubt that Jim ever did a trivial experiment or asked an inconsequential question. How many of us can say the same?

Some time after Jim and Nicki returned from Ann Arbor to Caltech, we began a new type of relationship that continued until we lost him. While we seldom saw each other, we telephoned each other often, and while the specific subject area was usually different, the question was, somehow, always the same. "Jim, Nicki, what do you think the raphé cells are really doing?" "Arnie, Mila, what is the thalamus really there for?" . . . or why is the cortex organized in columns? . . . or can we think holistically about the medial forebrain bundle? . . . or any number of others.

As psychiatrically trained people, we had tried to structurally blueprint our way toward the organic bases of behavior. As a psychologist, Jim was trying to plot out the functional substrate. But our work led us by steps toward function, and his pressed equally toward structure. Our points of departure were different but eventually led toward common ground.

No matter how often we spoke, we wondered at the speed of his associations — and the color of his images, for he drew on a wide palette. He did more than speak to you; he fired at you. And the thoughts were interrupted only by the familiar "Do you follow me?" or, "See what I mean?" He was creative and synthetic, and he often created faster than he could find the words for shaping. Again, elegance and insight were the words that best described him intellectually.

He called us just a week before he lost his life and asked about something we had done on the possible thalamic substrates of body image. We were in deep water, and he was too, but since we all knew it, there was no harm. When we finished, he said again what he had recently begun to say many times over. "It's the anatomy that will tell the story. One of your structural figures may contain hundreds of bytes of information, while a whole series of our experiments may give us only one or two. Damn it! I should be doing what you're doing. I'm in the wrong racket!"

But he had *never* been in the wrong racket. From those early observations with Milner, his work maintained drive and cohesion, and the system that he put together for us is so certain that today few high school biology students can be found who do not know of "the pain and pleasure centers in the brain."

As one looks back over the quarter century that frames his work, it takes on the aspects of a symphony — the statement in movements — varying in texture — but logical and inexorable in development.

His song is over, but what a song it was.

Mila and Arnold Scheibel are both MD's. Dr. Arnold Scheibel is professor of anatomy and psychiatry at UCLA.

Roger Stanton

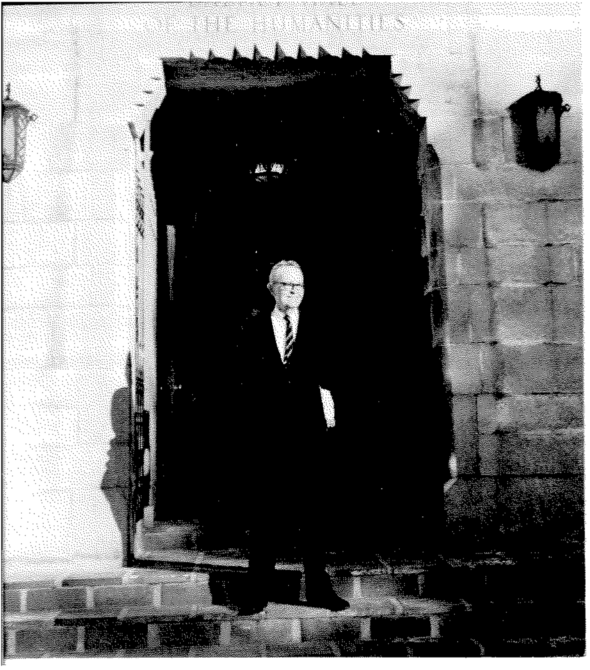
1898-1976

A Tribute
by Kent Clark

In February 1951, Roger Stanton, then Director of Institute Libraries, issued a plea to the faculty, alumni, and friends of Caltech. He intended, he said, to establish central archives — a collection of documents relevant to the history of Caltech — and he needed help from everyone who had records to contribute. The history of Caltech, he explained, constitutes "an exhibit of human achievement"; and the story of Caltech as an institution, he implied, is as fascinating and instructive as some of the arcane knowledge the Institute has produced. What Roger Stanton did not say (and probably never thought) as he began to assemble the now-voluminous archives was that his own career would make a bright chapter of Caltech history. In retrospect, however, this fact is obvious enough.

Roger Stanton, who died on July 26, came to Caltech in 1925 as an instructor in English. Armed with an MA from Princeton, a BS from Colgate, and one year's teaching experience at Colorado College, he launched into a career of teaching composition and literature to Caltech undergraduates. In this enterprise (roughly equivalent, many believed at the time, to bringing classic culture to the Ostrogoths) he was joined the same year by another bright young instructor from Princeton, L. Winchester Jones. The two men, soon to be known to all Caltech simply as Roger and Winch, were hired by Clinton Judy to strengthen the humanities program, and it was expected that in a pinch they could teach anything from Greek literature to contemporary history. Since Dabney Hall would not be completed until 1928, they were assigned to an office in West Bridge, hardly big enough (Winch recalls) to accommodate two desks and the pipe that Roger then affected, but adequate for the establishment of a lifelong friendship.

