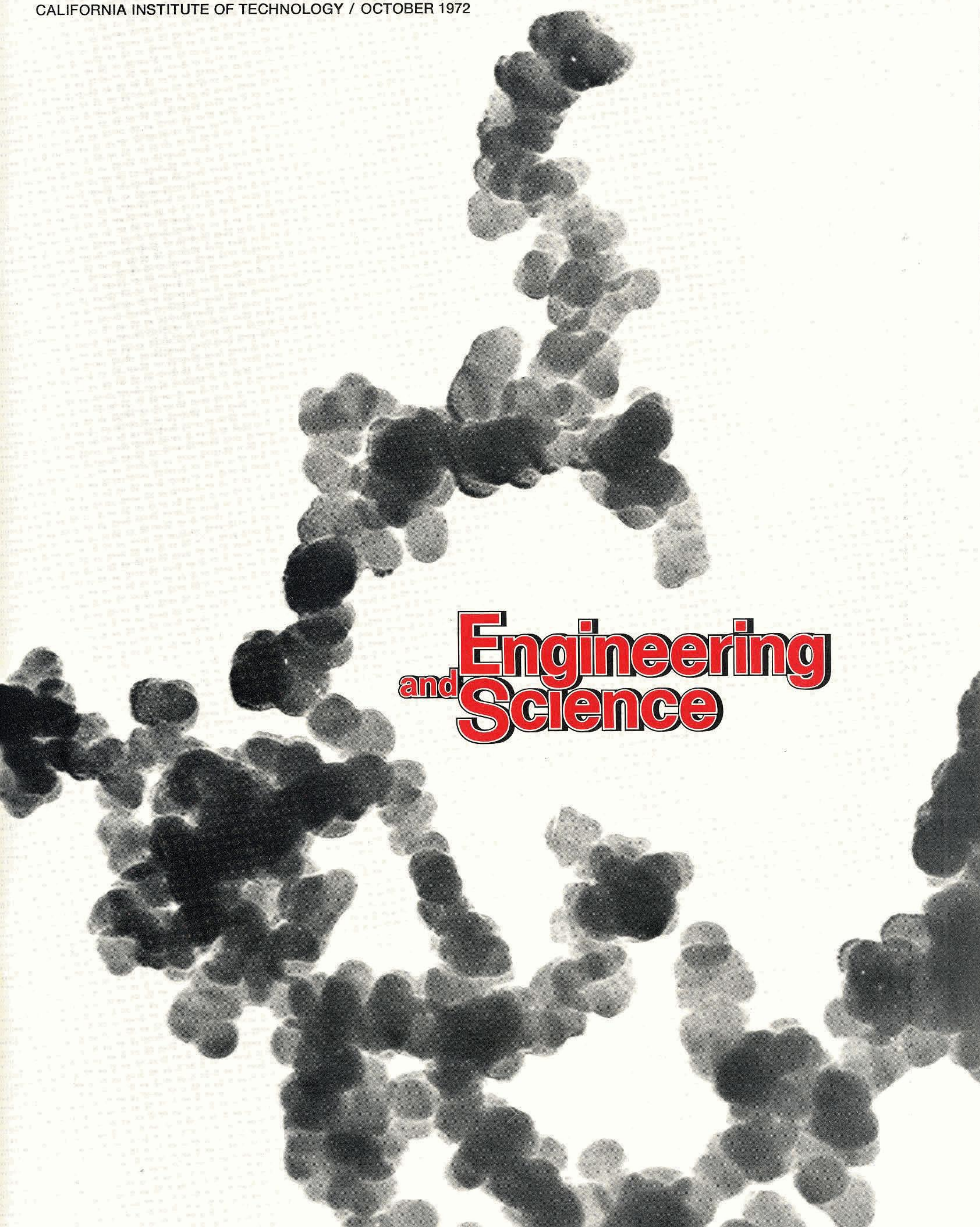
CALIFORNIA INSTITUTE OF TECHNOLOGY / OCTOBER 1972

Engineering and Science



OCTOBER 1972/VOLUME XXXVI/NUMBER 1

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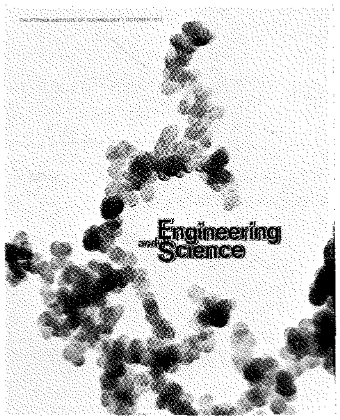

In this issue

Pollution Projects

On the cover—chains of lead halide particles (magnified 700,000 times in this photograph) are among the automobile-produced particulates that have been identified as major contributors to smog. These particular particles were captured from the air above Keck Laboratory and photographed by Rudolf Husar, research fellow in environmental engineering science. Husar is one of 14 Caltech scientists working in two projects to find out exactly how, where, and how fast all types of pollutants disperse through the environment. "Clearing the Air for Pollution Standards" (page 15) describes the programs.

How Do We Know?

Frederick B. Thompson, professor of applied science and philosophy, has been at Caltech since 1965—using his special competence in computational linguistics to help people make sense of their experience. With a background in mathematics and familiarity that has bred respect for the computer, Thompson discusses creativity in an automated society in "The Dynamics of Information" (page 4).

Warm Welcome

"Globetrotting with the Glee Club" (page 8) hits some of the high notes of the European tour taken by Caltech's peripatetic singers last summer.

Like It Is

Annual solicitation of Caltech's alumni was discontinued in 1967. Now it's back, and Donald D. Davidson, BS '38, is chairman of the newly formed Alumni Fund Council, whose first goal is to raise $300,000 for 1972-73. In "The High Cost of Being Good" (page 21) Davidson discusses the Institute's financial needs.

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PICTURE CREDITS: Cover, 15—Rudolf Husar/8-9—David Larwood/10, 21—Floyd Clark/12-13—Anthony Collings/19—JPL/25—David James of *Westways*/All others—Don Ivers

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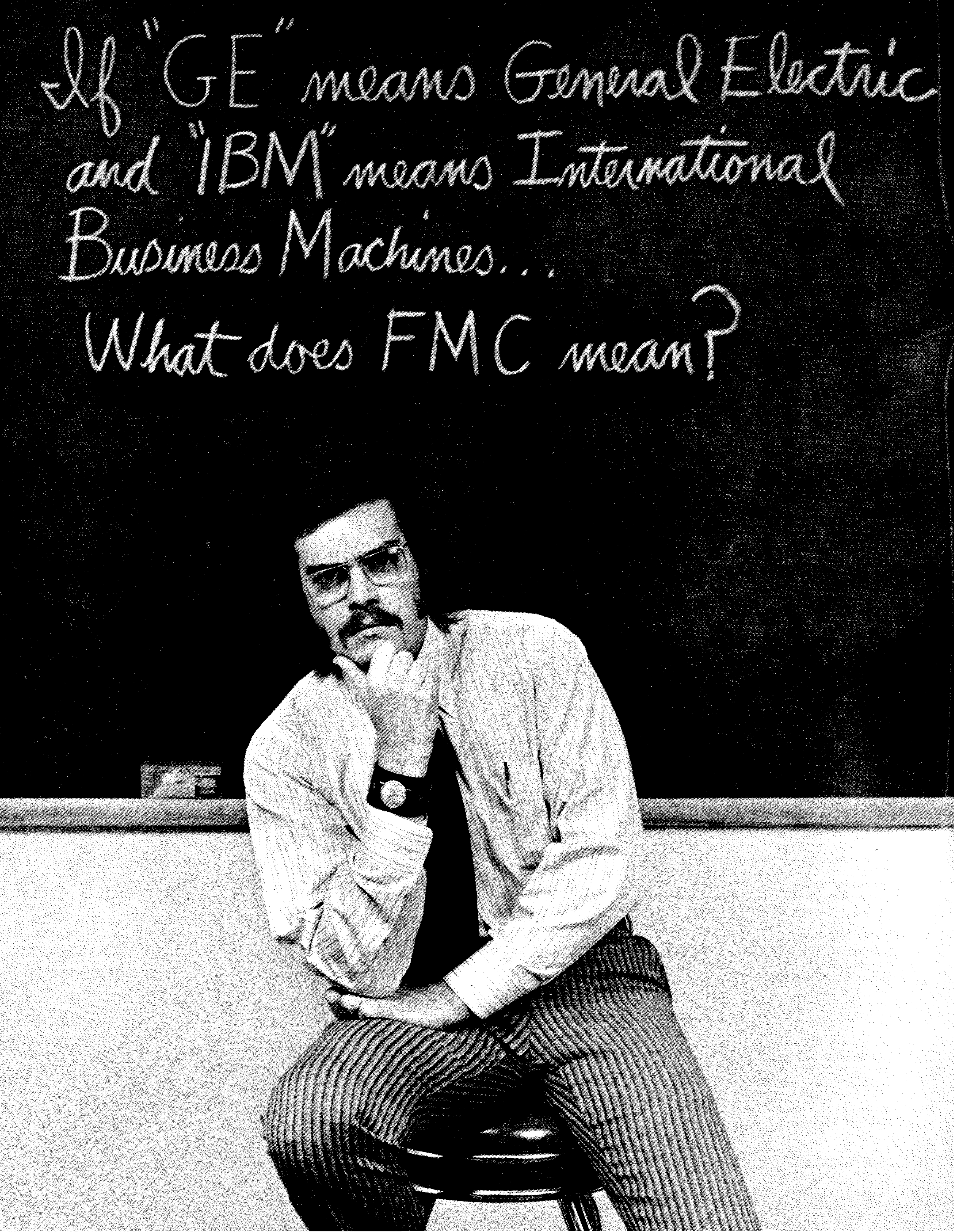

If "GE" means General Electric
and "IBM" means International
Business Machines...
What does FMC mean?

The Dynamics of Information

Our time seems marked by a growing sense of being out of touch, of a too rapid growth in what there is to know. To deal effectively with informational problems, we need to understand the dynamics of information.

Each of us feels somewhat informed about his individual corner of the world. At the same time, we are aware that our understanding is incomplete. Each of us in his own way seeks to make sense out of his experience. Some spend their entire lives in increasing our understanding; they are scientists and scholars, not because of what they know but because of their persistence in seeking to know more. And indeed this innate curiosity is a ubiquitous part of all of us. Since these informational activities of others are themselves part of our experience, we seek as well to understand each other. And thus, the dynamics of information.

But the results of these separate acts of knowing are not converging. Our time seems marked by a growing sense of being out of touch, of a too rapid growth in what there is to know. Creativity itself seems suspect when so much that is created is beyond our ken. Our day is fraught with informational problems. To deal effectively with these problems, we need to understand these dynamics of information.

The Nature of Information

The process of becoming informed can be factored into two parts. The first of these is experiencing. It is by interacting directly with the reality that is around us that we gain the raw materials of information. But raw experience is not enough. We must organize experience into a conceptual structure before it is meaningful to us. Nor does this structure come from the experience itself. Rather, we must impose structure on our experience. The knower must actively participate in the act of knowing. The matter was put vividly by the American philosopher-scientist William James:

> The world's contents are given to each of us in an order so foreign to our subjective interests that we can hardly by an effort of the imagination picture to ourselves what it is really like. . . . Is not the sum of your actual experience taken at this moment and impartially added together an utter chaos? The strains of my voice, the lights and shades inside the room and out, the murmur of the wind, the ticking of the clock, the various organic feelings you may happen individually to possess, do these make a whole at all?. . . We break it; we break it into histories, and we break it into arts, and we break it into sciences; and then we begin to feel at home. . . . We discover among its various parts relations that were never given to sense at all; and out of an infinite number of these we call certain ones essential and law giving, and ignore the rest.

It is our subjective habit to organize the individual elements of our experience, to cross-correlate these by Frederick B. Thompson

elements to others distant in space and time. It is only after this process of imposing organization that we feel informed.

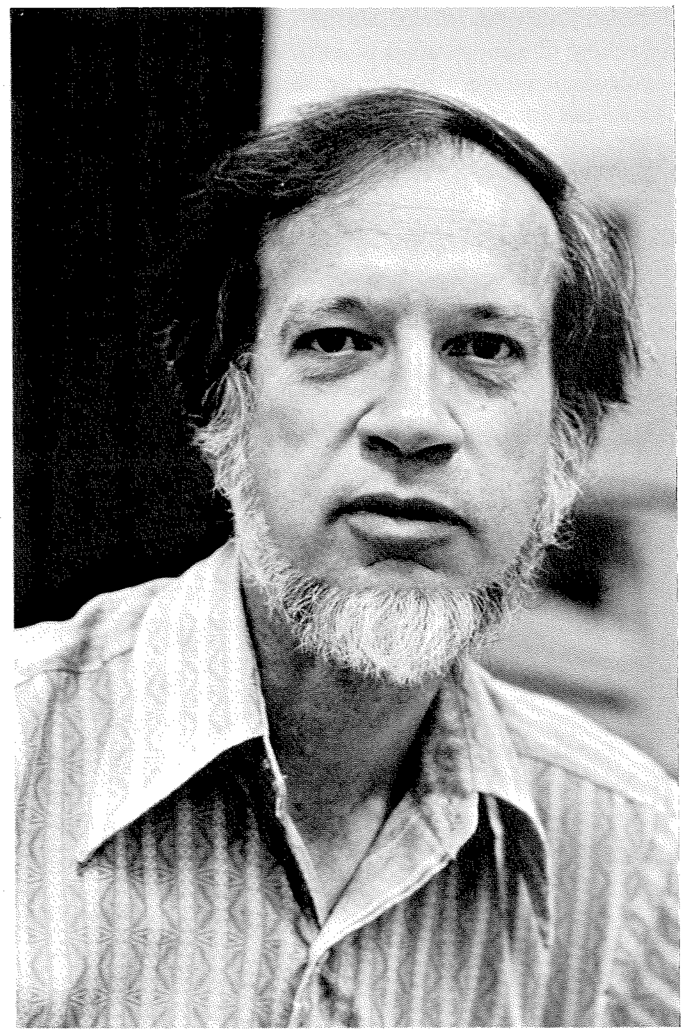
Notice the essential role of abstraction and projection beyond what we have confirmed. Each moment of our experience is peculiar unto itself. It is only by ignoring differentiating aspects of past experience that we can see its application to current concerns. And these patterns that we exploit are not proffered by experience, which does not choose between the infinity that are there. They arise only when we back off and let the shadows of our own subjective structure cast perspective on our cluttered view. I am not questioning the objectivity of these patterns, once perceived. I am emphasizing the essential role of the subjective selection and imposition of organization that determines to as great an extent as experience itself the information that it yields.