Along with an addiction to literature, Roger brought with him a passion for music and live theatre. Through his musical interests, he naturally gravitated to the Coleman Chamber Concert organization, and eventually served for 11 years on its board of directors — helping to establish the pattern of cooperation between Caltech and Coleman that still continues. Through his interest in theatre, he became acquainted with Gilmore Brown, the director of the old Community Theatre, then on Fair Oaks Avenue, and for about 10 years he acted in Brown's productions. In the thirties, he became co-director of Caltech student productions. The plays he directed, classical comedies by Plautus and Terence, are still remembered by Caltech veterans with something between admiration and awe. George MacMinn once said, in effect, that anyone who has missed seeing Techers clad in togas leaping about Culbertson Hall has never been truly happy. And Winch Jones has said, more recently,



that the polish of the productions was amazing — especially to Caltech professors accustomed to hearing their students mangle the language. To hear students declaiming Plautus with flawless rhythm and diction was enough to make English instructors weep.

In the late twenties Roger returned to Princeton to take a PhD and in the process made one of his greatest contributions to Caltech history. At Princeton he met his now-legendary friend and colleague Harvey Eagleson and influenced him to come to Caltech. Eagleson, in turn, recruited his friend Bill Huse. The result of this chain reaction in serendipity was to provide the new Dabney Hall with a remarkably versatile English staff. Under the wise and benign guidance of Clinton Judy and George MacMinn, the team of Stanton, Jones, Huse, and Eagleson soon established a formidable reputation for its teaching ability and for its effect on the social and cultural ambience of the Institute. To this happy combination Roger brought his own particular brand of discriminating taste and a wide variety of cultural experience. In the days before travel grants, he traveled a good deal, both in Europe and in the United States and Mexico; and he had an eye for art, architecture, and gardens to go with his interests in literature, history, and music. He became something of an expert (though he never claimed to be one) on everything from Norman farmhouses to the preserving of kumquats. While he guided his students through the mysteries of the English sentence or the philosophy of Browning, he was able to carry on a persistent, unannounced (and sometimes successful) campaign against provincialism.

Though Roger's tastes were highly literary, he did not contribute to literary journals; his published writing, done mostly for the benefit of the Institute, was chiefly technical and historical. During World War II, he collaborated with Henry Borsook on a series of articles on foods and nutrition, and shortly after the war he produced a 40-page history (which he describes as a publicity release) of the then-infant JPL. His later writing, both published and informal, dealt principally with libraries and the handling of scientific-historical documents.

In 1948 Roger accepted, on a temporary basis, an appointment as Director of Institute Libraries. This assignment, one of the best temporary appointments in Caltech history, was to last for 13 years. The range of Roger's interests, his devotion to clarity and order, and his knowledge of the Institute, along with much patience and quiet tact, enabled him to deal effectively with some crucial problems of growth and development: the planning of a central library to replace, or supplement, the scattered divisional libraries, the expansion of library holdings, and the modernization of techniques, to name only three. With a great deal of help from his friends on the faculty and an excellent library staff, he laid the essential groundwork for a new library system. At the time of his retirement, in 1966, he was inclined to regard his library service, next to his years of teaching, as his most significant contribution to Caltech.

Typically, as a collector of Caltech records, Roger was concerned with everyone's records except his own. His files in the faculty office and the humanities division consist principally of two vitae, one filled out in 1943 and the other in 1963. Both are as terse and laconic as telegrams, and although both contain some rare bits of information, they bear about the same relationship to the variety and texture of Roger's life at Caltech that an armload of bricks bears to a completed mansion in San Marino. They duly record the fact that Roger Fellows Stanton was born in Pittsburgh in 1898, that he received his secondary education at the Peddie School in Hightstown, New Jersey, that he came to Caltech in 1925, that he served on many committees, that he eventually went through all the ranks from instructor to professor. They also record, more unusually, that he served three months in the U. S. Army at the close of World War I and that for a year after his graduation from Colgate he worked as a bond salesman (of all things) for Security Bank in Los Angeles. What they do not record, or even hint at, is the complexity of his interests and accomplishments or the personal friendships and commitments that defined his relationship to the Institute. One item contained in both vitae, though perfectly true, should probably be revised. In reply to the question *Married* or *Single,* Roger correctly answered *Single.* Like his friends Harvey Eagleson and Don Clark, he was a lifelong bachelor. Perhaps it would be appropriate, however, if at least on the Divisional copy of the record his answer was changed to *Married, California Institute of Technology, 1925-1976.*

Kent Clark is professor of English at Caltech.

Jerome Vinograd

1913-1976

A Tribute by William R. Bauer

JEROME VINOGRAD, who was recently named the first Ethel Wilson Bowles and Robert Bowles Professor of Chemical Biology at Caltech, died at the Huntington Memorial Hospital on July 3. His death at the age of 63 was unexpected, even though he had previously experienced two major heart attacks during his 25 years at the Institute. Jerry is survived by his wife, Dorothy, and by two children by a previous marriage, Julie and Deborah.

Caltech was only about half its present size in 1957, and Jerry Vinograd had been a research associate in chemistry for about a year, when I arrived on the scene as a freshman. My initial plan had been to become a nuclear physicist, but that was before I had actually taken freshman physics. Verner Schomaker, who was my faculty section advisor in chemistry, suggested that I consider trying a research project in protein chemistry.

First on the list of names he gave me was that of Dr. Jerome Vinograd, and I remember making my way to the dimly lit subbasement of Church lab for our first encounter. He was very distinguished in appearance even at the age of 44, with snow-white hair ("you can always spot me in a seminar room") and an enthusiastic twinkle in his eyes. He started to explain his research, which was then concerned with the subunit association in hemoglobin, and before I knew it two hours had elapsed. Two hours with a freshman. For the first time Caltech had become a very friendly place, and I was hooked.

Jerry always dealt with others, scientists or not, on the basis of respect for their abilities and genuine interest in whatever they had to offer. Once, upon returning from an otherwise dull meeting in Washington, he waxed enthusiastic about a chance conversation with a labor leader while waiting for the return flight at Dulles. He was excited because he had learned something new — how a very different sort of person thinks and operates.

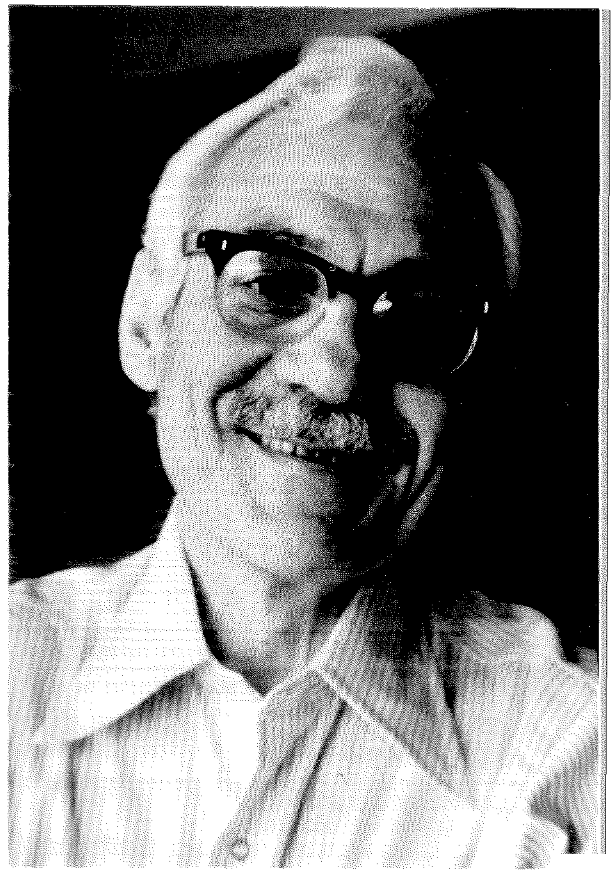
For Jerry, the method of dealing with a problem was of the greatest importance, and he was always concerned with fairness and propriety. This concern applied to science itself, to dealings with his colleagues, and to more everyday affairs. One of his most important characteristics was complete honesty, both intellectual and moral. The discovery of a new concept, or rather the concept itself, was of greater importance than the identity of the discoverer; and the members of his research group were encouraged to share even preliminary results, as soon as sufficiently well grounded, rather than to live in an aura of secrecy. Since leaving his lab, I have come to treasure this philosophy, which emphasizes the excitement and fun of research.

Jerry Vinograd's scientific career resolved itself into three major periods: before his arrival at Caltech, when he worked as a research chemist for the Shell Development Co. in physical and colloid chemistry; the period between 1951 and about 1960, during which he studied the behavior of gelatin gels and various proteins, and when he made several substantial contributions to the development of ultracentrifugation; and the more recent years, when his attention was focused upon the structure, replication, and enzymology of DNA. Jerry's later work shows clearly the mark of his earlier training in physical and organic chemistry, and his papers are outstanding in molecular biology for their rigor and exactitude.

One of his greatest assets was the ability to break down intellectual barriers and to apply what he had earlier learned about one system (detergent micelles, say) to another (DNA). He was able to pass on this ability to his students, and he was a truly great teacher in the classical sense.