Language and Conceptual Structure

Language is the embodiment of conceptual structure. We share our information with others. But to do so we must settle collectively on a structure into which our several experiences can be codified. It is this tacit, common structure that we exploit in communication. The essential characteristic of language is structure, as found in its word forms, its grammar, and its intrinsic logic. It is in the study of language that the common conceptual structures of a community are revealed.

Languages can give quite disparate perspective to the same experiences. This difference in languages, moreover, does not only refer to languages of different peoples. We often overlook the highly idiosyncratic nature of the varients of our own language. We often think a fluent native speaker speaks a common English. However, a moment's reflection brings us to realize that when we go from our work environment to our home, when we go from one class to another, we unconsciously shift from one idiolect—one form of thinking and communicating—to another.

I should like to use the notion of language in this more precise form as synonymous with conceptual structure. In particular I am not restricting it to verbal language. Think of the language that a person is using at any instant as the embodiment of the organization that he has imposed upon his experience and as the means for framing his current information. I should like to introduce the notion of an informational community as a group of people who share a common language, whose conceptual views are based upon a common structure. An individual can be



Frederick B. Thompson

considered as a special case of such a community. When looking at the dynamics of information, it is the community and its language which is the central focus.

The Dynamics of Information

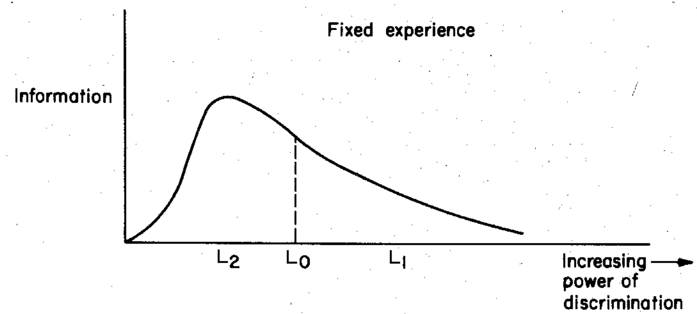
Now let us imagine a situation where we have a certain fixed body of observations or experience. Let us compare what would happen if we were to organize and conceptualize this experience in terms of one language or another. Each language would reveal certain information from its peculiar point of view. The concepts and means of expression in one language might be just so as to be quite inadequate for the experience at hand, while another language may be ideally suited to elicit revealing insight.

One can construct for a formal language a measure of information. Thus given a language and a body of observations, we can define the amount of information that can be elicited from the given observations in terms of the conceptual structures provided by the language. Different languages yield different amounts of information about the same observations.

Languages can be compared in the amount of information they provide. When we say that one language (L_1) is at least as powerful as another (L_2), we mean that whatever distinctions between possible states of the universe can be made in L_2, they can be made in L_1. On the other hand one can show that for any formal language (L) there is a much more powerful language (L′) which can express things not possible in L. As a consequence there is no most powerful language.

Let's examine the situation wherein we have a family of more and more powerful languages. Again we will assume that we are considering a family E consisting of a number of observations. Thus for each language L, we can determine the amount of information $I(L,E)$ that can be obtained from E in terms of language L. Let L_0 be the least powerful language in which all aspects of the observations E can be fully expressed. In L_0, the experiences E can be completely described. The question is: What happens to the amount of information as we move to either more powerful or less powerful languages than L_0? What can be shown quite convincingly is somewhat surprising.

Consider a more powerful language, L_1. The observation E can be completely described in L_1, and more. Indeed, L_1 opens many issues which cannot be decided on the basis of E; it gives rise to ambiguities and uncertainties that cannot be resolved. It is not only the case that it distinguishes between two states that were



Information as a function of the conceptual structure made available by the underlying language. Each language determines the amount of information that can be obtained from a fixed body of experience.

indistinguishable in L_0, but it permits states that violated the logic of L_0, that could not exist as far as L_0 is concerned. A language is essentially a means of correlation of otherwise disparate experiences; thus it perforce must impose assumptions not inherent in the experience it explicates. It is this drastic extension of alternatives in the areas germain but unresolved by the experiences at hand that disrupts the correlations assumed in L_0, and causes information to fall.

What happens when we move to the left? Obviously, if we move all the way to the one-word language, we lose all information. Suppose there are certain aspects of each observation that do not reoccur in any systematic way in the other observations, thus appear random; one assumes them irrelevant. Others may occur quite regularly without perturbation in all the observations; whereupon one assumes their universal regularity, thus equating differentiable characteristics. This indeed is the process of induction, moving us to higher levels of abstraction. Thus there is an intermediate position in which information is maximized.

We maximize our information at a level of conceptualization above that of our raw experience. The very essence of science has been to find those highly abstract first principles and laws which encapsulate broad stretches of our experience.

Our experience is not fixed but ever extending. In the face of changing experience, that language which maximizes our information also changes.

Our experience is not fixed but ever extending. In the face of changing experience, that language which maximizes our information also changes. Indeed, this is our simple model of cognitive processes, a model of the dynamics of how we are informed. We constantly change our language in such a way as to maximize the information we can elicit from our experience. We constantly modify and adjust the forms and relationships into which we encapsulate our experience in such a way as to keep us maximally informed.

Creativity

Information processes, the processes by which we are informed, can thus be viewed as language change. Creativity is precisely such a process. To be creative is to impose upon experience a new structure which suddenly reveals insights which were obscured before. A poet's turn of phrase, a musician's variations on a simple melody, a painter's juxtaposition of shape and color, a dancer's mime in motion, all interpret anew things common to us all; and from these new interpretations we strangely draw a sense of knowing more.

The great moments of scientific advances are just such moments of new conceptualization. Copernicus moved the conceptual center of the universe from the earth to the sun. Kepler gave order to the confusing observations of the planets by placing them on an ethereal ellipse, tacked at a focus to the sun. Dalton observed the integral combinations of the elements in chemical compounds. Bohr gave us the basic model of the atom. Einstein grasped the absolute character of the speed of light. Each enormously expanded our information and opened highways for its further extension only by insightful shifts in conceptual structure.

But the innovative community is not an isolated thing. It exists in a wider culture. In this wider sense, the effect of creative change can be negative as well as positive. Great conceptual change calls for deep reverberating changes in the central conceptual structures that underpin whole cultures. For example, the Copernican shift shattered the image of man as central to the universe and thus opened to question the basic assumptions on which the religious institutions of the day were established. As we have already seen, this "opening to question" increases enormously the number of alternatives which have to be dealt with and thus reduces the information these expanded conceptual structures contain.

When one recalls that the previous views had themselves been constructed to be maximally informing in face of existing evidence, one can see how such a shift of view in one area can be a grave threat to the over-all conceptual accommodation of a society. As the cultural pattern of a society is built, a balance is maintained across the growing community that permits and enhances communication. If that balance is destroyed by an alien concept locally extended to account for local experience, it can drastically lower the information in the total society even while it increases sharply the local information. The global effect of a creative act must be analysed quite separately from the analysis which accounts for its local introduction.

A creative act is like an earth movement, an adjustment of local structure to the stresses built up by on-going processes of change, an accommodation to account for local experience. Like earthquakes, such creative adjustment of structure propagates throughout the conceptual structure of the society. And all along this propagating change, information falls as new alternatives are opened and uncertainty is increased. In a culture such as ours, there are continual occurrences of microquakes, thousands of quakes felt in local communities, and from time to time major conceptual quakes such as Darwin's announcement of evolution and the explosion of the first atomic weapon, which reverberate their unsettling implications throughout the society's cultural view.

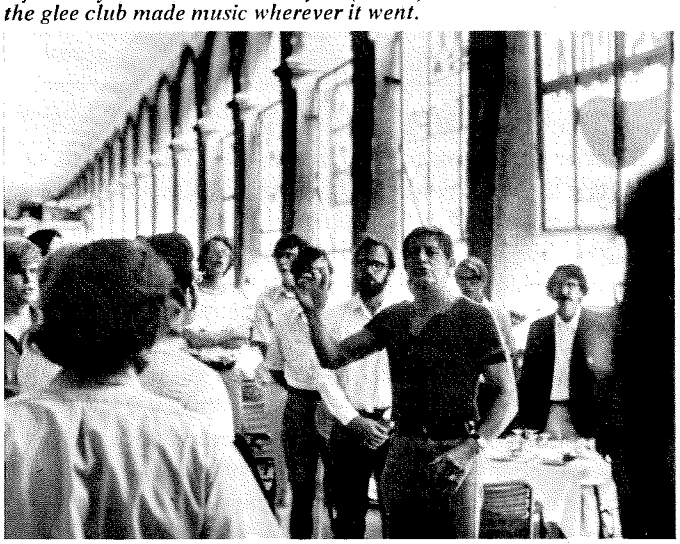
Information Communities and Rates of Conceptual Change

A common language, a common conceptual view provides a community with a powerful tool. On such a basis, it can coordinate its activities, marshal its skills, share its experience. As a community increases its

continued on page 27

Globetrotting with the Glee Club

Whether formally as in Baden (above) or informally in a restaurant in Rijeka (below), the glee club made music wherever it went.



If you plan a trip to Yugoslavia, there is a foolproof way of making yourself as popular there as plum brandy.

Sing!

That's what the Caltech glee club discovered during its three-week tour last June and July.

For years the glee club director, Olaf Frodsham, and his singers have planned and dreamed of a European concert tour. This summer they made it—thanks to major contributions from the alumni association, the Institute itself, the Caltech women's Service League, the sale of memberships in a support group, and efforts of the singers themselves who raised money through concerts and album sales.

Why Yugoslavia? Well, the group wanted to visit Eastern Europe to see what it was like; and their booking organization, the Institute of European Studies, supposedly had strong contacts in Yugoslavia. As it turned out, IES had the erroneous impression that the glee club was more interested in touring than singing, and booked them for only five formal concerts—a limitation they got around by doing "instant" concerts during their stopovers. All of that, however, was still ahead when in the early morning hours of Sunday, June 18, a group of 32 students 4 alumni (Reuben Moulton, '57; B. Kent Russell, '62; Oliver Seeley, '61; and Arnold Jones, '61), Frodsham, and accompanist John Jensen of the Occidental College music staff took off for Europe.

Two of the glee club's formal performances were sacred concerts, one in Vienna, another in Zagreb. Their Vienna appearance was in the Church of the Holy Trinity, where Beethoven's funeral service was held; and they rehearsed for it in a former palace room where he wrote many of his compositions.

The church was packed, and for the first time the group enjoyed the superb acoustics of one of Europe's great old churches. One surprise was that the organ was in a rear loft, and it took about ¾ of a second for its notes to reach the singers in front. But after some preliminary confusion, the singers found that the resonance of the old building more than made up for the necessity to shift auditory gears.

The actual Yugoslav tour started with the second sacred concert—in old St. Catherine's church in Zagreb. The audience completely filled the baroque church. In fact, the priest dragged in rough planks and made temporary seats behind the altar. The group had been told not to expect applause in Yugoslav churches, but at the end of the first number the priest himself led the clapping.

Wherever they gave a concert in Yugoslavia, they were in the care of the local *dumkultur* (the head of the town's cultural activities). He, or usually she, had charge of everything—setting the location, putting up the posters, getting out the pre-concert publicity. They arrived in Sarajevo in the midst of such festivity that at first they thought the *dumkultur* must have outdone himself. But it

One way to earn an extra letter is to get a Yugoslavian poster-maker to do your publicity.

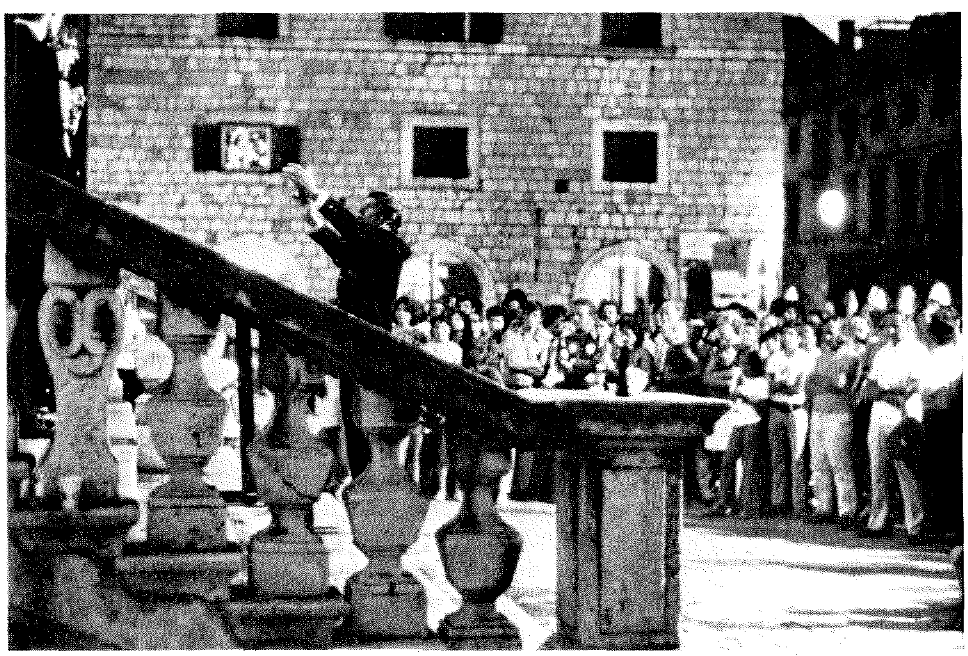
turned out to be an important national holiday. The Croats were celebrating the assassination of Archduke Ferdinand in 1914 and the beginning of pan-Slavism, as well as a 14th-century anniversary of defeating the Turks. The glee club sang in Red Army Hall, and the concert was broadcast over the national radio network.