Among his many major contributions to molecular biology was the development, with the help of several collaborators, of density gradient centrifugation in concentrated salt solutions. This technique, applied under conditions of either equilibrium or of the steady state, has been responsible for many of the subsequent major advances in nucleic acid chemistry and biochemistry.

He was the first person to understand that circular duplex DNA acquires special topological properties when both strands are covalently closed. These DNAs, which often possess a tertiary structure and which contain a new kind of chemical bond, a topological bond, have turned out to be of extreme importance in molecular biology. He provided the primary leadership in this field until his death, with later work including the replication of the closed



circular mitochondrial DNAs and the enzymology of closed DNA. His initiative and imagination will be sorely missed.

In retrospect, however, Jerry will be missed at least as much for his personal qualities and great warmth of personality as for his scientific accomplishments. Throughout my lengthy sojourn in his laboratory as an undergraduate, graduate student, research fellow and (finally) collaborator, I was present as he grew in recognition from being a relatively obscure research associate to holding an endowed chair, becoming a member of the National Academy (along with a host of other honors and awards), and acquiring an undisputed place of importance both at Caltech and nationally.

All this had little effect upon his character or upon his approach towards dealing with others, and the youthful enthusiasm was still there when I last talked to him, on July 2, just as it had been in December of 1957.

He was loved and admired by his many friends, and he will be greatly missed.

William Bauer (BS '61, PhD '68) is an associate professor in the department of microbiology at the State University of New York, Stony Brook.

probably with a backup computer in another part of the country).

Example 7 concerns goods movement. Goods movement by fuel-efficient combinations, like rail plus truck, is currently inventory *in*efficient because of great uncertainty as to when a shipment will arrive. This occurs because shipments, and indeed whole freight cars, are lost track of for days, and often weeks. The problem will be remedied only when computers begin monitoring and providing efficient *continual* management of each shipment from its origin to its destination — managing loading and transferring and train makeup and train movement. The first step was to paint a code on every freight car. This has now been done: You can now see, on every freight car that passes, a series of colored horizontal lines painted on its side; and code readers are deployed throughout the rail network. These constitute the "sensor" input to the computer. Dozens of independent railroads are cooperating to take the next step. They have a long way to go.

Example 8 addresses electric power consumption. Power companies must provide the region they serve with electricity by drawing on many sources — steam turbines using oil or coal, gas turbines for peak loading, hydro (waterfalls), perhaps some day also solar collectors, windmills, and others. And they must make prudent use of energy storage if more than a few percent is to come from wind or solar power.

To see how the computer saves oil, consider a simple hydro-plus-oil system. With reasonable manual control, the part of the load provided by oil is found inevitably to show high overloads at peak hours. These must be met with fuel-expensive oil-burning auxiliary generators. But with a computer optimizing the mix, oil need provide only the *average* sector of the energy, because the computer, knowing with precision about all parts of the system, can draw on hydro at just the right time to avoid the inefficient oil-based peaking.

Another way to avoid peaking is by smoothing out the demand — by "load leveling." There is a particularly good idea called "load shedding," which began with individual industrial companies noting that the charge for electricity use is scheduled in steps based on the amount used in each half hour interval. The companies contrived to have a computer turn off non-essential equipment, by priority, just long enough each half hour to avoid the next step in cost. Two companies that are friends of Caltech pioneered this idea — Thompson-Ramo-Wooldridge and Lockheed Electronics — and others are probably now in the market.

Here's how it works at TRW's Tapco Plant near Cleveland: The computer has been told that air conditioning has lowest priority; it can be turned off for five minutes of every half hour and will hardly be missed. Next lowest priority is the air compressor, because there is an accumulator that can be turned off for a short while. Then come certain presses and furnaces in this particular factory. So the computer cuts things in and out by priority whenever it predicts that the maximum allowable demand would otherwise be exceeded.

How do the power companies like this idea? In the city of Burbank, where Lockheed employs the scheme, the utility company found two problems from the city's viewpoint. First, many little companies in Burbank that couldn't afford the computer were not getting the same advantages from load shedding as the big companies. Second, everybody was shutting off their equipment all at once at the end of each half hour. However, the savings inherent in the Lockheed scheme were obviously impressive. So the City of Burbank Utility Company is in the process of putting together a deal that it will make with Lockheed, as well as several film studios, NBC, and numerous manufacturers in Burbank. The city plans to propose a rate reduction for each plant, in exchange for which the city, from *its* central computer, may cut out certain of that plant's equipment already agreed to ahead of time — and for only the length of time that plant has agreed to. The signal for doing all this can move through the existing 60-cycle power line, so very little additional equipment needs to be installed.