But Sarajevo was one of the crests of the roller coaster ride. In Belgrade they found that no publicity had been put out, except for a few posters on the concert hall. They arrived, found six people in the audience, and literally flipped a coin to decide whether or not to cancel the engagement. However, their woman tour guide had well-developed mother-hen instincts. She clucked a few times and then disappeared, returning in half an hour with about a hundred young people she had scratched up from some unknown source.

Dubrovnik, the resort town on the Dalmatian coast, was the scene of one of their best concerts—held in the square of the medieval part of town. And there was a reminder of home in the audience: Lance Davis, professor of economics.

Although they had originally been promised a concert in Venice, IES had scheduled it for the day after they were to fly home. But a concert in Frankfurt was substituted, and it turned out to be a fitting climax. Held in a park-like outdoor restaurant called the Palmengarten that was jammed with beer-drinking families and jolly old ladies, the glee club offered a program of every German song they had ever learned. According to Frodsham, they never sang better, and evidently no audience ever wept more joyfully. The sentimental Germans couldn't get enough of the Caltech glee club, and as they filed out of the Palmengarten, people were still standing, applauding, and reaching out to touch them. The impresario, after thrusting a bouquet of red roses into Frodsham's arms, took him aside and offered to personally take charge of bookings for a future German concert tour.

Everyone agrees that it will probably take several years to finance another European tour. But the enthusiasm of the 32 students, 4 alumni, 1 director, and an accompanist may lead them to underwrite another trip themselves, as quickly as possible.



A flight of stairs in the town square was an improvised platform for the concert in Dubrovnik.

ALIAS NEAL PINGS

Give a busy man another job, and you get a busier man. If he's C. J. Pings, you also get the job done.

Once upon a time a university professor could, with a clear conscience, hew to his scholastic specialty and let administrative chips fall where they might. But at Caltech those days are long gone. In fact, it's a rare scholar who *doesn't* have an administrative assignment outside his classroom and lab. It's even a rare man who doesn't have a couple of them. But "rare" is hardly adequate to describe a man who takes on three or four.

Take C. J. Pings, professor of chemical engineering and chemical physics, who is *also* executive officer for chemical engineering, vice provost, and dean of graduate studies. Membership in a clutch of committees and professional societies, co-editorship of the journal *Physics and Chemistry of Liquids*, and editorship of a new journal *Chemical Engineering Communications* round out his multifaceted and admirable career.

Admirable, that is, except for his troubles with the FBI. This blot on the escutcheon of someone who has risen to such heights at his alma mater—and become a highly respected scientist elsewhere as well—dates back to 1951 when Pings was a senior at Caltech. Though he had acquired the name "Cornelius" at birth in 1929 (via his father, his great-grandfather, and his mother's sister Cornelia), he had adopted "Neal" for all practical purposes. But the solemnity of a possible job with the Atomic Energy Commission after graduation led him to inscribe "Cornelius" on his application. The AEC sent a standard request for a recommendation to chemistry professor Ernest Swift. His crisp reply that he had never heard of any Cornelius Pings brought a swarm of FBI agents buzzing around Pings' hapless head.

"Living under an alias was over," says Pings. "Before applying for any more jobs, I knew I had to make the switch from Neal to Cornelius. I started by going to the Registrar's office to get my named changed on my transcript—and that's when I found out my troubles had just begun. There was no way, I was told, to make the change. I produced my birth certificate; the Registrar's staff was not impressed. I admitted that I had lied about my name when I entered Caltech; they suggested I get a court order for them to make the alteration. I think we finally compromised by putting Cornelius in parentheses on the records."

Cornelius John Pings is a native of Conrad, Montana, a small rural community on the east side of the Rockies. His family lived in Montana because his grandfather had left the family home in Wisconsin to take out a homestead in the West. (A generation earlier his great-grandfather had immigrated to the United States from Germany, about the same time that his mother's ancestors arrived from Ireland.) Neal's father struggled through the Depression years as an electrician with the Rural Electrification program, and finally in 1942 went looking for his greener pastures in California.

Those early years of economic insecurity gave Pings some sturdy opinions about what an education is for. The quest for knowledge excited him, but a strong motivation for getting a college degree was its promise of economic benefits.

At Hollywood High School, Pings was interested in history and English, and was editor of the school paper. His grades were almost all A's. As a senior he considered going to UCLA—and eventually to law school—but finally he and a group of his friends applied to Caltech. Though the possibility of being admitted seemed fairly remote, 1947 turned out to be a record year for Hollywood High graduates to make the grade at the Institute. Of the six who applied, five were admitted—and all five graduated four years later. (Ken Berg is now a research specialist with the Whittaker Corporation in El Cajon; Dick Brewer is a research staff member with IBM in San Jose; Winston Royce lives in Los Gatos and is a member of the technical staff of TRW Systems; and George Trilling is a physicist at UC Berkeley and the Lawrence Livermore Laboratory.)

Pings entered Caltech planning to become a nuclear physicist—an ambition that lasted just one term. But chemistry immediately filled the void—perhaps, he suggests, partly because of the quality of instruction he received. Linus Pauling and Norman Davidson taught him freshman chemistry, and Ernest Swift was his instructor in sophomore year. ("Anyone who survived that course will testify to its intellectual thoroughness.") Howard Lucas, professor of organic chemistry, taught him most of what he knows about laboratory techniques.

With visions of going to work eventually for a chemical or petroleum company, Pings took his BS in applied chemistry—having financed four years of college with a combination of scholarships, summer jobs, and student loans. And with the hope that this eventual job would be one of substantial technical responsibility in industry, he persisted through a PhD program in chemical engineering. It was with some surprise, then, that in 1955 he found himself turning down some attractive job offers in industry to go with his fellow alumnus Dave Mason, then on the staff at JPL, to set up a new chemical engineering department at Stanford. "I decided to try academic life for one year," he says, "and I've been at it ever since. So much for my industrial aspirations. But I often tell students about myself when they ask me for career advice. My experience is that flexibility is an asset."

Pings will testify that a little flexibility can take a man a long way—to northern Greenland, for instance. Thanks to his reading a notice posted on a campus bulletin board, that's where he spent the summers of 1955, '56, and '57. Graduate student Mark Meier, now a noted authority on glaciers, was organizing a geology field trip and recruiting a staff.

Right then, Pings liked what that job offered—summer work, distance from Pasadena, outdoor life, and moderately good pay. It also made good use of his research background (heat transfer and thermodynamics), and he is still proud of three professional papers resulting from the experience. ("And my children are still young enough to be impressed when I point to Greenland on the globe and say, 'I was there.' ")

After four years at Stanford, Pings came back to Caltech in 1959 as associate professor of chemical engineering and as resident associate for Fleming House. Two problems cropped up soon after he arrived. The first was overcoming his student-bred reticence at calling senior faculty members by their first names. Will Lacey, now professor emeritus of chemical engineering, cured that difficulty with a few well-chosen words. "You've graduated from calling me Doctor," he said. "My name is Will!"

The other problem was that hardy perennial—complaints about student-house food. As resident associate Pings had a head-on verbal collision about it with the dietitian and manager of the student houses, Marjorie Cheney. His recollection of the effectiveness of his battle in behalf of an improved cuisine is hazy. (Marjorie says: "At first I thought that he would be easier to cope with than the undergraduates, but . . . !") One result was an "honest-to-God campus romance." He and Marjorie were married in 1960.

Pings made a decision in his first year at Stanford about the general area of research he wanted to pursue—to understand liquids at the molecular level. He was struck by the fact that a fairly sizable body of knowledge existed about gases and solids, but comparatively little about liquids.

"There's a component of engineer in me," he says, "but I wanted to go into the hard science aspects of the liquid state. My experiments have been designed to lead ultimately to better theory, which may then be applied to practical problems. Now, 16 years after I started, the problems are far from solved, but I think we've made some progress."

Pings and his research group are currently interested in mixtures. Understanding mixtures by the brute force of numbers of experiments is hopeless; there are too many possibilities. The aim is to develop some rules for utilizing what is known about simple substances to say how they will behave when they are combined.

Essentially, the research is divided into three sub-groups, each involving use of a different technique and the simplest available systems (monatomic rare gases such as argon and krypton, which are liquid at the temperatures and pressures used in the experiments).

The technique Pings started working with, which is still the backbone of his research, is that of X-ray diffraction. Using it, his students are able to measure the structure of fluids—the average number of neighboring atoms and their distance apart.

The second technique is a study of the refractive index of fluids, chiefly at the critical state—in the borderline region between liquid and gas. The refractive index is a measurement of how much a beam of light is bent as it stabs through a liquid. The amount of bending is indicative of the electrical environment of local areas of the liquid and also gives some idea of its density.

Marjorie Pings

The third technique is to use lasers for light-scattering to study the motion of the molecules in fluids. This is fairly new, and with it, Pings says, "We can make some very exciting measurements and get some wholly new information. And we don't yet have any idea of its full potential."

While the orientation of Pings' research group is basically experimental, he makes sure that they keep in touch with theoreticians. "We try to find experiments to challenge or confirm the theories we hear about," Pings says. "Then, from our data, we are able to suggest new approaches to the theoreticians, and we listen when they suggest what we should be doing in the laboratory."

Of course, Pings doesn't listen to just the local theoreticians. He is a regular participant in scientific meetings, including the Gordon conferences—a series of week-long summer conferences for scientists, held on the campuses of various New England prep schools. The Gordon Research Conference on the Physics and Chemistry of Liquids meets biennially, and Pings has attended the last seven of them. (He was chairman of the one in 1969.) Attendance is limited to 120 researchers, carefully chosen for a good mix between already established and younger scientists. "Those conferences are a beautiful experience," Pings says. "For one whole week you're with your colleagues—theoreticians and experimentalists—in continuing conversation. And we correspond over the intervening months too—asking questions, checking results, making suggestions. I grumble a lot about meetings, but not about these."

Meetings are a fact of life for Pings. For example, his calendar for last May shows four trips out of town—to Washington for a monthly meeting with the provost-level

Neal Pings

representatives of seven other universities (he stopped en route to deliver a research seminar at the Sandia Laboratories); to China Lake for a meeting of the Advisory Committee of the Naval Weapons Center; to Washington again for a conference on the Financial Crisis in Higher Education; and to Tucson, where he is Caltech's administrative representative on the board of directors of the Associated Universities for Research in Astronomy. In between, he attended meetings on the campus of the Faculty Board, the Board of Trustees, the Institute Administrative Council, the Graduate Study Committee, the board of directors of the Alumni Association, and the faculty committee on Affirmative Action. He served as chairman at four sessions of an ad hoc committee on business economics and management science, sat on two PhD oral examination committees, attended three research seminars, and sandwiched in a large number of appointments with individuals.

Bringing ability and good nature to his meetings, Pings makes both friends and progress in the process. Some of his success must surely stem from his genuine commitment to Caltech and to higher education. "I want to do what I can to help both of them thrive, to adapt to changing times, and to stay ahead of their problems," he says.

Pings has taken some razzing about the number of jobs and titles he carries, but he doesn't feel that his case is noteworthy. "A lot of people around here are carrying administrative tasks and practicing the trade simultaneously," he says, "and it's not all that hard. The bureaucracy is minimal, which makes it possible to get hold of people and talk things out. Of course, you have to make choices. I regret losing some of the rapport I used to have with undergraduates. I missed teaching last year, so I'm glad to be back at it now—giving the thermodynamics course for sophomores this fall and winter. I suppose there's some ham in me, but to stand up in front of a class and feel you're conveying knowledge and maybe affecting attitudes can be very satisfying. But I won't go into class half prepared."

Juggling the requirements of his various posts and his available time also keeps Pings from getting into the lab to make his own measurements. But he meets with his research group (smaller in these days of funding difficulties than it used to be) as often as he can, and he makes himself available for conferences on individual problems. The formalities of setting up such meetings are a little more complex than they once were, but he feels responsible for keeping track of what's going on and trying to be helpful. William Corcoran, professor of chemical engineering and vice president for Institute relations, who has known Pings since 1952, puts the matter succinctly: "Nobody ever gets short-changed by Neal."

The list of Pings' contributions over the years on many Caltech administrative and faculty committees is a long one, and his chairmanship of the Ad Hoc Committee on the Aims and Goals of the Institute (1969-1970) epitomizes that kind and degree of service. Rodman Paul, Harkness Professor of History, who has known Neal since he taught him history as an undergraduate, was also a member of that committee. He recalls that through all the long months of its deliberations Neal "displayed tremendous fairness, calmness, and breadth of understanding. He is a good scientist who deals with human beings in human ways. When Harold Brown was chosen as president of the Institute, it was clear that somehow he would have to be thoroughly briefed. It was Neal more than anyone else who pointed out that the report of the Aims and Goals Committee would be exactly what was needed to do the job. So, we shoved it through with a speed that didn't seem possible, and gave it to the president. I think it was the most thorough analysis and appraisal of Caltech that has ever been made."

Pings says, "Working on that committee convinced me—and others—that an institution like this doesn't run itself. We're fortunate here that the faculty is involved in decision making. It was clear at the time the committee was appointed that we were heading into a period when we were going to be subject to severe constraints, that we were going to have to live by our wits. There were going to be choices and decisions, and if the faculty wanted to get in on those, it was going to have to make its views known and some of its members available for administrative positions. It's probably not a coincidence that 60 percent of the committee's members have ended up in administration."

Neal's own administrative posts include being executive officer for chemical engineering, vice provost, and dean of graduate studies. One reason he continues as executive officer is that the chemical engineering faculty is, on the whole, very young and involved in starting their own research. "It doesn't make sense to dilute their time with administration at this point," says Pings. "We're really victims of our own strategy, because we have deliberately been recruiting young men—but it will pay off in the long run."

Most of the day-to-day operations of the graduate office—admission and support of students, management of the office, direct contact with the various option representatives, and participation in national and regional groups concerned with graduate education—have been turned over to Associate Dean Stirling Huntley, with Pings being involved in policy making, budgeting, and working with the Graduate Studies Committee.

As vice provost, he has specific responsibility for all new and renewal appointments on the research ladder, for the faculty portion of the Institute's Affirmative Action Program, for the library and the Industrial Relations Center, and for interdisciplinary programs. Basically, however, he sees his task to be relieving the load carried by Provost Robert Christy. Somewhat ruefully he points out: "We have to handle questions that once didn't even arise: How do you try to do as much, and maybe more, research on less money? How do you keep a young faculty when you can't afford to appoint new people?