With the resulting savings in peak power requirement, the City of Burbank expects to be able to delay purchase of costly new generator equipment by as much as seven years — a very important saving.

LEVEL III: UNDERSTANDING ECONOMIC RELATIONS

At Level III the computer has only one role — to provide better understanding of economic relations and of how energy can be most prudently used. Computer "management" of human affairs is antithetical to a free society.

Example 9 concerns strategies for energy-efficient transportation. This concerns a 1971 study done at the U.S. Department of Transportation's Transportation Systems Center in Cambridge, Massachusetts, to improve everyone's understanding of which strategies would significantly reduce energy consumption by transportation — and which would not. (Transportation uses about two-thirds of our petroleum.) The study quickly found, of course, that highway vehicles are the major culprits. After looking at over 50 possible strategies, some first estimates were made of what could and could not be done to save significant amounts of this energy.

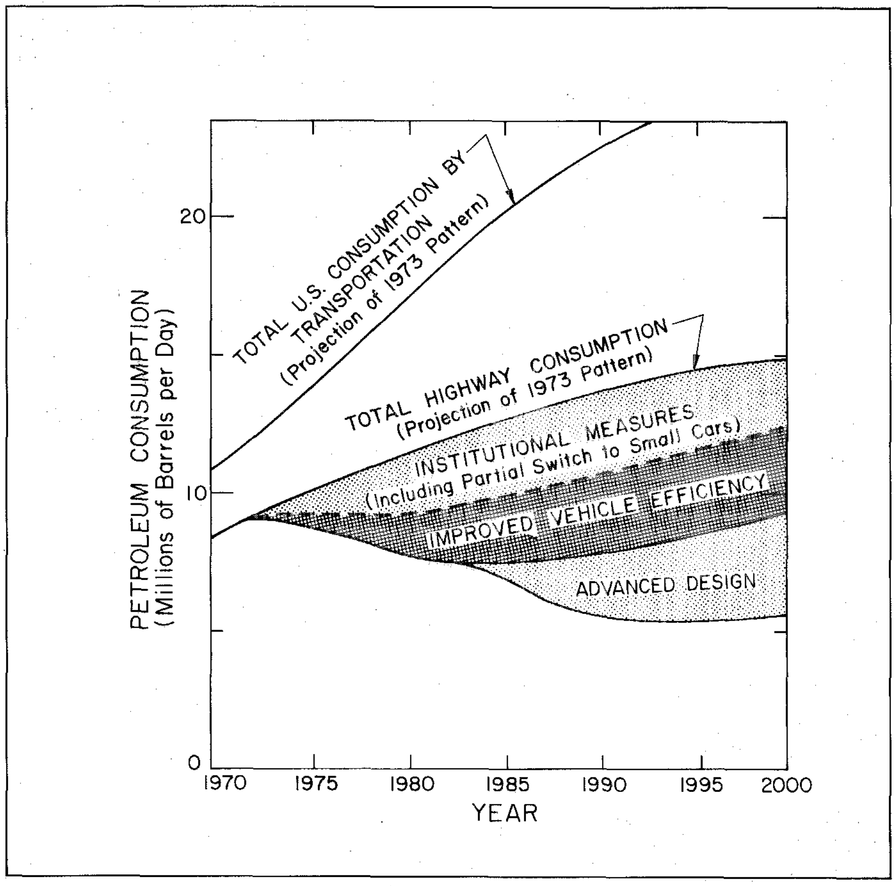
When the OPEC crisis hit two years later, the study suddenly got a lot of attention in Washington, and the Cambridge Center was asked to select some short-term winners from the strategies that had been studied. Carpooling and the national 55-mile-per-hour speed limit were quickly singled out. These could produce savings of about 4 percent on the automobile's consumption of energy, and that is a big saving.

The Center had also made a first projection of what longer-term strategies could save how much energy. These included reducing air drag (on which Anatol Roshko's group has done important research here at Caltech), proper transmissions, lighter materials, radial tires, and, of course, combustion controls. Beyond this, there can be additional improvements from new engines and other new technology that will take longer — a decade — to find their way into the fleet. The auto companies provided part of the data for these studies, which addressed not only technological improvements but fleet-mix versus time, retooling times, and so on. We checked all these data at the Center against our own measurements and estimates and every other source of data and judgment that we could find.

Based on this computer simulation of projected national energy consumption by automobiles, President Ford called for a new-auto efficiency improvement of 40 percent.

The role of the Center — and of the Department of Transportation — was to provide the government with some understanding of what actions were likely to pay off. But DOT depended (with some regulatory teeth) on the private auto industry to create and initiate the new engineering to improve the fleet. That's how it ought to work.