"There are lots of kinds of jobs around here, and I like to sample them," says Pings. "I enjoy feeling useful; I like to free time for others to do what they want to do. And there's enough of the competitor in me that I don't mind working at being successful. Each of my jobs calls on different talents, responses, parts of temperament, and combinations of whatever abilities I have. And each makes vulnerable different kinds of shortcomings. Research demands analytical thought processes plus whatever creativity I have, and that rather severely exposes the limits of my intellect. Supervision of personnel and administration in general require exercising judgment on problems dominated by values and the ramifications of human personality. I often find myself failing in these situations—either because I try to find an exact answer to a diffuse problem or, at the other extreme, I compromise in making a difficult decision because I give in to a desire to be liberal or compassionate."

Administrative work is harder than either teaching or research as far as Pings is concerned—a fact which, he thinks, may reflect his lack of training in its techniques. The problem boils down to persuading other people to do things for him, and he attacks it by assuming that the people he deals with are reasonable individuals.

Like many another Caltech professor, Pings often takes a loaded briefcase home. Even when he leaves his work at the office, he finds it hard to take a real break from his duties unless his family can lure him out of town—preferably to the mountains or the beach. He feels that he is overdue for a leave of absence for about six months at another university. Such breaks in routine lend perspective. But he expects the experience will just confirm his conviction that Caltech really is an outstanding place.

He has been investing in that conviction for a long time. As an undergraduate Neal Pings was a member of the Beavers, the Board of Control, the Interhouse Committee, Throop Club, and—with real devotion—the varsity football team. All this adds up to top-notch credentials for his election to the board of directors of the Alumni Association. He took on this three-year job in 1970 not only because he was interested but because he had a two-way feeling of responsibility. He believes the faculty hasn't made adequate use of the talents of the alumni, and that the alumni could do a lot more for Caltech. As a man with a foot in each camp, he thinks he may be able to improve communications between the two groups.

If Pings' services as vice chairman of Pasadena's Community Redevelopment Agency seem tangential to the academic circle in which he usually operates, the appearance is only superficial. He's not there as an official representative of Caltech, but he points out: "I'm concerned that 20 years from now Caltech will be located in a city where it's still pleasant to live and to send children to school. The decisions that are being made right now will affect that. Faculty members here have always been involved in national affairs, but local involvement is just as important. Caltech can't isolate itself from Pasadena, and maybe I can be a bridge."

Not even the FBI could find anything wrong with that.

—Jacquelyn Hershey

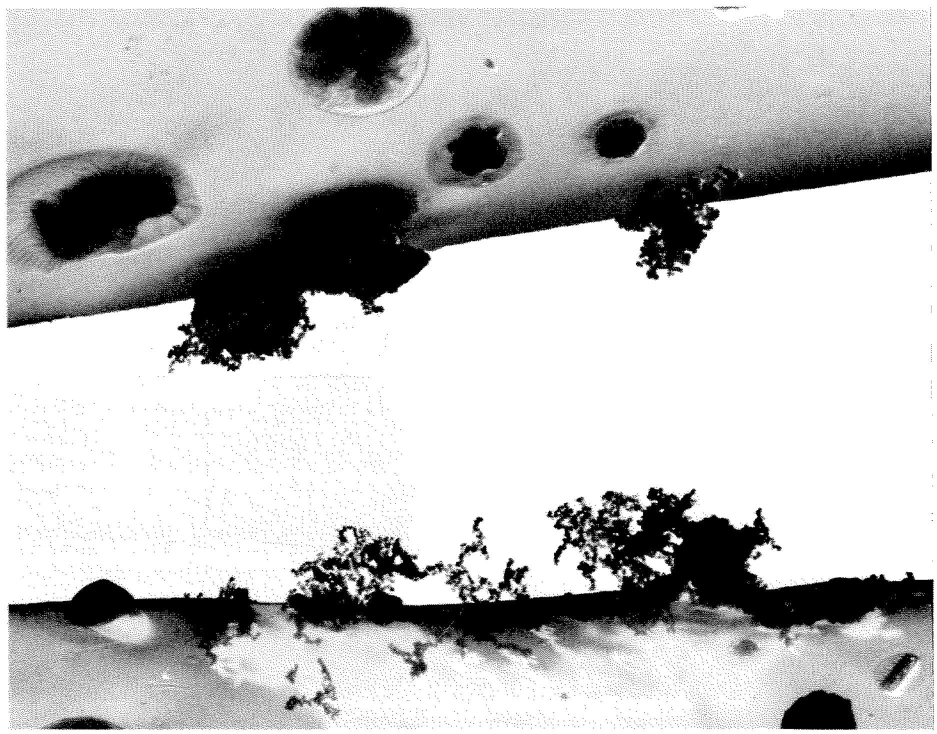
Research Notes

Clearing the Air for Pollution Standards

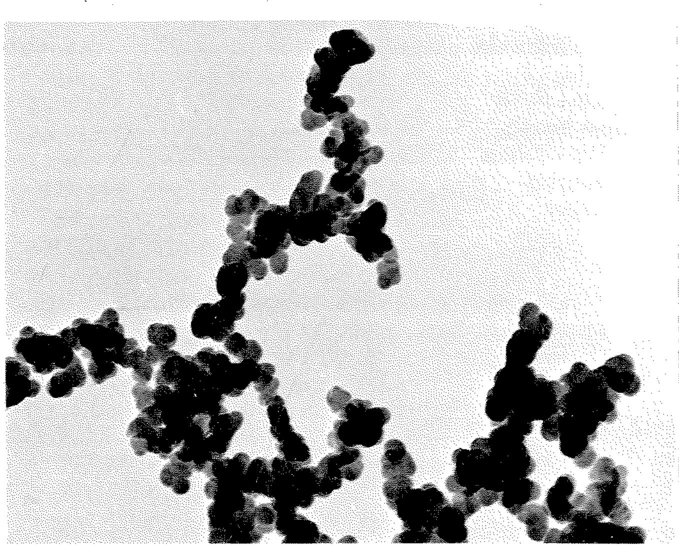
A key factor in government efforts to control pollution is the setting of standards for pollutant concentrations both in the environment and in emissions. The levels at which standards are set are usually imprecise because of difficulties in measuring environmental concentrations and effects.

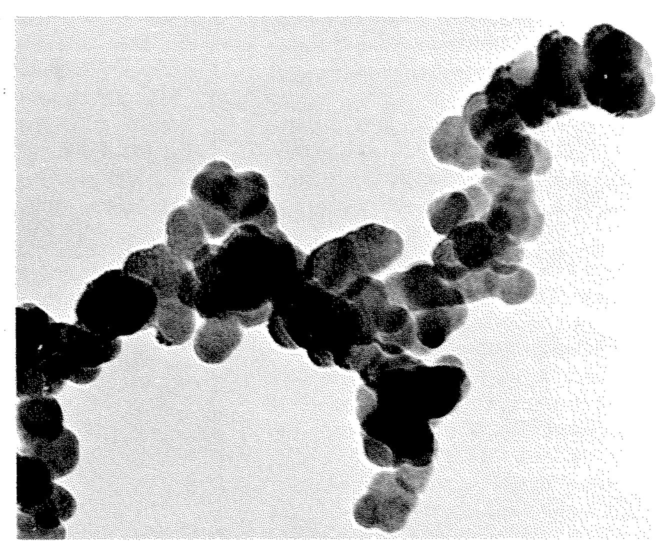
Nevertheless, decisions on standards have important implications for public health and the ecology; small changes in standards—an alteration of just a few percentage points in the amount of emissions, for example—may also mean millions of dollars spent on the purchase and development of new technology. With the costs of imprecise standards so great, it is essential to have as much information as possible before the standards are set.

The way to get this kind of information is to conduct long-term studies of the quality of the environment in the areas that will be affected by such standards. Obtaining this kind of comprehensive information about Los Angeles, the San Francisco Bay area, and the San Joaquin



Agglomerates of complex chains of lead halide particles are caught between two massive bars (which are really parts of a thin copper wire grid about a tenth of an inch in diameter). Solid particles like these make up 10 to 30 percent of the airborne particle mass that makes up smog; these samples were captured on the roof of Keck Laboratory on a thin transparent foil stretched across an electron microscope grid.



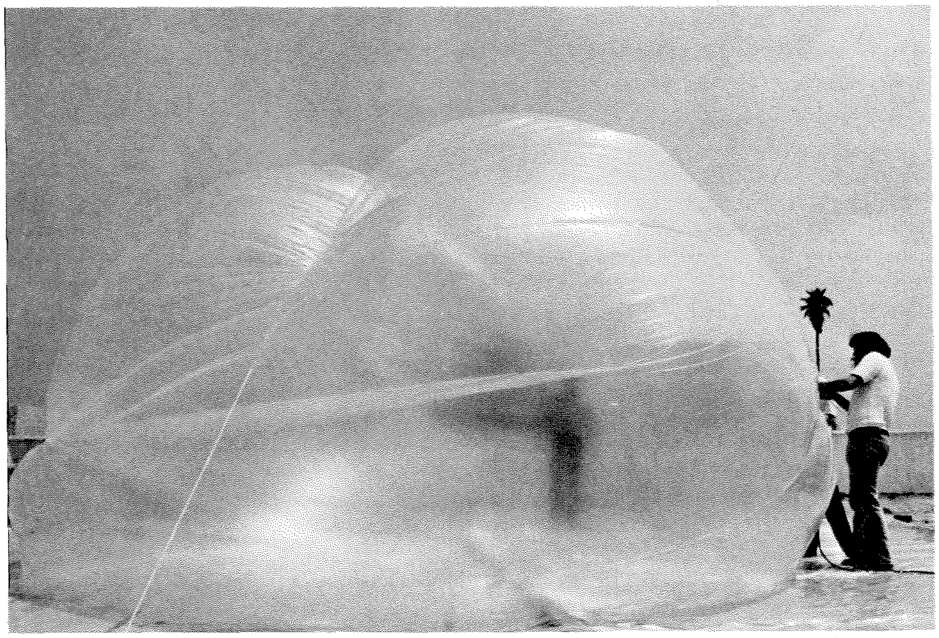


Closer (above) and still closer (right) views of the lead particles reveal what some of the particulates in the air we breathe really look like. The chains are formed when lead halides produced by automobile engines condense into spherical masses during combustion and link together in the tail pipe. Each sphere is about 150 Angstroms (six ten-millionths of an inch) in diameter.

Valley—California's three major air pollution basins, or areas of consistent and regular air circulation patterns —will occupy the time of at least 12 Caltech scientists over the next several years. Their research will be funded through two grants, one from the Rockefeller Foundation of New York for $150,000 and the other a portion of a $1,679,384 contract from the California Air Resources Board (ARB) to North American Rockwell Corporation (NAR).

The Rockefeller grant, which is for a one- to two-year period, will be used to start a study of the flow of pollutants, including lead and other metals, through the southern California environment. Principal investigators are Sheldon Friedlander, professor of chemical engineering and environmental health engineering; Norman Brooks, professor of environmental science and civil engineering; and James Morgan, professor of environmental engineering science. Other Caltech specialists engaged in the project include Sam Epstein, isotope geochemistry; R. B. Husar, aerosol physics; E. J. List, environmental fluid mechanics; Jack McKee, water supplies and wastes, and nuclear wastes; Wheeler North, marine biology; Clair Patterson, trace metals in the environment; and John Seinfeld, air pollution simulation and control.

Friedlander, Seinfeld, and Husar are also involved in the ARB-funded study, which is aimed at collecting, identifying, analyzing, and tracing aerosols in the state's three major smog basins. Aerosols



Rudolf Husar, research fellow in environmental engineering science, and his co-workers struggle with a 400-cubic-foot plastic balloon on the roof of Keck Laboratory. The balloon is used to capture samples of smog for analysis of how, where, and how fast particulates are produced in the Los Angeles Basin.

—particles suspended in the atmosphere—are the cause of the visible haze that hangs over most pollution-plagued cities. Aerosols are also the major transport mechanisms for heavy metals and non-volatile organic compounds through the air.

George Hidy, senior research fellow in environmental health engineering at Caltech and senior scientist at the NAR Science Center, is the principal investigator. Other Caltech researchers include Robert Lamb, chemical engineering research fellow; James Huntzicker, research fellow in environmental engineering science; and Steven Heisler, a graduate student in environmental engineering science.

The Rockefeller study is designed to serve as a pilot project for future large-scale environmental programs. It will provide an integrated picture of the pollutants through the total environment of the Los Angeles Basin—air, water, plants, animals, and man. It complements the ARB study as well as a southern California counties-sponsored study—the Southern California Coastal Water Research Project (SCCWRP). Headed by Morgan, SCCWRP will determine the trace-metal content of rivers during their winter-storm flow and how much of this they contribute to the ocean trace-metal content. The Rockefeller study will look at the contribution of sewage outfall and atmospheric pollution to the ocean trace-metal content.

Traditionally, such studies have been limited to one sector of the environment, such as the atmosphere. However, many persistent pollutants become widely dispersed through the total environment. Two types of substances have been selected for study—trace metals and their associated organic compounds. The metals include those with health and ecological significance—lead, zinc, barium, mercury, chromium, arsenic, and vanadium. Such pollutants are not biodegradable although they may change chemical form. The flow of associated organic compounds will also be investigated because of the potential biological importance of metal-organic compounds. It is hoped that data from the study will be used to help various governmental agencies set standards to control emissions of these metals.

The ARB study includes about 40 other scientists in addition to the Caltech investigators. They are associated with the California State Department of Health, the University of California at Riverside, the universities of Minnesota and Washington, the ARB, and Meteorology Research, Incorporated. The study has five major objectives: to determine the physical and chemical nature of the aerosols in the three basins; to determine what percentage comes from man-made sources and how much from natural sources and from processes taking place in the atmosphere; to identify the origins of the aerosols geographically; to estimate how better air quality standards can be achieved; and to improve instruments for monitoring stations.

Pollutants fed into the air from a wide variety of sources tend to fuse into aerosols, which grow and change constantly, becoming very complex chemically. They are composed of man-made pollutants, nature-made particles, and those produced by photochemical reactions in the atmosphere. Chemical analysis of the aerosols will help reveal their origins. Friedlander's laboratory will provide one of the two permanent monitoring stations in the Los Angeles Basin. The other will be at UC, Riverside. A mobile station in a large trailer will sample air in downtown Los Angeles, El Segundo, and Downey.

In some instances the atmosphere will be sampled continuously for 24 hours so that the evolution of aerosols can be mapped. Sampling will be done on the most and least smoggy days. Wind patterns, temperatures, and humidity will be monitored and compared with smog patterns. The sampling phase of the comprehensive project will continue for the rest of the year.

Checkup on Einstein

The studies of two Caltech researchers working independently—Cliff Will, instructor in physics, and Andrew Ingersoll, associate professor of planetary science—have recently produced evidence that favors Einstein's General Theory of Relativity over its many competing theories.

In 1915 Albert Einstein published his theory, which offered an entirely new view of gravitation (and, indirectly, of the universe), and scientists have been disputing it ever since. Einstein saw gravity as a property of space rather than as a force between bodies: As a result of the presence of matter, space became curved, and bodies followed the line of least resistance among the curves. Strange as this idea seemed, it explained things that the Newtonian law of gravity could not.

Nevertheless, there are now about 50 other serious theories—and literally hundreds of crackpot ones—that attempt to "improve" on Einstein's theory of gravity in various ways.

Working with Kenneth Nordvedt of Montana State University, Will has developed a kind of supertheory that tests various cosmological and gravitational theories for completeness, consistency, and accuracy. There is only one group of theories that meets the criteria set up by Nordvedt and Will—those theories which predict that gravity will bend light waves and produce the light shifts that appear to cause the planet Mercury's perihelion (its point of nearest approach to the sun) to change.

It is from this group of theories that the strongest competitor to Einstein's theory has arisen. It was proposed by physicist Robert Dicke of Princeton University in 1967. But if the calculations of Ingersoll and Gary Chapman, a solar astronomer at Aerospace Corporation, are correct, Dicke's theory is in error because it is based on a misinterpretation of data.

The cornerstone of Dicke's case against Einstein's theory is the mathematical prediction of the perihelion shift of Mercury. Long ago astronomers determined that the gravitational effects of the sun and planets accounted for all but a tiny fraction of the amount of the shift.

Einstein attributed the difference to relativistic effects and predicted that the value of this difference should be 43 seconds of arc every 100 years, which agrees with the observed value to the nearest second. In 1967 Dicke published a report claiming that about 3½ seconds of the 43-second shift comes, not from relativistic effects, but from the effect of the sun's equatorial bulge (oblateness)—which, according to Dicke, is five times greater than had been supposed.

Such a bulge would indicate that the sun's gravitational field is distorted, and such a distortion would have an observable effect on Mercury's orbit. If Dicke's conclusions are correct, then Einstein's prediction of Mercury's perihelion shift is wrong, and the basic assumptions underlying Einstein's theory must be re-examined.

In a recent issue of the *Astrophysical Journal,* Ingersoll and Chapman challenged the validity of the observations on which Dicke made his predictions. In their 1966 observations Dicke and his co-worker, H. Mark Goldenberg, had used a spinning disk on a telescope to mask out all but the sun's outer rim. They observed more light at the outer edges of the sun at the equator than at the poles, and attributed this to bulging at the sun's equator, due to a rapidly rotating inner core.

To check these observations, Chapman and Ingersoll examined photographs of the sun taken at Aerospace Corporation's San Fernando Observatory on the same days in 1966 on which Dicke had observed. They found that there was indeed more light being emitted from the equatorial regions, but they considered it evidence not of bulging but of large numbers of faculae—bright clouds that often appear near sunspots and that seem to be more concentrated at the sun's equator.

Dicke had discarded the data on faculae, but Ingersoll and Chapman fed their observations of faculae into a computer and compared them to the original measurements of brightness by Dicke and Goldenberg. It was found that there was a close correlation between the two signals.

This is evidence, Chapman and Ingersoll believe, that Dicke had simply observed more faculae at the equator and not an excess bulge. If they are right, Einstein's theory has survived another challenge.

However, there are large uncertainties in both the original and computer-simulated signals, and the possibility that the sun is really oblate still remains. But it must be oblate by a much smaller amount than Dicke originally claimed.

A Revised View of Mars

After a summer of analyzing thousands of feet of computer print-outs and thousands of photographs, Mariner 9 scientists at the Jet Propulsion Laboratory are busy revising their views of Mars—again.

The early unmanned probes of Mars by Mariners 4, 6, and 7 seemed to deflate the beliefs of many who believed life was possible on that planet. Investigators concluded that Mars was an ancient planet, a product of the accumulation of cosmic debris; that it was cold and dead; that there was no water on it; and that there was no possibility of an atmosphere suitable for life.

But the data from Mariner 9 indicate that Mars is, on the contrary, a young planet with considerable variation in topography and climate; that it has had recent tectonic activity, evidence that it is not cold and dead geologically; that there is water vapor in the atmosphere and signs of water erosion in the past on the surface; and that there are faint traces of ozone, a molecular form of oxygen, in the atmosphere, an indication that in the past it may have been more hospitable to life.

As a result, some scientists are a little more optimistic about the chances of life—no matter how primitive—being found on Mars when two unmanned Viking spacecraft land on the surface in 1976 and 1977.

The 7,200 photographs returned by Mariner 9 have been used to piece together a map of the planet's surface. From these photographs, JPL scientists have identified four major types of terrain on Mars.

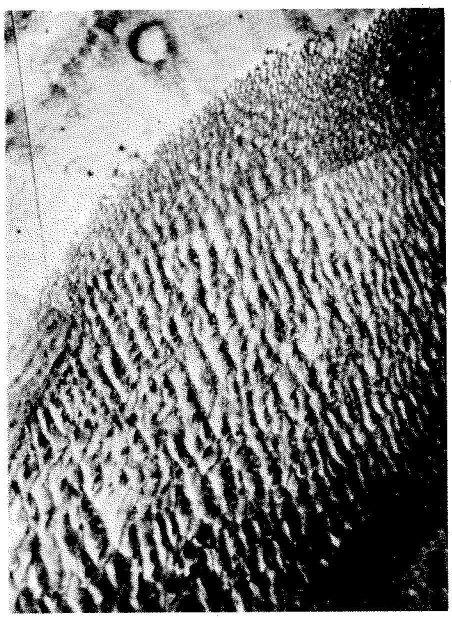
The first of these types is volcanic. These areas include the most prominent of the volcanic peaks, Nix Olympica. The caldera, or crater, formed by the collapse of the central part of this volcano is 315 miles wide at its summit, twice as wide as that of the volcano that formed the Hawaiian Islands. One of the measures used to determine planetary age, the frequency and number of meteorite impacts, indicates that the region is a rather young feature. But scientists have been unable to determine how young because Mariner 9's sensing devices have detected no clear-cut indications of heat sources such as from geologically recent active volcanoes.

The second type is an equatorial plateau area marked by deep canyons and great cracks, or faults, in the crust—evidence of significant tectonic activity during the recent history of Mars. The features of the Martian Grand Canyon, ten times the length of our own and three times deeper, include a network of tributaries to the canyon and a delta-like region extending from its eastern end—evidence of possible water erosion.

The third type of terrain, which seems to extend over half the planet, is a heavily cratered region that looks much like the broad plains of the moon. One of its many impact basins, Hellas, is larger than any similar basin on the moon. Great expanses of sand dunes are also seen in the area. This cratered terrain is thought to be the most ancient on Mars, because its many craters appear to have been eroded by wind, water, rain, subsequent meteorite impacts, and other as yet unidentified forces.

The fourth type is a spectacular expanse of stair-step terraces and deep grooves radiating from the south polar region. Scientists suspect that glaciers moving out from the polar ice cap gouged out the grooves and piled up rocky debris to form the terraces. Such terrain is an indication

This Mariner 9 photograph of the Martian atmosphere, taken along the rim of the planet, shows a double-layered haze that was at first thought to be dust. But scientists now think both layers may consist of water ice crystals. The lower layer rises about 9 miles above the surface; the upper layer is 28 miles high.



Dark spots observed in some of the bigger craters on Mars were a mystery until Mariner 9 cameras zeroed in on one and discovered it was a sand dune field reminiscent of the Mojave Desert. This one is roughly 40 miles wide and 80 miles long.

The first sign of spring in the northern hemisphere of Mars is the retreat of the northern polar ice cap (the curved swath through the center of the photograph). The crater on the left may possibly be rimmed with a deposit of water ice.

that Mars, like Earth, has had its ice ages and is now in a warmer period.

Other Mariner 9 findings include:

—Clouds containing water crystals which appear to form around large volcanoes. The source of the water could be the volcanoes themselves; on Earth volcanoes spew forth copious quantities of water and may have been the source of the oceans. However, it seems more likely to most investigators that the water vapor is from the polar regions.

—Ozone, which appears on a seasonal basis in the polar regions in amounts of about one part in a million. None has been detected in the warmer equatorial regions.

—A multi-layered haze structure over the north polar region that could consist of carbon dioxide and water moved by winds with velocities up to 300 miles an hour.

—Surface temperatures ranging from about 81 degrees Fahrenheit near the equator to –189 degrees at the poles. Although evidence of internal activity is growing, the infrared radiometer aboard Mariner 9 has not detected any internal heat.

Also, an increasing number of signs indicate that Mars has had considerable seismic activity. To check out the possibilities of both tectonic and volcanic activity, a set of miniature seismometers built at Caltech's Seismological Laboratory will be among the instruments aboard the Viking Lander probes. Designed by a multi-institutional research team headed by Don L. Anderson, professor of geophysics and director of the Seismological Laboratory, the devices are cube-shaped, five inches on a side, and weigh three and a half pounds.

Though the primary purpose of the seismometers is to record local quakes, they also can pick up average-size temblors originating anywhere on Mars. They can record ground motions as small as one twenty-five millionth of an inch. Each seismometer is, in effect, an electric generator driven by ground motion. When the ground moves, a weight in the instrument, supported by a string, tries to remain stationary while the rest of the instrument moves with the ground. This causes a coil to be pumped in and out of a magnet, generating an electric current. The greater the quake, the greater the current. Each cube contains about 54,000 transistors which will amplify the signal, digitize it, store it, and then transmit it from the Viking Lander to the orbiting portion of the spacecraft, which in turn relays the signal to earth.

In addition to measuring seismological activity, the instruments will register winds and meteorite impact. They will also provide valuable information about the planet's crust, as well as data about the composition and evolution of the interior and the evolution of the atmosphere.

In fact, the answer to whether Mars ever had an atmosphere suitable for life may depend on whether Mars has quakes. A geologically active Mars means life is more likely. Quakes would indicate that it has an unstable interior similar to Earth's which—eons ago—produced the hot gases that escaped to the surface to form oceans and an atmosphere.

How It All Began?

It has generally been assumed that the earth and moon were formed over a period of several million years by the coalescence of cold meteorite material long after the formation of the sun.

Satisfying as this theory is in many ways, it leaves many questions unanswered. For example, why does the earth have a solid inner core and a molten outer one, when common sense indicates that it should be just the reverse? And why are there so many chemical differences among the different classes of meteorites, among the planets, and in the surface geochemistry of the moon?

These enigmas could be explained if the earth-moon system was born very quickly—the earth in about 10,000 years and the moon in 2,000 years—from hot material that had just condensed from the solar nebula. This concept has now been proposed by Don L. Anderson, professor of geophysics and director of Caltech's Seismological Laboratory, and Thomas Hanks, research fellow in geology, in an article in the British scientific journal *Nature*. The theory is an elaboration of one proposed by Fred Hoyle of Cambridge, England, and its development by a group at Yale headed by Sydney Clark, Jr.

The Anderson-Hanks theory makes use of the temperatures at which different materials solidify from a gas to a solid. The two investigators assume that the minerals united into solid aggregates in the order that they solidified from the very hot whirling cloud of gas from which the solar system is believed to have been born some five billion years ago.

As the hot gas gradually cooled beyond the embryo sun, the first compounds to condense out of the cloud were those that were rich in calcium, aluminum, titanium, and the radioactive elements of uranium and thorium. They were converted from a gas to a solid when the cloud cooled to about 2,800 degrees Fahrenheit.

These compounds came together to form the nucleus of the earth, the moon, and the other planets. As all these newly formed objects orbited the embryo sun, they tended to attract and sweep up dust composed of these elements. The earth at that time was probably about 2,500 miles in diameter (roughly the size of the moon today) rather than its present 7,909 miles.

As the gas continued to cool, iron condensed out at about 2,500 degrees and was swept into the earth. Eventually the cloud cooled to about 2,000 degrees, and normal mantle silicates condensed to form the earth's mantle. The earth was fully assembled in the very short time—geologically speaking—of 10,000 years. At that time the deep interior of the earth was entirely solid. Then the radioactive materials in the nucleus heated up and melted the layer of iron and nickel outside the nucleus, a process that took about 300,000 years. When the iron melted, the material in the inner nucleus, because it was lighter in weight, rose to the top of the melted nickel-iron core, and the nickel-iron sank to the center of the earth, where it solidified because of the greater pressure there. This explains why the inner core is solid and the outer core molten. Some radioactive material may still be in the outer core, but most of it was plastered into the base of the mantle. A little may have melted its way up through the mantle in certain locations to start forming continents.

The Anderson-Hanks model of the earth's formation helps explain the chemical differences among the meteorites and among the planets by supposing that they accreted from material that condensed at different temperatures. Mercury, for example, has a different mix of elements and is smaller than the earth because solar radiation "blew away" the lighter elements before they had a chance to accrete to that planet.

The theory attributes the differences in size and composition of the moon and the earth to the fact that the moon formed at a later date and was in an orbit almost perpendicular to the plane of the ecliptic, where most of the planet-forming was taking place. The moon started accreting when the earth was about 50 percent assembled.

By this time the earth had swept up most of the iron. Even after the moon began developing, the earth still got most of the remaining iron and the silicates, because its orbit was largely in the high-density areas of the still-forming solar system, and the moon crossed those areas only twice a year. In the regions out of the plane of the ecliptic—where the developing moon was most of the time—there was only a hot gas of aluminum, titanium, and similar high-temperature condensates from which the moon could form. That process, calculated by Hitoshi Mizutani, a research fellow at the Seismological Laboratory, took about 2,000 years. Later, the effects of drag and collisions slowly reduced the moon's inclination from the perpendicular to its present orbit.