Moreover, it is important to realize that simulation of an economic system is really different in kind from simulation of a power plant, or an aircraft, or of an air traffic control system. Simulation of physical systems has been developed to a highly reliable art. The stability of an aircraft can be predicted precisely before it is ever built. Landing at the Seattle airport can be experienced with rather high fidelity inside a building in Denver. But with simulation of economic systems, such confidence is far from possible. Indeed, done without extreme prudence, presented without humility, and accepted without the most sceptical judgment, economic simulation could be downright perilous.



A computer simulation of projected national consumption of petroleum by automobiles indicates some of the strategies that might lead to improvements in our energy situation.

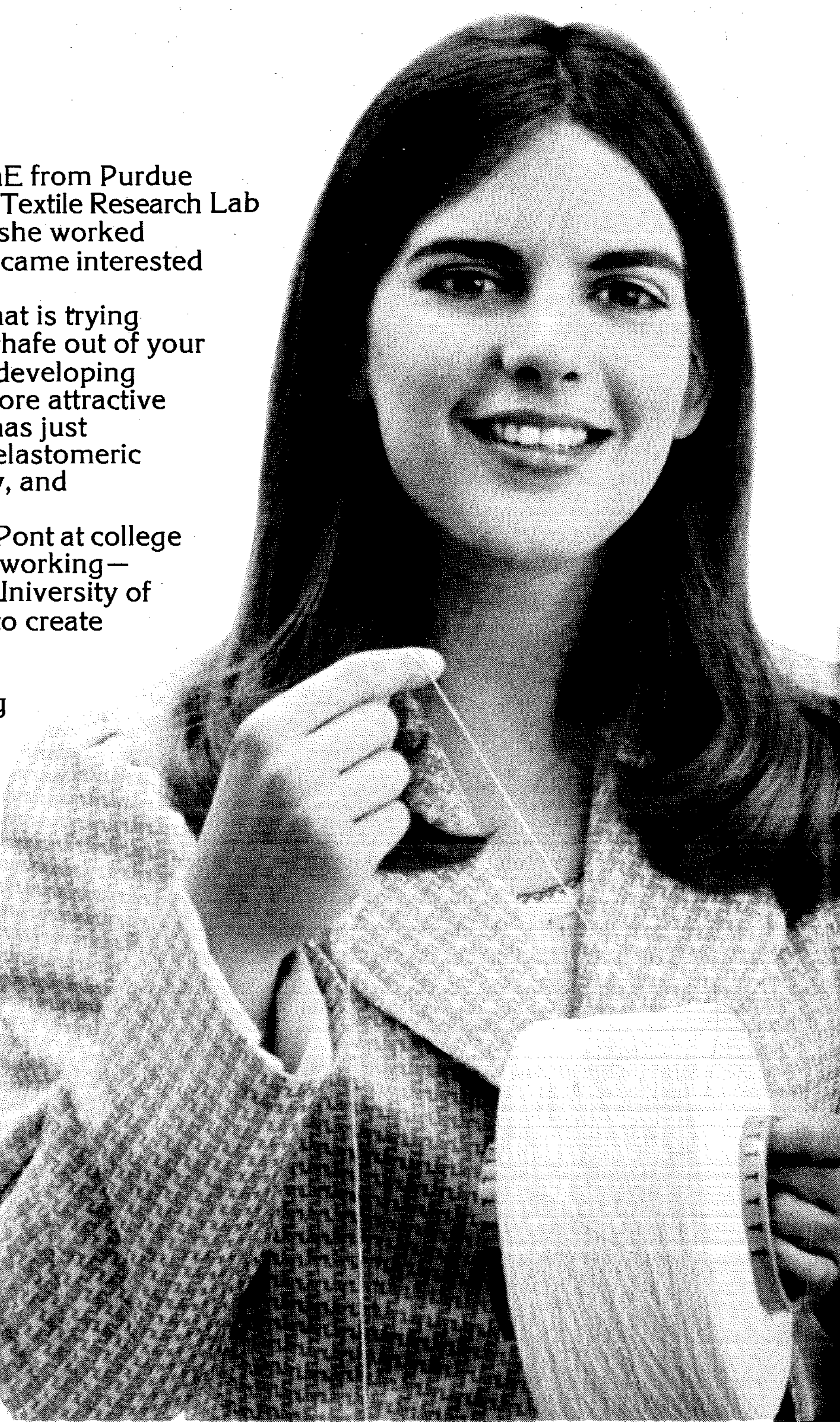
Recently some progress has been made in economic modeling. The progress has come from one thing: Computers can now handle massive amounts of data about the economy — about what is built, what is purchased, and what energy is used. These data can be used through a technique called "regressive analysis" to test various models on the computer in order to get some idea of what might happen. But the uncertainty is very great. There is an even more fundamental difference: There is no direct way to do an experiment, and experiments are vital for a reliable model. The economic system involves millions of people exercising free choices — people in all their splendid inscrutability. We have only the most approximate models for these phenomena. Moreover, and above all, individual privacy must be rigorously protected.