The High Cost of Being Good

—or Calling on All Alumni

by Donald D. Davidson

Some of Caltech's best friends are its alumni. And the Institute needs the wholehearted support of all 11,500 of them to maintain and expand its research programs, to build new laboratories, to hire new faculty, and to increase its general operating funds.

So, the Caltech alumni are now launching an Alumni Fund drive for 1972-73. Under the direction of an Alumni Fund Council, we are planning and conducting a drive to raise $300,000. From California to Florida, 72 area chairmen are set to begin solicitation programs—and their goal is *total* alumni participation.

Of course, $300,000 is only a small part of Caltech's total budget—and only a small part of what Caltech currently needs. But it is a vitally important sum, because it is for general operating expenses. Without it a lot of urgent needs simply won't be met.

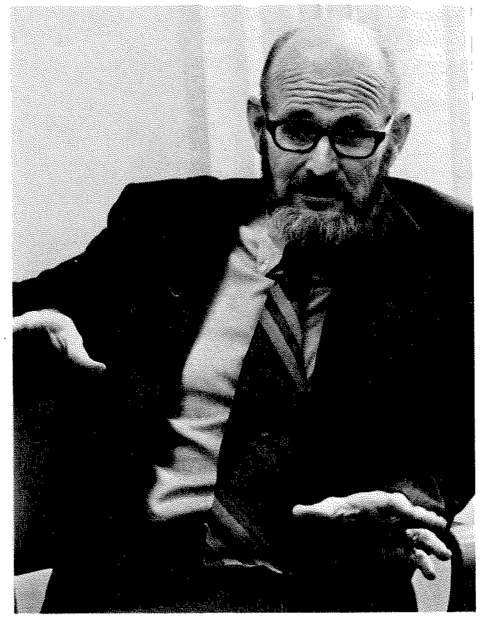
Being a great university has never been easy—or inexpensive. Today it's harder than ever. Costs are higher, and underwriting them is more difficult—particularly for a private, non-tax-supported school.

For the last ten years Caltech's costs have grown at an average rate of about 1 percent a year above its income, accelerating during the last two years at the rate of $3-400,000 a year. An internal austerity program has resulted in considerable savings, but has by no means been able to close the gap.

In 1971, for the third year, the Institute was forced to draw from its reserves in order to balance expenditures and income. This time the withdrawal was more than three-quarters of a million dollars.

Why is Caltech in such straitened circumstances? Because of spiraling inflation for one thing, and increased competition with other institutions for support—and because of the stiff price Caltech has to pay to maintain the quality of the vital research it does and the superb education it offers. The costs of educating a student are going up 7 or 8 percent a year, and tuition is farther than ever from meeting these costs. Last year the Institute spent over a million dollars just to renovate laboratories, and keeping up with current publications adds 15 to 19 percent to the library budget every year.

Because of careful long-range planning by the Institute's administration and trustees in the late 1960's, Caltech's financial condition looks better than that of a lot of other universities. But President Harold Brown reminds us that Caltech has a "particular vulnerability to changes in government policy on support of university reesarch—for example with respect to partial reimbursement of



faculty salaries or awards of graduate student trainees and fellowships—despite the fact that total federal research at Caltech has been increasing during the past years."

"We are vulnerable," he adds, "in our dependence on the future of the space program, through Caltech's management of the Jet Propulsion Laboratory. And we are extremely vulnerable to fluctuations in gifts from private sources."

In an effort to bring its income into line with expenses, in the late 1960's the Institute adopted several guidelines for economies:

- Minimize support and service activities that are not essential to the instruction and research program.
- Go into new areas only when they are important, when Caltech can make a unique contribution, and when funds are visible.
- Curtail, or at least do not expand, any activities that appear to draw inordinately on Caltech's resources.

Applying those principles resulted in these savings:

- Costs of administrative services and support have been held to a growth rate of 5 percent a year for the last two years—one-half the rate of growth of instructional and research activities.

- The physical plant and campus architect's activities together have grown by less than 3 percent.
- Several departments in business administration have actually *decreased* their expenditures.
- Support of the computing center from the general operating fund is expected to drop below $500,000 in 1972, after peaking at $714,000 in 1971.
- Employees in central administration and services decreased by 100 (out of a total of 1,300) between July 1970 and July 1972.

Teaching and research offer other potential areas for cutting costs, but the Institute wants to move very cautiously here, to be sure that cutting costs doesn't cramp growth or lower teaching effectiveness or limit research.

Additional cost cutting is difficult because much of the Institute's income is committed to fixed obligations—paying salaries of tenured faculty members and others on multi-year contracts, providing basic administrative services, heating and lighting buildings, and supplying student aid, for example.

Three years ago, at the same time it set up internal austerity measures, Caltech instituted a plan to stimulate growth of its endowment through more aggressive management. The Trustee Investment Committee split the endowment's equity portfolio into two parts and engaged two investment advisory firms to manage them. Results so far indicate that the new plan is likely to prove effective.

Now, with confidence that its own affairs are soundly managed, Caltech is ready to approach alumni donors and assure them that their gifts for general operating funds will be used with maximum effectiveness.

General operating funds provide the foundation that makes all of Caltech's programs possible. Without them, the Institute couldn't exist. They provide leeway in that critical time between the loss of one source of support and the discovery of a replacement. Often they pick up the tab for a project only partly funded by restricted gifts. In many instances, money in the form of governmental grants and contracts, corporate sponsorship, or gifts from individuals or foundations isn't sufficient to cover the total cost of the activity for which it is given. General operating funds can be used to pay the balance.

They provide the flexibility and stability Caltech must have to innovate. Scientific progress follows an unpredictable path, and the money has to be available for the Institute to move quickly into new areas while it seeks out long-range sources of funding.

General operating funds may support an established professor, enabling him to launch a new project, or they may provide initial financing for research by a brilliant but unproven new professor. They may provide badly needed support for PhD thesis research. Graduate students are often restricted in their selection of research to areas where government funds are available, so general operating funds can give them increased freedom to explore undeveloped areas.

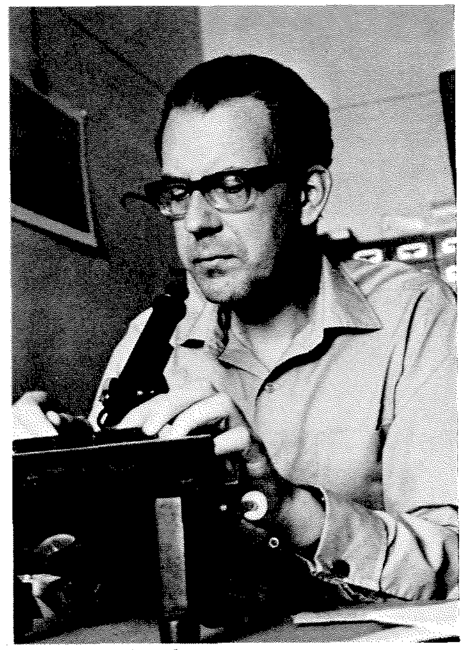
These funds are vital, too, in launching the teaching innovations that are among the Institute's greatest contributions to the educational community. They act as midwife to exciting new projects—a Saturday school on the campus to motivate and challenge high school students interested in science and mathematics, or new project laboratories in applied physics and experimental engineering to teach undergraduates how to apply the theoretical knowledge they have been acquiring at the Institute.

One other need for general operating funds is not always obvious to the casual observer. Every restricted gift for a new building or some other facility brings a corresponding need for spending for support services: equipment, furnishings, maintenance, utilities, staff—all funded through the general operating budget. Caltech has to have funds available to develop the potential created by restricted gifts.

In fact, the list of items funded by general operating money is as long and varied as the needs of the Institute. It includes money to supplement the salary of a valued faculty member in order to keep him on the staff; to replace outworn or obsolete laboratory equipment; to publish a special piece of work; to buy new books; or to help pay the Institute's power bill (an unglamorous but absolutely essential item that costs three-quarters of a million dollars a year).

The individual who makes his gift to the Institute in the form of general operating funds never knows the exact dimensions of his act. But as an alumnus, he knows that he may have helped to start something that could change the world.

The Summer at Caltech



Maarten Schmidt

Turnabout in Astronomy

Maarten Schmidt, professor of astronomy and staff member of the Hale Observatories and the Owens Valley Radio Observatory, has been named executive officer for astronomy. He replaces Jesse Greenstein, Lee A. DuBridge Professor of Astrophysics and also a staff member of the Hale and Owens Valley observatories.

Schmidt, 42, is a native of Groningen, Holland. He received a BS from the University of Groningen in 1949 and a PhD in astronomy from the University of Leiden in 1956. For two years after that he was a Carnegie Fellow at the Mount Wilson and Palomar Observatories, and in 1959 became associate professor of astronomy at Caltech.

Almost from the beginning of his career at the Institute, Schmidt has been involved in trying to understand the curious objects that turned out to be quasars, the brightest and probably the most distant known objects in the universe. (Probably—but not positively.) Although Schmidt and Greenstein's interpretation that quasars are extragalactic and that their red shifts arise from the continuing expansion of the universe is hotly debated by some astronomers, it has also led to a search of the heavens for other similar explosive phenomena. What has resulted is a new picture of the universe—one of general cosmic violence, with not only quasars but also exploding galaxies, almost omnipresent high-energy particles and magnetic fields, and events suggesting relativistic collapse (black holes).

"Whatever the true nature of quasars—whether they are far or near—their discovery has put new life into astronomy," says Schmidt. "The string of discoveries over the last ten years has probably added much more rapidly to our problems than to our knowledge. There are still more questions than answers. But that is very healthy—and very exciting."

With the question of quasars still up in the air, Schmidt today devotes much of his research time to basic theory—"trying to figure out what it all means." He is currently studying the effects of star formation and the evolution of galaxies—considerations that may lead to an estimate of how our own and other galaxies evolved.

Taking over as executive officer for astronomy will cut into his research time, but Schmidt is dedicated to retaining the momentum of Caltech's astronomy program. That momentum is a tribute to Jesse Greenstein, who is stepping down after 24 years (nine of them unofficial) as executive officer.

"It's important to get out while you're ahead," says Greenstein. "Astronomy, at Caltech and in general, has moved with the speed of light in recent years. It's quite startling to realize that I have ridden so long without getting thrown. Besides, it's time for new directions. It's time for somebody with more optimism and new ideas."

But Greenstein's most important reason for stepping down is also the most personal. He simply wants more time to devote to research. He doesn't want to be faced with continuing to make choices between administrative duties and scientific work. "One is sacred, the other profane," he says. "The observing is sacred. The way it's been, if I got four nights of observing on the 200-inch telescope, I went to Palomar and used them. But I went knowing very well that if I got anything usable I would have to give it to someone else to work on.

"There's a point at which you begin to envy your colleagues their time. I don't like being the third author in a paper with seven authors. I have my own work, and it's about time—now that I'm 62—that I devote more time to it."

As a cooperative enterprise, Greenstein admits, the astronomy department has

Jesse Greenstein

accomplished a lot to be proud of over the past quarter-century. "We're very modest here," he says, "but if you want me to be chauvinistic, I can be. In both the teaching of astronomy and in the research we do, we are extremely good. I brought almost everybody here; they're all my foster children scientifically—and they are the best."

When Greenstein came to Caltech in 1948, there was only one other professor in astronomy—Fritz Zwicky. When funding was at its height in the 1960's, the department had about 100 people. Now there are approximately 10 professors, 30 undergraduate students, and another 30 graduate students.

"Our impact on astronomy has been profound," he says. "We've had a finger in almost every major development in ground-based astronomy, and we're becoming increasingly involved in space astronomy. We are, in essence, the establishment—the Caltech Mafia—which is another good reason for a change. You start to worry when people begin to ask if you are prejudiced. Has the picture of the universe that is official in Pasadena anything to do with the universe as seen by astronomers who are 50, 100, or 1,000 miles away?"

Greenstein thinks the picture of the universe that has been formed by Caltech and Hale Observatories astronomers is based on hard, scientific data—not on prejudice. He points out that it is generally accepted throughout the world, although specific details are debated ferociously.

Despite his load of administrative duties, Greenstein has done his part in painting that portrait of the observable universe. Since 1948 he has published more than 250 papers on astronomical investigations such as the nature of gas and dust in interstellar space and their interaction with the stars; absorption and polarization of light in space; the composition of stars from their spectra; the discovery and study of stars of peculiar composition; nuclear processes in the stars; the interstellar magnetic field of our galaxy; and the study of quasars.

"When I came here at the age of 38, astronomy was just an immense blackboard to fill in," Greenstein says. "It was wonderful. Every possibility was open to us. We had the biggest telescopes in the world to work with, and every place to look. Everything in cosmology was up for grabs. I don't know that there will ever be another period quite like it."

Watson Lectures

Caltech's regular Monday evening lecture series in Beckman Auditorium has been given a new name to honor the memory of the man who started the lectures: the late Earnest C. Watson. From now on the series will be called the Earnest C. Watson Caltech Lecture Series at Beckman Auditorium.

Watson, who died in 1970, came to Caltech in 1919. He was made a full professor of physics in 1930 and dean of the faculty in 1945. He also acted as chairman of the division of physics, mathematics and astronomy from 1946 to 1949. He originated a series of Friday night demonstration lectures on campus that became one of the most popular public events in Pasadena—and his own lecture on liquid air was the most popular of all. He repeated it for many groups over many years. In 1964 he gave it for the last time—as the first faculty lecture in the brand new Beckman Auditorium.