Can we, then, simulate in any useful way the behavior of the economy under various assumptions? I think the answer is: only in certain respects, only with large uncertainty, only where massive and reliable data are available, and only if the very best human judgment, caution, and humility are brought to bear.

What simulation can do is establish the boundaries of what is possible. And it can help predict, quantitatively, some pitfalls. It can, for example, combine a mass of estimates of earth's natural energy resources and other information about production and market, and can produce some understanding of the environmental and safety costs of pursuing them.

But, limited as they are, these are still important advances, important helps to our understanding. We must draw on this new tool to help us manage our data and — with care and scepticism — help us organize our understanding. For the stakes are high, and we need to bring to bear every tool we have.□

Cathy Hamilton is trying to take the bind, chafe, and pull out of your life.



Cathy is 23 years old. She's a BSChE from Purdue and has been working in our Chestnut Run Textile Research Lab since January, 1973. Before graduating, she worked a summer in process development and became interested in customer service.

Right now Cathy is part of a team that is trying to take the bind out of your beltline, the chafe out of your collars, and the pull out of pantyhose by developing new, more comfortable, more durable, more attractive fabrics for clothing. For example, Cathy has just completed a project that will result in an elastomeric fabric with greater stretchability, recovery, and breathability than ever before.

She also finds time to represent Du Pont at college Women's Opportunities Seminars. She is working—with Du Pont's support—on her MBA at University of Delaware. And, she finds the spare time to create all her own fashions.

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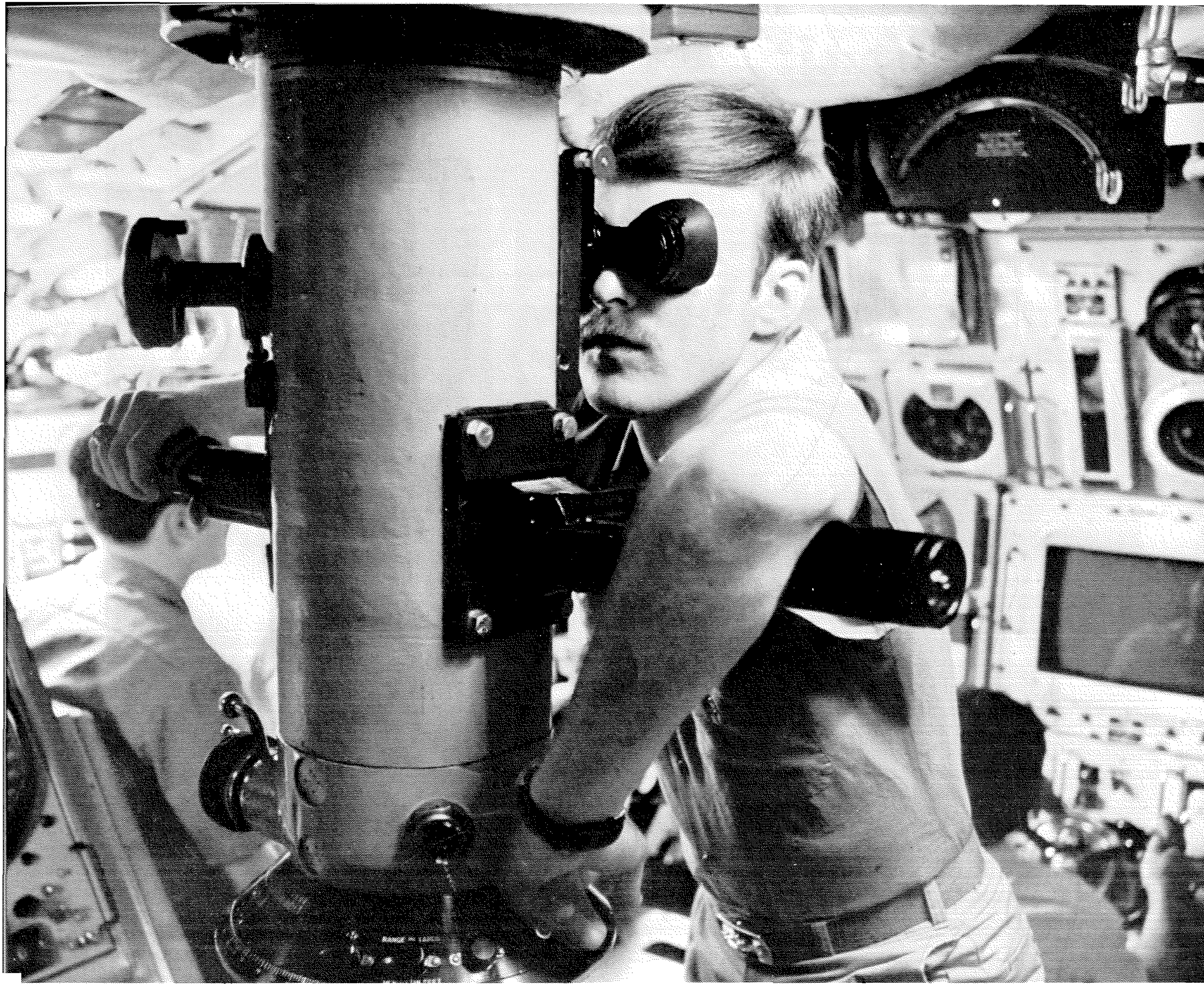