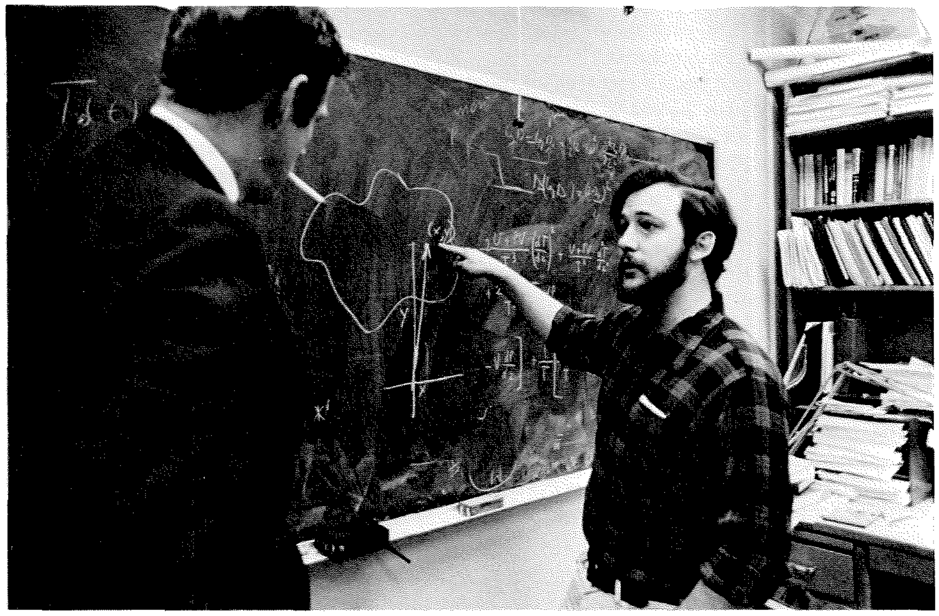
Project Centroid

If you don't know where the centroid of Los Angeles County is (or even *what* it is), you have a lot of company. But if you read the August and September issues of *Westways* magazine, you no longer have an excuse.

At the request of one of the magazine's editors, a quartet of graduate students in geophysics at Caltech—Tom Jordan, George Mellman, Richard Strelitz, and Larry Burdick—recently figured it out. They began by editing the editor's question. A nonscientific man, he first asked them to find the county's geographical center. Too meaningless, they replied. But if the editor asked them to find the "centroid," it could be done. The centroid, or center of mass, is "that point where if you cut out the exact shape of Los Angeles County in cardboard and molded it to conform to the curvature of the earth, it could be balanced on the head of a pin."

To make the problem a bit more difficult a number of conditions were stipulated:

Graduate students Tom Jordan, Larry Burdick, Richard Strelitz, and George Mellman scan a computer print-out to find the centroid of Los Angeles County.



Tom Jordan tells a Westways *editor how to make a flat-map error correction.*

►The offshore islands would be included in the computation.

►The land being measured would be considered "smooth-faced."

►The mean high-tide line would be considered the boundary with the sea.

►The answer must be accurate to within ten meters.

For two months during the summer the graduate students used their time off from earthquake research to work on Project Centroid.

For those who, like Jordan, Mellman, Strelitz, and Burdick, had time, know-how, ingenuity, and/or access to a digitizer and a computer, the August *Westways* provided all the information needed to get an answer. All the rest of us had to wait until that nonscientific editor revealed it in the September issue.

Where is the centroid of Los Angeles County? Why, where else but at 34°19′15.358″ north latitude and 118°13′24.276″ west longitude.

In case you're still baffled, the centroid of Los Angeles County is just below Condor Peak—about 2½ miles due north of Big Tujunga Station in the Angeles National Forest.

In appreciation of the effort the four geophysics students put into Project Centroid, *Westways* donated $1,000 to Caltech for the scholarship support of a graduate student in seismology.

Dino Morelli, 1916-1972

Dino A. Morelli, professor of engineering design, died on September 12 in Pasadena. He had been a member of the Caltech faculty for 24 years.

Dr. Morelli was born in Queensland, Australia, in 1916. He attended the University of Queensland, receiving a BE in 1937 and an ME in 1942. He taught at the University of Queensland and owned a sheet metal firm and instrument-making company in Brisbane before coming to Caltech, where he received an MS in 1942 and a PhD in 1946.

An inventor and developer of precision instruments as well as a teacher of machine and engineering design, Morelli also served as a consultant to several firms, and for a time designed children's furniture. Among the instruments he designed at Caltech were a number of vibration generators for testing the earthquake resistance of various kinds of structures. Morelli was frequently called as a technical expert witness in court trials. He was a member of the American Society of Mechanical Engineers and of Sigma Xi.

Elbridge H. Stuart, 1888-1972

Elbridge H. Stuart, trustee emeritus of Caltech since 1962, died on September 16 at the age of 84. He was elected a member of the Institute's board of trustees in 1950, and was also a life member of the Associates.

A native of El Paso, Mr. Stuart graduated from Yale University and was first employed by the Carnation Company in 1911. At the time of his death—having been president, chairman of the board, and chief executive officer—he was honorary board chairman of the company. He was a Chevalier in the Order of the Legion of Honor of France and held the Order of Merit of the government of Peru.

Faculty and Administrative Changes 1972-1973

ADMINISTRATION

ROBERT A. HUTTENBACK—*chairman of the division of humanities and social sciences*
W. BARCLAY KAMB—*chairman of the division of geological and planetary sciences*
HANS W. LIEPMANN—*director of graduate aeronautical laboratories*
JAMES J. MORGAN—*dean of students*
JOHN D. ROBERTS—*acting chairman of the division of chemistry and chemical engineering*

PROMOTIONS

To Research Associate, Emeritus:
JOSEPH B. KOEPFLI—*chemistry*

To Professor:
BARRY C. BARISH—*physics*
GORDON P. GARMIRE—*physics*
JAMES E. GUNN—*astronomy*
WILFRED D. IWAN—*applied mechanics*
PAUL C. JENNINGS—*applied mechanics*
FREDRIC RAICHLEN—*civil engineering*

To Research Associate:
JAMES E. BROADWELL—*aeronautics*
EVA FIFKOVA—*biology*
PETER H. LOWY—*biology*
MARIANNE N. OLDS—*biology*
HELEN R. REVEL—*biology*
GEORGE A. SEIELSTAD—*radio astronomy*
CHANG-CHYI TSUEI—*applied physics*

To Associate Professor:
E. J. LIST—*environmental engineering science*

To Senior Research Fellow:
ERIC E. BECKLIN—*physics*
CHRISTOPHER BRENNEN—*engineering science*
BARBARA R. HOUGH—*biology*
RICHARD B. MACANALLY—*electrical engineering*
TSE-CHIN MO—*electrical engineering*
DIMITRI A. PAPANASTASSIOU—*planetary science and physics*

To Assistant Professor:
MICHAEL ASCHBACHER—*mathematics*
MORGAN KOUSSER—*history*
GEORGE R. ROSSMAN—*mineralogy and chemistry*

NEW FACULTY MEMBERS

Professor:
HIROO KANAMORI—*geophysics*

Research Associates:
MARYLOU INGRAM—*biomedical engineering*
ROBERT C. Y. KOH—*environmental engineering science*
JOHN H. SCHWARS—*theoretical physics*
J. C. SHAW—*information science*

Associate Professors:
LOUIS BREGER—*psychology*
PER BRINCH-HANSEN—*computer science*

Senior Research Fellows:
JOHN P. HOLDREN—*population studies*
JOHN C. HUNEKE—*planetary science*
BENJAMIN D. ZABLOCKI—*sociology*

Assistant Professors:
MORRIS FIORINA—*political science*
MIHAILO D. TRIFUNAC—*applied science*
MICHAEL W. WERNER—*physics*

TERMINATIONS

JOSEF ALONI—*senior research fellow in biology,* to Israel
GARRY L. BROWN—*senior research fellow in aeronautics,* to the University of Adelaide in Australia
CHARLES B. CHIU—*senior research fellow in theoretical physics,* to the University of Texas' physics department
PETER L. CRAWLEY—*professor of mathematics,* to Brigham Young University's department of mathematics
RICHARD DOLEN—*senior research fellow in physics*
EDMUND O. FISET—*senior research fellow in physics*
MOSES GLASNER—*assistant professor of mathematics,* to Pennsylvania State University
GEORGE S. HAMMOND—*Arthur Amos Noyes Professor of Chemistry; chairman of the division of chemistry and chemical engineering,* to the University of California at Santa Cruz
ANDREW E. KERTESZ—*senior research fellow in applied science,* to the Technical Institute of Northwestern University
EVELYN LEE-TENG—*senior research fellow in biology,* to the University of Southern California's medical school
PATRICK W. NYE—*senior research fellow in applied science,* to the Haskins Laboratories in New Haven, Connecticut
HEINRICH RINDERDNECHT—*senior research fellow in chemistry,* to the Veterans' Administration Hospital in Sepulveda
EDWIN C. SELTZER—*senior research fellow in physics*

RETIREMENTS

JOHN B. WELDON—*registrar*

 continued from page 7

information, it thereby increases its capabilities to meet its needs and to successfully adjust to its environment. It also increases its capability to gain information. The invention of the telephone added a small item of information to human knowledge, but this small piece of information, how to design a telephone, was multiplied manyfold by its impact on the information its use made readily available in the society. The processes of becoming informed are self-accelerating.

There are two roads open to a society faced with catastrophic fractionization of context, and we stand at the cross-roads of these two paths today–the choice between the innovative society and the single conforming world.

What are the implications of this fact, the self-acceleration of information? As innovative change takes place in a community, it must be communicated throughout the community. The community's language must absorb the change, and all members of the community must recognize and adopt it. Communication takes time. The larger the community, the more time and effort are required to assimilate the result of innovative change. Thus the first conclusion we can draw is that community size must be inversely proportional to the rate of innovative change.

But information processes are self-accelerating; the rate of innovative change is increasing. As the community builds up a strong base of information, this base can be exploited on all sides. Innovation is stimulated at many places in the communitty. And if the community is to maintain itself, these changes must be communicated and absorbed. At some point in time, the rate of innovation becomes too great. People get out of touch. Some groups in the community are privy to information others do not have. Conflicts in view develop. The community fractionates. The seeds of its own fractionization are sown at the very birth of a community in the self-acceleration of its information.

But the fractionation of a community need not be catastrophic. In fact one can look at the evolution of social mechanisms as the development of means for retaining high levels of information in a society even while it fractionates into a multiplicity of communities. Diversity of views and skills can be tolerated by a society if there are maintained avenues along which communication can take place. Let us review several ways society has learned to accommodate orderly fractionization.

The acceptance of a common medium of exchange is one. In the economic sphere we call it money, in the political sphere it is the vote.

Social organizations are another way society accommodates orderly fractionization. It is a common presumption that an organization has a goal and all of its members work toward its accomplishment. The myth of its goal does indeed give common coinage to the activities of its members, but it is hardly more than myth. Indeed the very essence of organization is to create channels of communication which allow groups and individuals with diverse skills and goals and values to realize high levels of total information without the too costly maintenance of a single encompassing language. Think for a moment of the immense amount of information to be found in, say, the Department of Defense. The coordination of activities is worldwide and ties together in rational sequence such diverse affairs as the negotiation for the design of a new weapon system and its employment by men trained in its use years later on an unanticipated battlefield. But how few aspects of that information are to be found in any single Pentagon office, or at the fingertips of any single officer. Organization is thus a powerful means of maintaining orderly fractionization of a society.

Mechanisms such as the marketplace and social organizations are one way in which a society maintains higher levels of information in face of the self-acceleration of information. But there is another more basic one. Fractionization occurs when rates of innovation exceed the ability of the community to communicate the results of innovation. Thus if the technological means of communication can keep pace, the moment of fractionization can be postponed.

The Impact of the Computer

What activities of an informational community *determine this fractionization? It is its data gathering and* communicating that ties a community together, maintains the cohesiveness and consistency of its underlying conceptual structure. It is the activities of structuring and theorizing that are innovative activities that tend to fractionate the community.

Ever since the invention of the printing press there has been one major technological innovation after another that enhances our capabilities to communicate and to observe; the telegraph, radio, television, in fact the whole electronic revolution—the microscope, camera, linear accelerators, and bathyspheres—all support the gathering and communicating activity. As far as technological support of structuring, little has been done beyond pencils and paper.

We can record and communicate enormous amounts of data. As a consequence, the commonality of conceptual structure and the confirmation of that structure are very high. At no time in history has there been the commonality of human culture that exists today. The same popular music, the same kinds of transportation, the same values, the same technology are found almost everywhere. We virtually exist as a single informational community.

Into this situation has come the computer. So far it has been used largely to apply known theories and models to special cases in engineering and business. But the potential for technologically supporting the processes of structuring and theorizing, the innovative processes, are there and beginning to be realized.

Let me enlarge upon this somewhat. Suppose I have a large body of data or find myself in an experimental laboratory and I try to make some sense out of what I find at hand. I try to construct a conceptual framework that accounts for the data or the experimental results in an insightful way. This is precisely the process we discussed earlier in the paper, the process in which one seeks to find that higher level structure that maximizes one's information. To do this I examine some small sector of the data or I conduct a limited sequence of experiments. On the basis of these, I form a hypothesis, which I proceed to test by further examination of data or further experimentation. In this way I build up an increasingly complex model or theory. But the process is not only one of accretion of structure. There comes a time when the model becomes unwieldy and unaesthetic. I try a variant on the theory, I simplify the model in a novel way that I could not have seen prior to its construction. I begin to change the model in quite creative ways, much like a sculptor takes a bit of clay off here and puts a bit on there. And at each stage I must step back and assess the implications across the entire theory, and see if the change still fits the data or the results of my experiments. This reverberating adjustment of the conceptual model is the tedious, time-consuming part of research. In the past, each research step was small, simply because checking out the implications of small changes in theory was already taxing.

In such a laboratory as I have described above, the construction of models has always played an important role. If we could make an actual physical model of what we were working on, then we could poke it, warp it, and change it here and there, and the implications of our change would be evaluated quickly and immediately by the model itself. In the design of electronic equipment we could build a prototype, a "breadboard," and then we could turn dials and switches, and see immediately on our oscilloscope their over-all effects.

But there has been no apparatus in which the abstract conceptual theory itself could be held and manipulated; there has been no way short of tedious calculations with pencil and paper to change the theory in one area and check the implications of these changes in other areas—capability to build complex models and then to set them in motion and see how they work. That is, there has been no such apparatus up to now. But this is precisely what the digital computer is suited to provide.

For example, in our laboratories at Caltech we build complex conceptual models of nerve cells. We then take many of these simulated cells and build them into networks similar to those found in the nervous system, all of course in the computer. The computer is also hooked up to tiny electronic probes that are inserted into the nervous systems of living animals and that can sense their nervous activity. Both our conceptual model and the actual living nervous system feed the same analysis programs. We can thus compare them, adjusting the parameters of our model in immediate interaction with computer analysis, to fit the reality we are trying to understand. In this process the computer is handling data rates from the model and from the animal of 50,000 to 1000,00 items a second.

Let me cite another example. Caltech anthropologist Thayer Scudder is studying a Tonga population of about 50,000 individuals in Zambia. Ten years ago they lived as simple farmers in an isolated valley. The Kariba Dam was built at the head of the valley, and these people had to be relocated. Recently industry has come to the area into which they were moved. Professor Scudder and his associates have extensive field notes covering this entire period, giving family relationships, vocations, education, property, etc., of hundreds of these people. We are now putting these data in the computer. In this computer system, Professor Scudder can ask questions and build conceptual models of cultural change, testing these models against the data, all in natural English and in direct conversation with the computer. This capability accelerates the processes of understanding and theory building manyfold.

The introduction of the computer is for the first time giving major technological support to structuring and theorizing. What is its effect? There will be a large return in information for this movement. Thus the economic coercions for this change can be expected to be great. And indeed they are, as evidenced by the extremely rapid growth of the computer market and the application of computers in all aspects of our life. We should not underestimate the ubiquitous effect computers have already had. Our highway program, as well as our space program, could not exist without them. The effect on industrial inventories is a major factor in our economic stability. But it will be in the vast expansion of our information frontiers that they will have their greatest effects.

Our Current Situation

As greater use is made of computers, the balance between conceptualizing and communicating changes. And this change will be such as to reduce drastically the size of the viable informational community. The rate of fractionization will be greatly increased. We should expect a time of rapid divergence in points of view and values. Because innovative change in conceptualizations of our environment will be accelerated, we will feel more and more out of touch with others; and their effectiveness in dealing with affairs in ways we neither understand nor value will threaten even more our sense of being informed.

I have mentioned methods a society may use in attaining orderly fractionization. In this regard we discussed the marketplace and the use of social organization. These social mechanisms can be drawn upon and strengthened under current conditions too. However, what are the roads open to a society when faced with catastrophic fractionization of context? There are two, and we stand at the crossroads of these two paths today.

The first is to slow down the rates of conceptual change. Cut the national research budget. Reduce the support of public education relative to the general economy. Repress divergent groups. Enforce conformity to established codes of behavior. But the explosive forces of change cannot be controlled by half measures. This road leads to dictatorship.

The second road is characterized by the tolerance for diversity. It seeks a new, more enlightened conceptual base for our culture—one that recognizes that divergence of views can be enriching to a culture. What a challenge there is to society when innovation runs high! Are there deeper wellsprings of humanity on which we can base a new communication, one that revels in the richness of human diversity and welcomes the kaleidoscopic patterns of a creative culture? It is this choice between the challenge of the innovative society and the grim maintenance of a single conforming world that we face today.

Creativity in an Automated Society

But let us turn away from this crucial issue. Let's suppose we take the challenge. And indeed there is no question in my mind that we ultimately will, even if that ultimate follows a difficult period for free men. What is in store for creativity in an automated society?

It has taken the best brains and a prolonged and intense effort to forge our single science. Today science stands as a single edifice of astonishing complexity, yet yielding stunning simplicities of view. With the limited tools for conceptual structuring we have had in the past, the belief in science's uniqueness of objective view has been a necessary discipline. Science is the result of those forces that maximize the information that we can obtain from our experience. The intolerance of science of its own history is evidence that it dared not recognize its many changes. The belief that there can be only a single science, that truth lies in only one package, has been necessary when the effort to uncover that truth has taxed our ablest minds.

Yet even now the humanistic aspects of science are well recognized, at least by our scientific leaders. Conant referred to science as policy, not truth, policy to guide further experimentation. Schrödinger, while acknowledging the objectivity of science, called attention to its highly subjective aspects as well. The great expanses of unexplored reality leave open to the subjective curiosity of the individual scientist what corner he will examine, what experiments he will perform. Whatever our philosophical views on reductionism, as a practical matter the scientific landscape is sparsely settled. There are no bridges today between political science and psychology, individual psychology and psychobiology, psychobiology and molecular biology.

But what of the future? As we augment radically the technological support of the processes of conceptual structuring, each community can build its own science. From its accumulated experience it can distill that conceptual view that best expresses its own inner feelings, its values, its aesthetic taste. Science itself will become our greatest art form. With the material affluence of our automated society, we can turn our full attention to that which is most peculiarly human, the building and communicating of conceptual structure. The humanities—philosophy, the arts, literature, and science too—these will be the proper province of creative man in the automated society. We will find again in the spiritual values, in our oneness as human beings, the people of the glorious blue planet, that commonality which is necessary for communication. And in that humaneness, we will glory in the creative diversity that will enrich our lives beyond our brightest dreams.

Books

WHERE HAS ALL THE IVY GONE?
By Muriel Beadle
Doubleday & Company, Inc. $8.95

Reviewed by Colene Brown

"A university presidency can . . . absorb all one's time and energies, and it is an advantage if both husband and wife are equally committed to it."

Muriel Beadle's comment describes the contents of her book, *Where Has All the Ivy Gone?* It is an account of the George Beadles' years at the University of Chicago from 1961 to 1968. Before accepting the presidency of the university, the Nobel laureate in physiology and medicine was acting dean of the faculty and chairman of the division of biology at Caltech.

After a stay at Caltech only half as long as the Beadles' at Chicago, I agree that there is an irrestible temptation for a university president's wife to spend all of her waking moments involved, actively or passively, with university situations. I might add that this produces satisfaction at the price of exhaustion. One of my suggestions to any future presidents' wives is that they have an iron constitution.

I wish Muriel Beadle's book had been published before I came to Caltech, or during our first year here, because so many of the things confronting me were the same as those she faced, though in different degree.

The nature of a university is often misunderstood by those on the outside and frequently given too little thought, or taken for granted, by those of us who are a part of it. One of the pleasures inherent in Mrs. Beadle's book is the clarity with which a university's basic makeup, both the good and the troublesome, is described by a woman of frankness, insight, common sense, and humor.

The Beadles entered an environment different from Caltech's in a variety of ways. The University of Chicago is many more things to many more people than is the specialized Caltech. Also, it is an urban institution set down in the middle of the inner city. Like Siamese twins, university and environs shared a common bloodstream infected by shifting neighborhood character, slum conditions, and all the complications of urban renewal and big city politics. Then too, the 1961-68 years were characterized by mounting tensions on campuses all across the country, and Chicago had its full share.

Mrs. Beadle found the environmental problems around them as much a part of her life as the hundreds of receptions for thousands of people that she gave in the old 16-room Victorian mansion the president and his wife called home. She also has much to say that is thought-provoking about the essentials of governing a university, including the composing of differences among various groups within it, and interpreting it to those outside.

Although the Beadles' seven years at Chicago ran from everyday-complicated to downright nerve-wracking, it is obvious on every page that neither of them would have missed the experience for anything. In fact, upon George's retirement they immediately bought and moved into a house in the same neighborhood.

In concluding her chronicle of these Chicago years, Muriel Beadle proposes that everyone having to do with colleges and universities (and she includes the general public) should begin to find the answers to two questions: How can the faculties do a better job of governing the internal affairs of their institution? What is the purpose of colleges and universities? She gives her own answers in a way that will give many readers food for thought for some time.

WHAT'S A NICE GIRL LIKE YOU DOING IN A PLACE LIKE THIS?
by Joyce Teitz
Coward, McCann & Geohegan, Inc. $6.95

Any woman who runs a happy home for herself, husband, and four little boys under seven, lives in Santa Monica, and works at Caltech as a physicist, deserves a chapter in a book like this.

Devrie Intriligator is the physicist in a compilation of eleven interviews with a variety of young women who have in common a rich emotional life and professional success. The author is a Harvardeducated lawyer who organized the successful lobby against the SST.

Some may find it ironic that there are still so few women in so-called men's fields that they warrant a book. Nevertheless, Teitz has chosen individuals who are, for the most part, remarkable people regardless of sex; and Dr. Intriligator comes off as one of the most remarkable. The others are women in broadcasting, law, medicine, science, industry, government, and public service. Joyce Teitz' style of interviewing, combined with the candor of her subjects, brings forth highly readable material.

Devrie Intriligator, whose husband is a mathematical economist at UCLA, is an experimental physicist who came to Caltech in 1969. She has worked as a research fellow in space physics and astrophysical plasma physics and has been analyzing data from instruments aboard the Pioneer spacecraft orbiting the sun. She is particularly concerned with research on solar wind plasma, and designed the Pioneer 10 instrument measuring it. She is co-investigator of NASA's Ames Research Center solar wind plasma probe for the Pioneer 10 and 11 missions to Jupiter, and has been housed in the same corridor in Downs laboratory as colleagues Leverett Davis and J. R. Jokapii, who are playing in the same outer space ballpark. She has particularly enjoyed working in proximity with Davis and Jokapii since their research as theoreticians complements hers.

The chapter about Dr. Intriligator describes a woman who is highly satisfied with her life as a scientist, woman, and social human being, and who appreciates her own never-ending flow of energy.

During her student years at MIT, her social success was on a par with her success as a physics student. And although she was subjected to the usual pressures of the "What's a nice girl etc." type, she early developed a tin ear for such nonsense. Also, having to work 40 hours a week as well as study, she didn't have time to brood about it. The necessity to take jobs brought her up to graduation with some good professional experience to her credit, and helped focus her interests.

As her professional life has developed, she hasn't encountered enough sex discrimination to find it at all bothersome. Sometimes, because of her unusual name, people aren't quite sure what sex she is until they see her. One time, when she was a student and also working full time for the Air Force in some cosmic ray research with balloons, she went to Texas on an assignment and was met by a group of slack-jawed new colleagues on the project. They had expected an East Indian man, not a young, attractive female.

Unfortunately for the Caltech community, lively Mrs. Intriligator wound up her work at Caltech this summer and has moved over to USC where she is now an assistant professor.

Although she will miss many aspects of her professional life at Caltech, USC *is* 20 minutes closer to Santa Monica. And with 40 more available minutes per day, there's no telling what she can do.

—*Janet Lansburgh*

notes & news

Help Wanted— Steelmaking

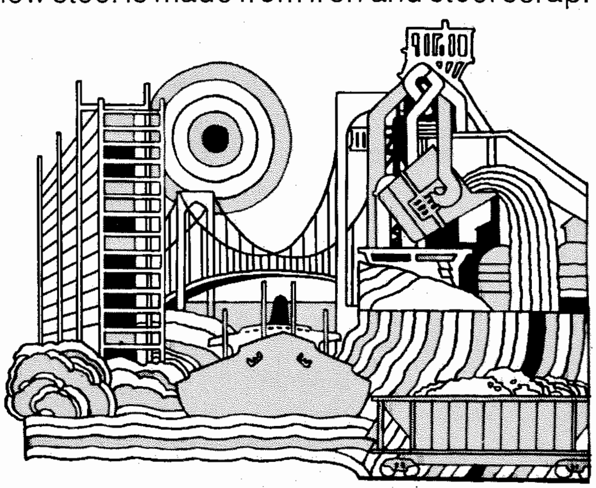
We're planning to talk with a lot of candidates for employment in Steel Plant Operations during the next few months. Students working toward M.E., Met. E., E.E., or several other engineering or technical degrees should give serious thought to careers in steelmaking through the Bethlehem Steel Loop Course. And remember, we're a leader in steelmaking technology—our capital investments total $980 million for the last three years alone!

A word to the wise—COAL

According to the U.S. Bureau of Mines, our nation's consumption of bituminous coal will *double* by the year 2000. That fact alone suggests something about career opportunities in the coal operations of our Mining Department. We're looking for mining, electrical, and mechanical engineers.

Steel's magnetic "personality"

Iron and steel are magnetic. So, what's the big deal? Just this: ferrous wastes are the easiest materials to recycle. Magnetic extraction separates ferrous scrap from trash, recovers metal after waste incineration, even permits "mining" of dumps. About 50% of all new steel is made from iron and steel scrap.



Construction Quiz:

What do San Francisco's Golden Gate Bridge, New York City's Madison Square Garden Center, Washington's Robert F. Kennedy Memorial Stadium, and Chicago's CNA Building have in common? Answer: fabricated and erected by Bethlehem's Fabricated Steel Construction Division. That's where the action is for people who want to help build the big ones!

From inspiration to application

Three Bethlehem researchers recently won the AIME's coveted Charles H. Herty, Jr., Award for their paper describing a significant steelmaking advance from conception to application. The team developed a high-speed automated sensor lance that measures both bath carbon and bath temperature instantaneously during the BOF steelmaking process.

Want more information?

We urge you to read our booklet, "Bethlehem Steel's Loop Course." If copies aren't available in your placement office, drop us a line. Write: Director—College Relations, Bethlehem Steel Corporation, Bethlehem, PA 18016.

BETHLEHEM STEEL an equal opportunity employer

Unidentical twins.

What do you call two stereo systems that have identically the same insides, but not the same outsides?

Well, you call one a Sylvania compact stereo system. It's stacked and compact with tuner/amplifier, turntable, and tape player all in one unit.

And you call the other a Sylvania component stereo system. Each unit is separate so you can spread it around any way you want it.

Inside, though, they're the same. Both have an RMS rating of 12.5 watts per channel (20 watts IHF) with each channel driven into 8 ohms. There are identical FETs, ICs, and ceramic IF filters in the AM Stereo FM tuner/amplifiers. Both offer the same switchable main and remote speaker jacks, headphone jacks, aux jacks, tape monitor, and built-in matrix four-channel capability for the new quadrasonic sound. The turntables are Garrard automatics with magnetic cartridges and diamond styluses. The 4-track stereo record/playback cassette decks are the same. And both air-suspension speaker systems contain two 8-inch woofers and two 3-inch tweeters.

So if they're the same, how come they're different?

Because different people want the same great stereo sound different ways. So we give it to them.

Come on down to your Sylvania dealer's for a look and a listen.

Then you can pick the shape you want as well as the sound you like.

GTE SYLVANIA

Sylvania Entertainment Products Group, Batavia, N.Y.