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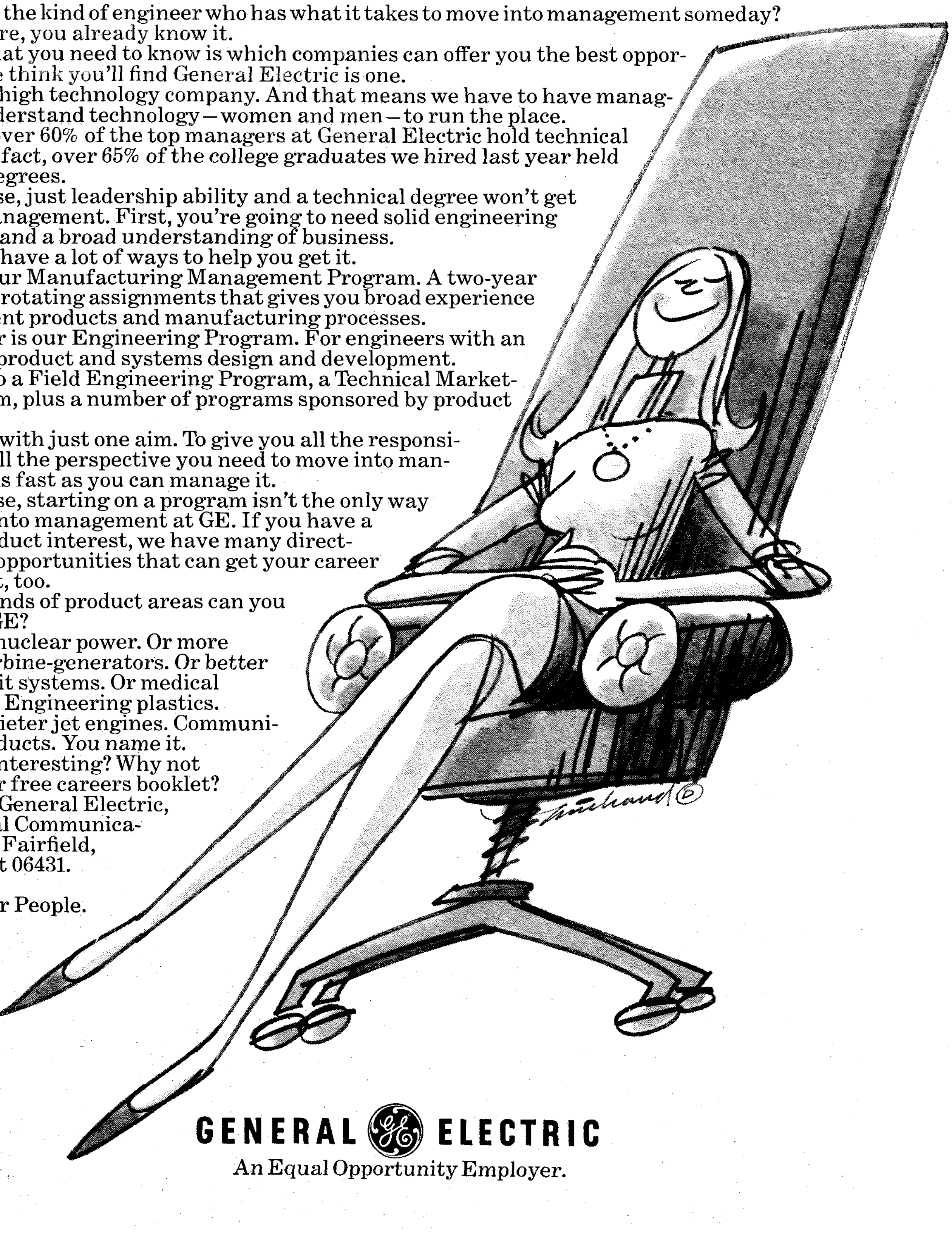

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